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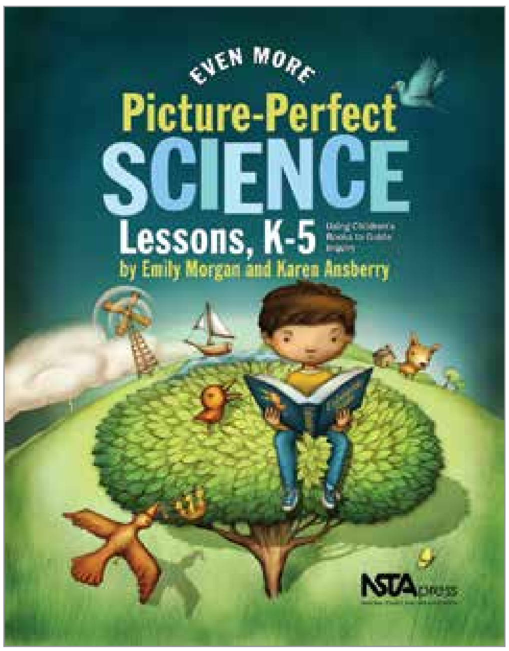
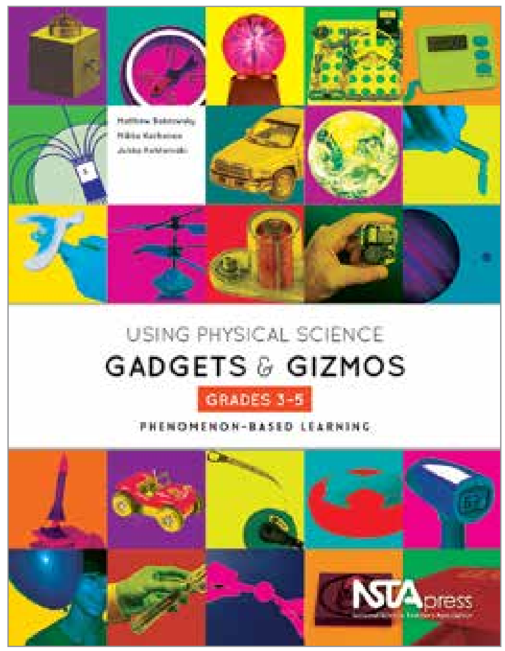
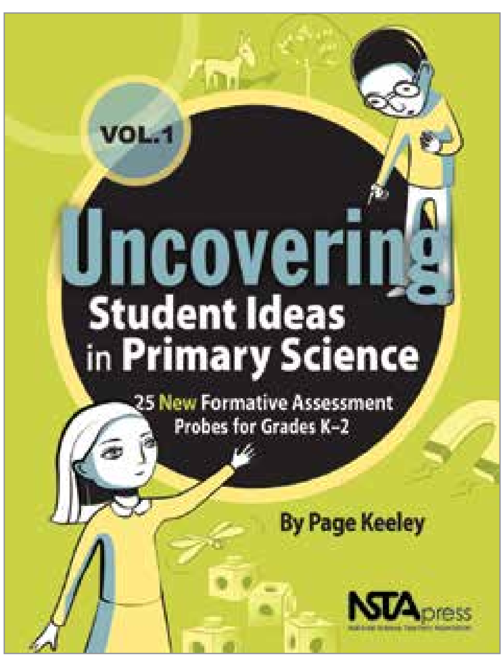
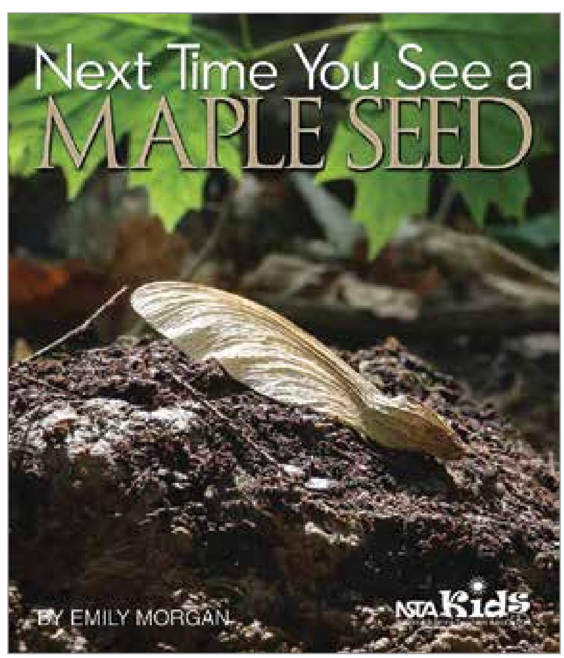
Elementary School Sampler









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Even More Picture-Perfect Science Lessons, K–5

Next Time You See a Maple Seed

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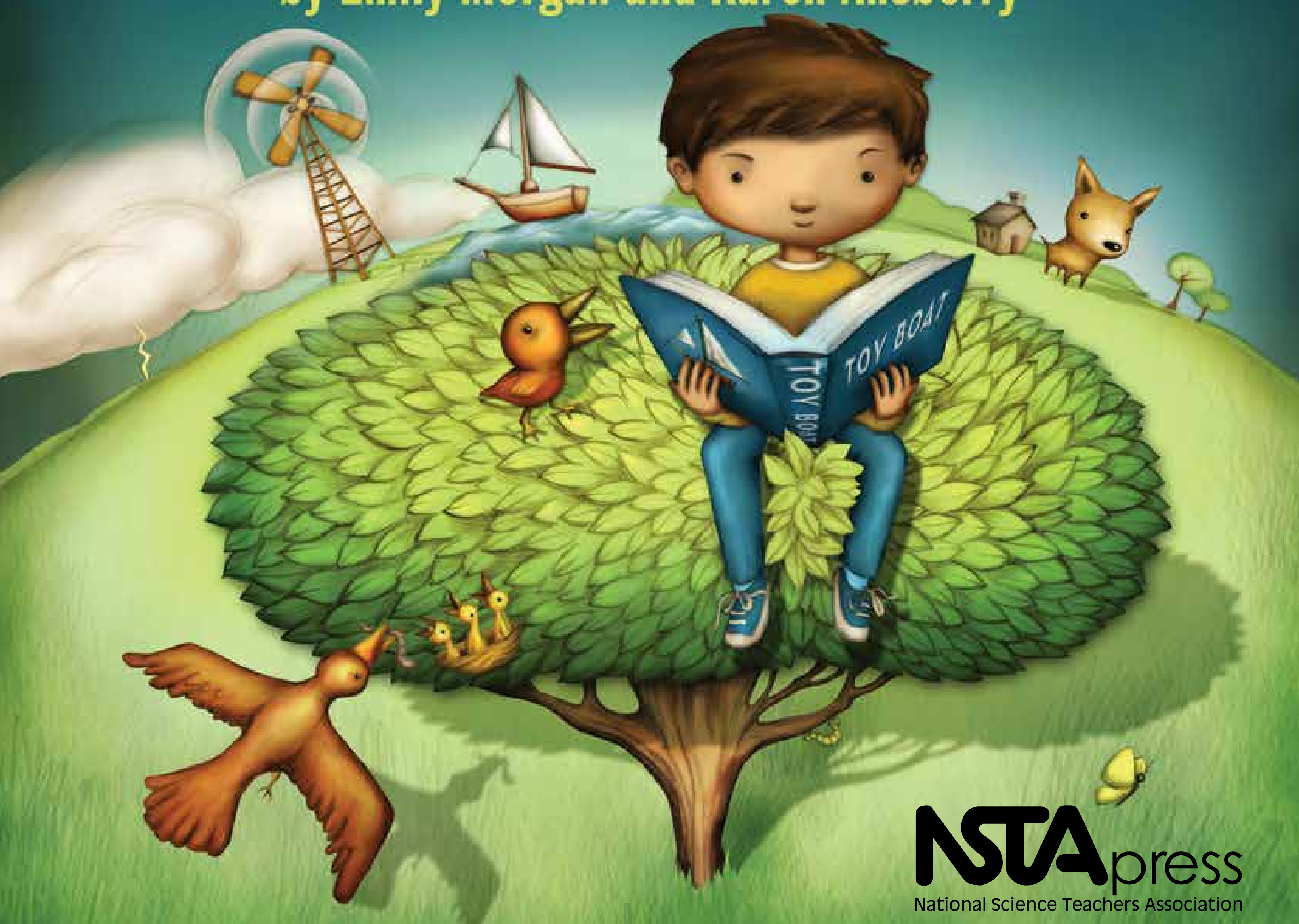
Using Children's Books to Guide Inquiry

by Emily Morgan and Karen Ansberry



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1840 Wilson Blvd., Arlington, VA 22201
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Contents

Preface

A class of fifth-grade students listen as their teacher reads *The Boy Who Harnessed the Wind*. This is the true story of William Kamkwamba, a 14-year-old African boy whose perseverance and ingenuity brought electricity and running water to his drought-ravaged village. With nothing but scraps from a junkyard and the knowledge he acquired from library books, William built a windmill and waited for the wind. Students sit in awe as the teacher reads the dramatic account of what happened next. "Like always, it came, first a breeze, then a gusting gale. The tower swayed and the blades spun round. With sore hands once slowed by hunger and darkness William connected wires to a small bulb, which flickered at first, then surged as bright as the sun. 'Tonga!' he shouted. 'I have made electric wind!'" The teacher asks the class, "How do you think William's windmill was able to light a lightbulb?" In a lesson inspired by this extraordinary story (Chapter 9, "Harnessing the Wind"), students discover the answer to this question by first investigating how a simple handheld generator, the Dynamo Torch, transforms energy of motion into electrical energy. Students then build on this experience by reading an article about energy transformations and listening to a nonfiction read-aloud that explains how wind turbines produce electricity. Eventually, students develop explanations that explain how William's windmill was able to light a bulb. They elaborate on what they have learned by researching various energy resources. Through hands-on inquiries and high-quality readings and picture books, students learn difficult concepts about energy—all within the context of William's remarkable true story.

What Is Picture-Perfect Science?

This scenario describes how a children's picture book can help guide students through an engaging, hands-on inquiry lesson. *Even More Picture-Perfect Science Lessons, K–5* contains 20 science lessons for students in grades K through 5, with embedded reading comprehension strategies to help them learn to read and read to learn while engaged in inquiry-based science. To help you teach according to *A Framework for K–12 Science Education* (NRC 2012), the lessons are written in an easy-to-follow format for teaching inquiry-based science according to the BSCS 5E Instructional Model (Bybee 1997, used with permission from BSCS; see Chapter 4 for more information). This learning cycle model allows students to construct their own understanding of scientific concepts as they cycle through the following phases: engage, explore, explain, elaborate, and evaluate. Although *Even More Picture-Perfect Science Lessons* is primarily a book for teaching science, reading comprehension strategies and the Common Core State Standards for English Language Arts (Common Core ELA; NGA for Best Practices and CCSSO 2010) are embedded in each lesson. These essential strategies can be modeled while keeping the focus of the lessons on science.

Use This Book Within Your Science Curriculum

We wrote *Even More Picture-Perfect Science Lessons* to supplement, not replace, an existing science program. Although each lesson stands alone as a carefully planned learning cycle based on clearly defined science objectives, the lessons are intended to be integrated into a more complete unit of instruction in which concepts can be more fully developed. The lessons are not designed to be taught sequentially. We want you to use the lessons where appropriate within your school's current science curriculum to support, enrich, and extend it. And we want you to adapt the lessons to fit your school's curriculum, your students' needs, and your own teaching style.

Special Features

Ready-to-Use Lessons With Assessments

Each lesson contains engagement activities, hands-on explorations, student pages, suggestions for student and teacher explanations, opportunities for elaboration, assessment suggestions, and annotated bibliographies of more books to read on the topic. Assessments include poster sessions with rubrics, teacher checkpoint labs, and formal multiple-choice and extended-response questions.

Reading Comprehension Strategies

Reading comprehension strategies based on the book *Strategies That Work* (Harvey and Goudvis 2000) and specific activities to enhance comprehension are embedded throughout the lessons and clearly marked with an icon. Chapter 2 describes how to model these strategies while reading aloud to students.

Standards-Based Objectives

All lesson objectives are grade-level endpoints from *A Framework for K–12 Science Education* (NRC 2012) and are clearly identified at the beginning of each lesson. Because we wrote *Even More Picture-Perfect Science Lessons* for students in grades K–5, we used two grade ranges of the *Framework:* K–2 and 3–5. Chapter 5, "Connecting to the Standards," outlines the component ideas from the *Framework* and the grade band addressed for each lesson.

The lessons also incorporate the Common Core State Standards for English Language Arts. In a box titled "Connecting to the Common Core" you will find the Common Core ELA strand the activity addresses (e.g., reading, writing, speaking and listening, or language) as well as the grade level and standard number (e.g., K.9 or 5.1). You will see that writing assignments are specifically labeled with an icon.

Science as Inquiry

As we said, the lessons in *Even More Picture-Perfect Science Lessons* are structured as guided inquiries following the 5E Model. Guiding questions are embedded throughout each lesson and marked with an icon **?**. The questioning process is the cornerstone of good teaching. A teacher who asks thoughtful questions arouses students' curiosity, promotes critical-thinking skills, creates links between ideas, provides challenges, gets immediate feedback on student learning, and helps guide students through the inquiry process. Chapters 3 and 4 explore science as inquiry and the BSCS 5E Instructional Model, and each lesson includes an "Inquiry Place" box that suggests ideas for developing open inquiries.

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Bybee, R. W. 1997. *Achieving scientific literacy: From purposes to practices*. Portsmouth, NH: Heinemann.

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National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

Children's Book Cited

Kamkwamba, W., and B. Mealer. 2012. *The boy who harnessed the wind.* New York: Dial Books for Young Readers.

Editors' Note

Even More Picture-Perfect Science Lessons builds on the texts of 31 children's picture books to teach science. Some of these books feature animals that have been anthropomorphized, such as a caterpillar that does magic tricks. While we recognize that many scientists and educators believe that personification, teleology, animism, and anthropomorphism promote misconceptions among young children, others believe that removing these elements would leave children's literature severely underpopulated. Furthermore, backers of these techniques not only see little harm in their use but also argue that they facilitate learning.

Because *Even More Picture-Perfect Science Lessons* specifically and carefully supports scientific inquiry—the "Amazing Caterpillars" lesson, for instance, teaches students how to weed out misconceptions by asking them to point out inaccurate information about caterpillars and butterflies in a storybook—we, like our authors, feel the question remains open.

Acknowledgments

We would like to dedicate this book to the memory of Sue Livingston, who opened our eyes to the power of modeling reading strategies in the content areas and for teaching us that every teacher is a reading teacher.

We appreciate the care and attention to detail given to this project by Jennifer Horak, Agnes Bannigan, Pat Freedman, and Claire Reinburg at NSTA Press.

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- To Shannon Homoelle for sharing her expertise with the Common Core State Standards for English Language Arts
- To Don Kaufman and Cecilia Berg for giving us the opportunity to share Picture-Perfect Science as part of the GREEN Teachers Institute at Miami University in Oxford, Ohio
- To Bill Robertson for sharing his content knowledge

The contributions of the following reviewers are also gratefully acknowledged:

- Carol Collins
- Miriam Jean Dreher
- Christine Pappas

Contributors

Ideas and activities for the lessons in this book were contributed by the following talented, dedicated teachers. We thank them for their creativity, willingness to share, and the important work they do each day in their classrooms.

Jackie Anderson is a multiple disabilities teacher at Roselawn Condon School in Cincinnati, Ohio. Jackie contributed to Chapter 11, "Do You Know Which Ones Will Grow?"

Missy Breuer is a fifth-grade teacher at Pattison Elementary School in Milford, Ohio. Missy contributed to Chapter 20, "Problem Solvers."

Tim Breuer is a seventh-grade teacher at Milford Junior High School in Milford, Ohio. Tim contributed to Chapter 18, "What Will the Weather Be?"

Katie Davis is a second-grade teacher at Mason Early Childhood Center in Mason, Ohio. Katie contributed to Chapter 14, "Ducks Don't Get Wet"; Chapter 16, "Fossils Tell of Long Ago"; and Chapter 17, "Reduce, Reuse, Recycle."

Allyson Day is a sixth-grade math and science teacher at Monroe Elementary School in Monroe, Ohio. Allyson contributed to Chapter 7, "Float Your Boat."

Jenny DeBord is a first-grade teacher at Monroe Primary School in Monroe, Ohio. Jenny contributed to Chapter 7, "Float Your Boat."

Jenny Doerflein is certified to teach art K–12. Jenny contributed to Chapter 11, "Do You Know Which Ones Will Grow?"

Karen Eads is a first-grade teacher at Sharpsburg Elementary School in Norwood, Ohio. Karen contributed to Chapter 6, "Freezing and Melting."

Maria Eshman is a first-grade teacher at Sharpsburg Elementary School in Norwood, Ohio. Maria contributed to Chapter 6, "Freezing and Melting."

Faye Harp is a teaching and learning consultant at Lakota Local Schools in West Chester, Ohio. Faye contributed to Chapter 12, "Seeds on the Move."

Kathy Gall is a second-grade teacher at Monroe Primary School in Monroe, Ohio. Kathy contributed to Chapter 7, "Float Your Boat."

Aubrey McCalla teaches first grade at Williamsburg Elementary School in Williamsburg, Ohio. Aubrey contributed to Chapter 11, "Do You Know Which Ones Will Grow?"

Michelle Gallite is a third-grade teacher at Western Row Elementary School in Mason, Ohio. Michelle contributed to Chapter 8, "The Wind Blew," and Chapter 15, "Amazing Caterpillars."

Colleen Phillips-Birdsong taught second grade for 11 years and now is a Reading Recovery teacher and reading specialist at Mercer Elementary School in Cincinnati. Colleen contributed to Chapter 10, "Sounds All Around"; Chapter 13, "Unbeatable Beaks"; and Chapter 19, "Sunsets and Shadows."

Lisa Haines is a title one reading teacher at Wilmington City Schools in Wilmington, Ohio. Lisa contributed to Chapter 11, "Do You Know Which Ones Will Grow?"

Katie Woodward is a second-grade teacher at Monroe Primary School in Monroe, Ohio. Katie contributed to Chapter 7, "Float Your Boat."

About the Authors

Emily Morgan is a former elementary science lab teacher for Mason City Schools in Mason, Ohio, and seventh-grade science teacher at Northridge Local Schools in Dayton, Ohio. She has a bachelor of science in elementary education from Wright State University and a master of science in education from the University of Dayton. She is also the author of the *Next Time You See* picture book series from NSTA Press. Emily lives in West Chester, Ohio, with her husband, son, and an assortment of animals.

Karen Ansberry is an elementary science curriculum leader and former fifth- and sixth-grade science teacher at Mason City Schools in Mason, Ohio. She has a bachelor of science in biology from Xavier University and a master of arts in teaching from Miami University. Karen lives in historic Lebanon, Ohio, with her husband, two sons, two daughters, and too many animals.

Emily and Karen, along with language arts consultant Sue Livingston, received a Toyota Tapestry grant for their Picture-Perfect Science grant proposal in 2002. Since then, they have enjoyed facilitating teacher workshops at elementary schools, universities, and professional conferences across the country. This is Emily and Karen's third book in the *Picture-Perfect Science Lessons* series.

Emily and Karen would like to dedicate this book to the memory of Sue Livingston.

About the Picture-Perfect Science Program

The Picture-Perfect Science program originated from Emily Morgan's and Karen Ansberry's shared interest in using children's literature to make science more engaging. In Emily's 2001 master's thesis study involving 350 of her third-grade science lab students at Western Row Elementary, she found that students who used science trade books instead of the textbook scored significantly higher on district science performance assessments than students who used the textbook only. Convinced of the benefits of using picture books to engage students in science inquiry and to increase science understanding, Karen and Emily began collaborating with Sue Livingston, Mason's elementary language arts curriculum leader, in an effort to integrate literacy strategies into inquiry-based science lessons. They received grants from the Ohio Department of Education (2001) and Toyota Tapestry (2002) to train all third- through sixth-grade science teachers, and in 2003 they also trained seventh- and eighth-grade science teachers with district support. The program has been presented at elementary schools, conferences, and universities nationwide.

For more information on Picture-Perfect Science teacher workshops, go to *www.pictureperfectscience.com.*

Lessons by Grade

Chapter	Grade	Picture Books
6	K–2	*Wemberly's Ice-Cream Star* *Why Did My Ice Pop Melt?*
7	3–5	*Toy Boat* *Captain Kidd's Crew Experiments With Sinking and Floating*
8	3–5	*The Wind Blew* *I Face the Wind*
9	3–5	*The Boy Who Harnessed the Wind* *Wind Energy: Blown Away!*
10	K–2	*What's That Sound?* *Sounds All Around*
11	K–2	*Do You Know Which Ones Will Grow?* *What's Alive?*
12	K–2	*Flip, Float, Fly: Seeds on the Move* *Who Will Plant a Tree?*
13	K–2	*Unbeatable Beaks* *Beaks!*
14	3–5	*Just Ducks!* *Ducks Don't Get Wet*
15	K–2	*Houdini the Amazing Caterpillar* *From Caterpillar to Butterfly* *The Very Hungry Caterpillar*
16	3–5	*Fossil* *Fossils Tell of Long Ago*
17	K–2	*The Three R's: Reuse, Reduce, Recycle* *Michael Recycle*
18	3–5	*Come On, Rain!* *What Will the Weather Be?*
19	3–5	*Twilight Comes Twice* *Next Time You See a Sunset*
20	3–5	*Now & Ben: The Modern Inventions of Benjamin Franklin* *Build It: Invent New Structures and Contraptions*

Amazing Caterpillars

Description

In the eyes of a child, the transformation of a caterpillar into a butterfly is nothing short of magic! In this lesson students construct their own understandings about the complete butterfly life cycle by observing, exploring, and journaling about live caterpillars and butterflies before scientific explanations and vocabulary are introduced. Then they learn that butterflies aren't the only ones that go through these dramatic changes. In fact, most insects do.

Suggested Grade Levels: K-2

LESSON OBJECTIVES *Connecting to the Framework*

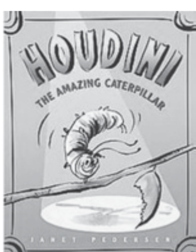
LIFE SCIENCES

Core Idea LS1: From Molecules to Organisms: Structures and Processes

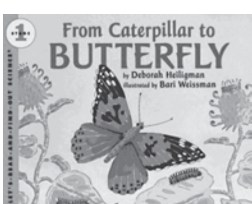
LS1:B: Growth and Development of Organisms

By the end of grade 2: Plants and animals have predictable characteristics at different stages of development. Plants and animals grow and change. Adult plants and animals can have young. In many kinds of animals, parents and the offspring themselves engage in behaviors that help the offspring to survive.

Featured Picture Books



TITLE: ***Houdini The Amazing Caterpillar***
AUTHOR: **Janet Pedersen**
ILLUSTRATOR: **Janet Pedersen**
PUBLISHER: **Clarion Books**
YEAR: **2008**
GENRE: **Story**
SUMMARY: *Houdini is a classroom caterpillar with "magical" abilities. He makes a leaf vanish, crawls across a high-wire stick, and grows before your very eyes. When the audience tires of his tricks, he performs one final act to amaze everyone, including himself.*



TITLE: ***From Caterpillar to Butterfly***
AUTHOR: **Deborah Heiligman**
ILLUSTRATOR: **Bari Weissman**
PUBLISHER: **HarperCollins**
YEAR: **1996**
GENRE: **Narrative Information**
SUMMARY: *Simple text and colorful illustrations describe a butterfly's life cycle within an elementary classroom.*

TITLE: ***The Very Hungry Caterpillar***
AUTHOR: **Eric Carle**
ILLUSTRATOR: **Eric Carle**
PUBLISHER: **Penguin Group**
YEAR: **1969**
GENRE: **Story**
SUMMARY: *The story follows a caterpillar as it makes some unusual food choices and grows into a beautiful butterfly.*

Time Needed

This lesson will take several class periods. Suggested scheduling is as follows:

Part 1

About Two weeks: **Engage** with *Houdini the Amazing Caterpillar* Read-Aloud and **Explore** with Our Amazing Caterpillars Journal

Part 2

Day 1: **Explain** with *Houdini the Amazing Caterpillar* and *From Caterpillar to Butterfly* Read-Aloud, card sort, and Pasta Life Cycle Diagram

Day 2: **Elaborate** with Butterflies Aren't the Only Ones

Day 3 **Evaluate** with *The Very Hungry Caterpillar* Retelling Book

NOTE: Allow about two weeks between part 1 and part 2 of this lesson. During those two weeks, students will need several opportunities to observe the caterpillars/chrysalides and record these observations in their journals.

Materials

For caterpillar observations (per class)

- Painted lady butterfly kit containing caterpillars or caterpillar coupons, food, and mesh butterfly habitat. (Butterfly kits are available at *www.insectlore.com* and *www.carolina.com*.)

For card sort (one set per pair of students)

- Butterfly Life Cycle cards (cut out in advance by teacher)

For Pasta Life Cycle Diagram (per student)

- Pasta shapes to represent the stages of the butterfly life cycle: small beadlike pasta such as pearl pasta, acini di pepe, or couscous (egg), rotini (caterpillar), shell (chrysalis), and bowtie (butterfly)
- Green, brown, and black markers or colored pencils
- 9" or 10" paper plate
- White glue

Student Pages

- Our Amazing Caterpillars Journal (Copy the cover on a separate sheet, then copy pp. 1 and 8 back-to-back with 2 and 7; copy pp. 6 and 3 back-to-back with 4 and 5. Fold and staple along the spine.)
- Butterflies Aren't the Only Ones
- *The Very Hungry Caterpillar* Retelling Book

Background

A Framework for K–12 Science Education recommends that by the end of grade 2 students recognize that plants and animals have predictable characteristics at different stages of development. With young children, it is best to develop understanding of biological concepts such as this through direct experience with living things and their life cycles. Butterflies are ideal to use in this type of exploration. They are familiar, interesting, and often found in the local ecosystem.

Butterflies experience *metamorphosis* as they progress through their life cycles. Almost all insects go through metamorphosis, with the exception of a few such as silverfish and springtails (which hatch from the egg as a small replica of the adult and mature by growing bigger). Metamorphosis is marked by distinct stages, often resulting in an abrupt change of physical appearance. The butterfly begins its life as an egg and hatches into a *larva*, known as a caterpillar. In this *larval stage*, the caterpillar spends most of its time eating plant material. As it grows, the exoskeleton becomes tight, so it molts, or sheds, the old one. This process is repeated several times as the caterpillar grows. Finally, the caterpillar makes a special silk "button" which it uses to hang upside down from a twig or other surface. The soft body that the caterpillar reveals when it molts for the final time is called a *chrysalis* (plural: *chrysalides*), which hardens to form a protective shell. Many children and adults confuse this structure with a cocoon; however, a cocoon is a silk covering that most moths spin to protect their chrysalis. (Some species of moth caterpillars also disguise their cocoons with leaves or other debris.) Inside the chrysalis, a remarkable transformation takes place. This is known as the *pupal stage* of the butterfly life cycle, during which the butterfly is immobile. In the pupal stage, parts of the caterpillar's body break down into undifferentiated cells, which then form new structures. The amount of time required for this transformation varies depending on the species. After the caterpillar completely transforms, the chrysalis cracks open and the *adult* butterfly emerges. At first, its wings are damp and crumpled. As it pumps blood into them, the wings straighten out and dry. Soon the adult butterfly is ready to take its first flight.

Many animals (such as fish, birds, reptiles, and mammals) have fairly simple life cycles in which they are born or hatched, then grow into adults. Amphibians have a bit more complex life cycle where they hatch from an egg, live underwater breathing through gills, grow into adults, move to land and breathe air through their skin and lungs. Most insects, however, have a dramatic life cycle in which they go through the following stages: egg, larva, pupa, and adult. A few insects, like dragonflies, grasshoppers, and cockroaches, go through an incomplete metamorphosis, which means they go from egg to larva to adult, without a pupal stage. In the elaborate phase of this lesson, students apply what they learn about the stages of insect metamorphosis to other insects, so they will understand that butterflies aren't the only ones that go through this dramatic change.

About the Painted Lady Butterfly

This lesson uses painted lady butterflies to demonstrate the stages of a metamorphic life cycle. The painted lady butterfly (*Vanessa cardui*) is found in most of the United States as well as Canada. Several companies have marketed ready-made kits that include everything you will need to help your butterflies develop. Most contain coupons to send away for the live caterpillars. You are unlikely to see the egg stage of the life cycle; therefore, you should be prepared to describe this to your students. Female painted lady butterflies lay their eggs on plants such as thistle, hollyhock, and mallow. When the caterpillars hatch, they eat the leaves of the plants. The eggs are light blue-green in color and the size of a pinhead. The caterpillars emerge within three to five days.

Excluding the egg stage, the life cycle should take approximately three weeks. Your caterpillars will likely ship in a ventilated plastic cup containing food (referred to as "nutrient" by some vendors). The caterpillars will spend most of their time eating and may spin a small amount of silk. You will notice small balls in the container; the balls are caterpillar waste, or *frass.*

When your caterpillars are ready for the pupal stage, they will crawl to the lid of the container and hang upside down in a hook shape. If they are not disturbed, the caterpillars will harden into chrysalides in one to two days. Once all of your caterpillars have entered the pupal stage, you should remove the lid and hang it inside of your butterfly home. You may notice the chrysalides shaking. This is natural and helps to prevent predator attacks in the wild.

The adult butterflies will emerge in 7 to 10 days. You may notice that the chrysalides become transparent just before this occurs. The new butterflies' wings will be wrinkled and soft. They will be ready to fly within a few hours. Do not be alarmed if you notice your butterflies excreting a red liquid. This is meconium, a waste product from the pupal stage. You may want to line the bottom of your butterfly home with paper towels or a paper plate to catch the meconium.

To feed your butterflies, dissolve 3 teaspoons of sugar into 1 cup of water. Sprinkle this mixture onto fresh flowers or saturate a crumpled paper towel. Place them in your butterflies' home. You will see your butterflies uncurl their proboscises and sip the sugar water.

When you are ready to release your butterflies, make sure the temperature is above 55°F. Painted lady butterflies are one of the most widely distributed butterfly species in the world, but check your state's wildlife release rules prior to setting them free in your area. If you are unable to release them, your butterflies may mate and lay eggs. When the larvae hatch, add thistle, hollyhock, or mallow leaves to your butterflies' home. The adult butterflies have a life span of only two weeks. Reassure your students that this, too, is a part of the life cycle, and the young will continue the circle of life.

engage

Houdini the Amazing Caterpillar Read-Aloud

Making Connections: Text-to-World

Ask

- ? Have you ever seen a magic show?
- ? What kinds of tricks do magicians do? (make something disappear, pull a rabbit out of a hat, guess a card, escape from an enclosed space, and so on)
- ? Have you ever heard of a magician named Houdini?

Tell the students that Harry Houdini was one of the most well-known magicians of all time. Houdini became famous for his escape acts. He could free himself from prisons, handcuffs, ropes, chains, and water-filled containers. One of Houdini's most famous illusions involved making a full-grown elephant and its trainer disappear from the stage! Then tell the students that you have a book about a very unusual magician, also named Houdini, to share with them. Show the students the cover of *Houdini the Amazing Caterpillar,* and introduce the author and illustrator.

Inferring

Connecting to the Common Core
Reading: Literature
Key Ideas and Details: K.1, 1.2, 1.3

Read the book aloud, stopping after page 19. ("Suddenly, he knew just what his next act would be. It would be his most daring act ever.") *Ask*

? How are Houdini's actions like magic? (Houdini makes leaves vanish by eating them; he grows before their very eyes and breaks free from his skin; he holds a pose for almost two weeks without food, water or taking a break.)

Model questioning by saying, "I wonder what Houdini's next act will be?" Give each student a sticky note, and ask them to write or draw what they think Houdini's next, most daring act will be. Collect the sticky notes and use them to assess student preconceptions. Tell students that they are going to see some "magic" in their own classroom before you read the rest of the book to them.

explore

Our Amazing Caterpillars Journal

Connecting to the Common Core
Writing
Research to Build and Present Knowledge: K.7, 1.7, 2.7

Hold up the caterpillar container, and tell students that you have some amazing little "Houdinis" for them to observe.

Pass out the Our Amazing Caterpillars Journals. Tell students they are going to be observing these caterpillars for several weeks, just as the children in *Houdini the Amazing Caterpillar* did. For observation 1, first have students record the date. Throughout the day, allow small groups of students to visit the caterpillars to record their observations. Continue to have the students make observations every few days, or as needed when changes occur. At this point, it is not necessary to reveal the scientific terminology for each stage, although some students may already be familiar with some of these words. You will continue with the rest of this lesson when all of the caterpillars have become adult butterflies.


Observing the Butterfly Life Cycle

Use the following guidelines to help students work through the journal:

Observation 2: Complete one to two days following the initial observation.

Observation 3: Complete two to three days following the second observation.

Observation 4: Complete when at least one caterpillar is hanging upside down, preparing for the pupal stage.

Observation 5: Complete once all chrysalides have formed, and you have removed them from the caterpillar container. Allow students to make their observations before


Painted Lady Chrysalis

placing the chrysalides in the butterfly home. The drawing of the circle is the disk upon which the chrysalides are attached.

Observation 6: Complete when one or more butterflies have emerged. This can also be used if you are lucky enough to observe a butterfly as it is emerging.

Observation 7: Complete once all of the butterflies have emerged.

Wonderings: Students can record any questions they have about the caterpillars and butterflies on this page.

explain

Houdini the Amazing Caterpillar and *From Caterpillar to Butterfly* Read-Aloud

Making Connections: Text-to-World

Tell students that now that they have witnessed the "magic" of their own caterpillars, you will read the entire story of *Houdini the Amazing Caterpillar* to them. Tell them that as you read, you would like them to signal when they see Houdini doing something that they saw their caterpillars doing. Students should signal that both Houdini and their classroom caterpillars ate, shed their skin, grew, hung upside down for a long time, and emerged as butterflies. After reading, *ask*

? Is this book fiction or nonfiction? How do you know? (fiction, because the caterpillar smiles and talks)

Tell students that you have a nonfiction book that can help them learn more about the life cycle of a butterfly, including the names of all the stages that they observed. Introduce the author and illustrator of *From Caterpillar to Butterfly.* As you show the cover, *ask*

? What do you think this book has in common with Houdini the Amazing Caterpillar? (Answers may include that they are both about butterflies, there are caterpillars in both books, and the butterflies in both books are orange.)

Open Sort

Before reading the nonfiction book, give each pair of students a set of precut Butterfly Life Cycle cards with the names and pictures of the four stages of butterfly metamorphosis: egg, caterpillar (larva), chrysalis (pupa), butterfly. Before reading, ask students to put the cards in the order in which they think they go.

Determining Importance

> Connecting to the Common Core
> **Reading: Informational Text**
> Key Ideas and Details: K.3, 1.3, 2.3

Tell students that as you read the book aloud, you would like them to listen for the names of the stages on their cards. Read the large-print text of the book aloud. As you read about each stage, have students move their cards in the correct order. Be sure to read the small-print text on page 11 ("The caterpillar is also called the larva.") and page 19 ("The chrysalis is also called the pupa.").

Closed Sort

After reading, make sure students have put the cards showing the stages of the butterfly life cycle in the correct order: egg, caterpillar (larva), chrysalis (pupa), butterfly. *Ask*

? Where do butterfly eggs come from? (adult butterflies)

Have students move the cards to create a circle that represents the continuation of the egg-caterpillar-chrysalis-butterfly cycle.

Ask if students have ever heard the term *cocoon.* Explain that butterflies do not make cocoons, but moths do. Cocoons are spun out of silk during a moth's pupal stage. Some moths also camouflage their cocoons by covering them with bits of leaves or other plant material. They go through their metamorphosis inside the safety of their cocoon. *Ask*

? "Where do butterflies go through their pupal stage?" (inside a chrysalis)

Pasta Life Cycle Diagram

Pass out one paper plate and one piece of each of the following pastas to each student: beadlike pasta, rotini, shell, and bowtie. Students will also need green, brown, and black markers or colored pencils. Guide students through the following steps to make a butterfly life cycle diagram on a paper plate:

> **SAFETY**
>
> Tell students not to eat or taste any food (e.g., pasta) or beverage that has been made or used in the lab or classroom activity unless instructed to do so by the teacher.

1. *Ask*

   ? How does a caterpillar begin its life? (as an egg) Show the illustration of butterfly eggs on page 9 of *From Caterpillar to Butterfly*. Tell students to hold up the pasta that looks most like a butterfly egg (beadlike pasta). Tell them to place the beadlike pasta at the 12:00 position on their plates. Then have them sketch the outline of a leaf with a green marker or colored pencil around the "egg." Tell them that they will glue the pasta onto the "leaf" later. Have students write "egg" below the beadlike pasta.

2. *Ask*

   ? What hatches from a butterfly egg? (caterpillar) Show the illustration of a caterpillar on page 15 of the book. Tell students to hold up the pasta that looks most like a caterpillar (rotini). Tell them to place the rotini at the 3:00 position on their plates. Remind them that they will glue the pasta onto the plate later. Have students write "caterpillar" below the rotini.

3. *Ask*

   ? What is another name for a caterpillar? (larva). Have students write "larva" in parentheses next to the word "caterpillar."

4. *Ask*

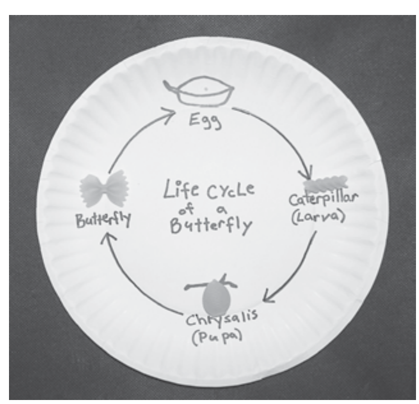
   ? What happens after the caterpillar molts for the last time? (It makes a chrysalis.) Show the illustration of the chrysalis on page 20 of the book. Tell students to hold up the pasta that looks most like a chrysalis (shell pasta). Tell them to place the shell pasta at the 6:00 position on their plates. Then have them use a brown marker or colored pencil to draw a twig just above the shell pasta (so the "chrysalis" has a place to attach). Remind them that they will glue the pasta onto the paper plate later. Have students write "chrysalis" below the shell pasta.

5. *Ask*

   ? What is another name for the chrysalis? (pupa) Have students write "pupa" in parentheses next to the word "chrysalis."

6. *Ask*

   ? What comes out of the chrysalis? (butterfly) Show the illustration of the adult butterfly on page 29 of the book. Tell students to hold up the pasta that looks most like a butterfly



Pasta Life Cycle Diagram

(bowtie pasta). Tell them to place a piece of bowtie pasta at the 9:00 position on their plates. Remind them that they will glue the pasta onto the plate later. Have students write "butterfly" below the bowtie pasta.

7. Have students draw arched arrows from the egg to the caterpillar to the butterfly to show that these stages occur in a set order. *Ask*

 ? Should we draw an arrow from the butterfly back to the egg?

 Reread pages 28 and 29 of *From Caterpillar to Butterfly*. Introduce the term *life cycle* by telling students that every living thing is born, grows and changes, reproduces by laying eggs or having babies, and dies. The babies, or offspring, grow up to repeat these stages. *Ask*

 ? What is the word for the changes that a butterfly goes through in its life cycle? (metamorphosis, p. 6).

 Tell students that the word *metamorphosis* means "really big change." Explain that all living things go through a life cycle, but only some of them, like the butterfly, go through a metamorphosis. Then have students draw an arrow from the butterfly to the egg to demonstrate that the life cycle will continue.

8. Have students write "Life Cycle of a Butterfly" in the center of their plates with a black marker.
9. Have students use white glue to affix the pasta shapes to their appropriate places on the paper plates.

elaborate

Butterflies Aren't the Only Ones

Explain that many animals, such as fish, birds, reptiles, and mammals, have fairly simple life cycles in which they are born or hatched, then grow into adults. Amphibians, such as frogs, have a bit more complex life cycle—they are born, live underwater breathing through gills, grow into adults, then move to the land and breathe air. Most insects, however, have a dramatic life cycle where they go through the following stages: egg, larva, pupa, and adult. Write the names of these stages on the board. *Ask*

? What is the larval stage of the butterfly called? (caterpillar)

? What is the pupal stage of the butterfly called? (chrysalis)

Explain that a few insects, like dragonflies, grasshoppers, and cockroaches, go through an incomplete metamorphosis, which means they go from egg to larva to adult, without a pupal stage. However, most insects, like butterflies, go through a metamorphosis, or really big change.

POINTING OUT SCIENTIFIC INACCURACIES

Pass out the Butterflies Aren't the Only Ones student page to each student or pair of students. Explain that they will apply the concepts and vocabulary they have learned about the stages of the butterfly life cycle to another kind of insect. Assign each student or pair of students an insect that goes through a metamorphosis and have them research the life stages of their insect on the internet or in nonfiction books. Examples of such insects include ant, bee, beetle, firefly, housefly, ladybug, mosquito, moth, praying mantis, and wasp. Have students use the student page to draw the different stages of that insect's life cycle, then have them share what they learned about their insect with the class.

evaluate

The Very Hungry Caterpillar Retelling Book

Introduce the author and illustrator of *The Very Hungry Caterpillar.* Read the book aloud to students. After reading, *ask*

? Is this book fiction or nonfiction? (fiction) How do you know? (The caterpillar eats food that caterpillars don't really eat, and so on)

Rereading and Determining Importance

> Connecting to the Common Core
> **Reading: Literature**
> CRAFT AND STRUCTURE: K.5, 1.5

Tell students that you are going to read the book again, but this time you would like to point out everything in the book that is not factual based on the things they have observed and read about caterpillars and butterflies. If they see a picture or hear something in the book they think is incorrect, they should raise their hands and explain their reasoning. Responses might include

- Caterpillars would not eat the foods in the book like ice cream, salami, cake, and so on.
- Butterfly caterpillars make a chrysalis, not a cocoon.
- Butterflies must let their wings dry before flying.
- Butterflies push out of the chrysalis. They don't nibble.

Many children have asked Eric Carle why the butterfly in *The Very Hungry Caterpillar* comes from a cocoon and not a chrysalis—so many, in fact, that it appears in the "Frequently Asked Questions" page on his website. This is the answer he gives:

> *Here's the scientific explanation: In most cases a butterfly does come from a chrysalis, but not all. There's a rare genus called* Parnassian, *that pupates in a cocoon. These butterflies live in the Pacific Northwest, in Siberia, and as far away as North Korea and the northern islands of Japan.*
>
> *And here's my unscientific explanation: My caterpillar is very unusual. As you know caterpillars don't eat lollipops and ice cream, so you won't find my caterpillar in any field guides. But also, when I was a small boy, my father would say, "Eric, come out of your cocoon." He meant I should open up and be receptive to the world around me. For me, it would not sound right to say, "Come out of your chrysalis." And so poetry won over science!*
>
> *Eric Carle,*
> www.eric-carle.com/q-cocoon.html

Tell students that Eric Carle did not write *The Very Hungry Caterpillar* as a science book, so it's okay if it is not scientifically accurate, or true. Anything can happen in fiction; a caterpillar can even eat ice cream and salami! But tell students they are going to get a chance to create a version of the story so that it *is* scientifically accurate. Pass out *The Very Hungry Caterpillar* Retelling Book. As you read it aloud, have the students illustrate the story and label the correct stages of the butterfly's life cycle. When students are finished, they should cut out each page separately and staple the pages together in order.

Inquiry Place

Have students brainstorm questions about animal life cycles. Examples of such questions include

- ? How does the moth life cycle compare with the butterfly life cycle? Observe it or research it! (*Note:* Life cycle kits for saturniid and hornworm moths are available from *www.carolina.com*.)
- ? How does the mealworm life cycle compare with the butterfly life cycle? Observe it or research it! (*Note:* Mealworms are available at pet stores and bait shops.)
- ? What kinds of cocoons do different moths make? Research it!
- ? Which insects go through an incomplete metamorphosis? Research it!
- ? What are the stages of an amphibian's life cycle? Research it!

Then have students select a question to investigate or research as a class, or have groups of students vote on the question they want to investigate or research as a team. Students can present their findings at a poster session or gallery walk.

Websites

The Children's Butterfly Site
www.kidsbutterfly.org

National Geographic video "Butterfly: A Life"
Watch the transformation of a monarch butterfly from egg to larva to pupa to adult in two minutes.
http://video.nationalgeographic.com/video/national-geographic-channel/all-videos/av-8520-8756/ngc-butterfly-a-life

More Books to Read

Allen, J. 2003. *Are you a butterfly?* New York: Kingfisher.
Summary: Simple text and soft illustrations help the readers imagine themselves as butterflies experiencing metamorphosis.

Bunting, E. 1999. *Butterfly house.* New York: Scholastic Press.
Summary: A young girl saves a caterpillar from a hungry jay and creates a home for it. She raises the caterpillar until it becomes a painted lady butterfly. The girl releases the butterfly, but as she grows older, painted ladies continue to flock to her garden.

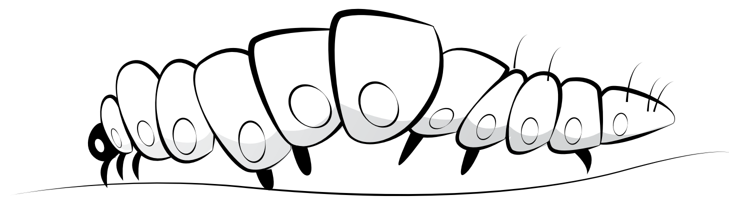
Kalman, B. 2006. *The life cycle of a butterfly.* New York: Crabtree.
Summary: This scientific text clearly explains the stages of a butterfly's life cycle. Attractive photographs and clear illustrations enhance the fact-filled book.

Pashley, H., and L. Adams. 2010. *Look, ask and learn about butterflies.* New York: Little Science Books.
Summary: This encourages the reader to observe and ask questions about butterflies. Stunning, up-close photos show various butterflies at different stages in their life cycles.

Ryder, J. 1996. *Where butterflies grow.* New York: Puffin.
Summary: Strong imagery helps the readers connect to the story and experience life as a growing black swallowtail butterfly. The author includes suggestions for creating your own butterfly garden.

Slade, S. 2008. *From caterpillar to butterfly: Following the life cycle.* Minneapolis, MN: Picture Window Books.
Summary: Bright illustrations and informative text describe the life cycle of the monarch butterfly.

Our Amazing Caterpillars Journal



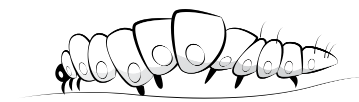
Scientist: ____________________

Date: From __________ to __________

Wonderings

What are you wondering about caterpillars?

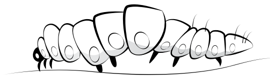
Observation #1



Date: ____________

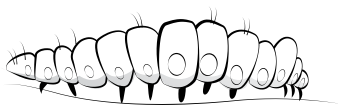
Look closely at one of our caterpillars.
Draw and color it below.

Observation #2

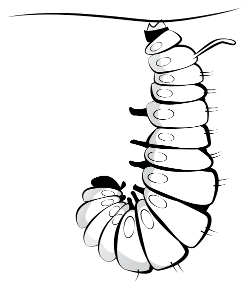


Date: ____________________

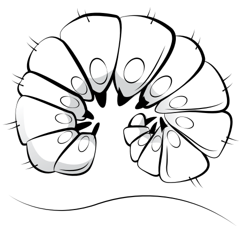
What are the caterpillars doing? Record the number of caterpillars doing each activity below.



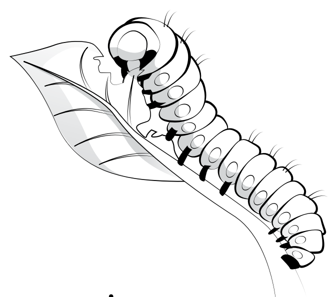
crawling ____



hanging ____



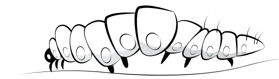
resting ____



eating ____

Page 2

Observation #7

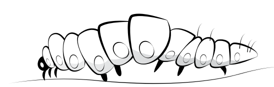


Date: ____________________

Draw and color what you see in the container today.

Page 7

Observation #4

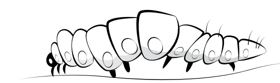


Date: ____________________

Draw and color what you see in the container today.

Page 4

Observation #5

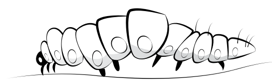


Date: ____________________

Where did our caterpillars go? Draw and color what you see.

Page 5

Observation #6

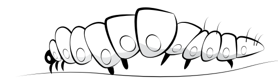


Date: ____________________

What do you observe now? Draw and color what you see inside the container.

Page 6

Observation #3

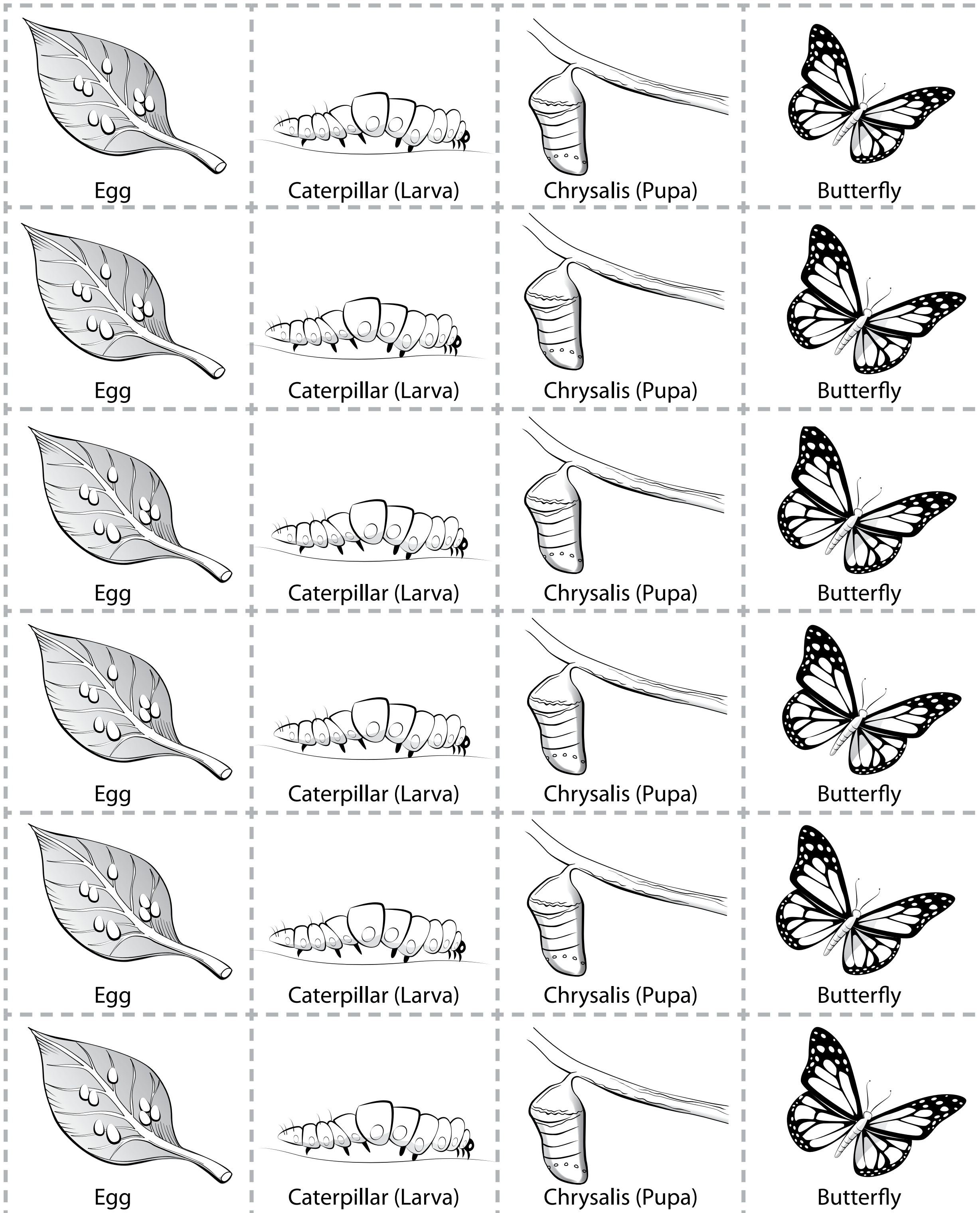


Date: ____________________

Draw and color what you see in the container today.

Page 3

Butterfly Life Cycle Cards



Name: ________________________________

Butterflies Aren't the Only Ones

Directions:
Draw the stages of the life cycle of an insect other than a butterfly.
Be sure to draw arrows from one stage to the next.

Egg

Life Cycle of a ________________

Adult

Larva

Pupa

Name: ______________________________

The Very Hungry Caterpillar

Retelling Book

By Eric Carle

*Retold by*______________________

In the light of the moon a little egg lay on a leaf.

One warm day—pop!—a tiny and very hungry caterpillar ate its way out of the egg.

He started to look for some food.

Name: ____________________________

The Very Hungry Caterpillar

Retelling Book

For many days, the caterpillar ate through nice green leaves, and after that he felt much better.

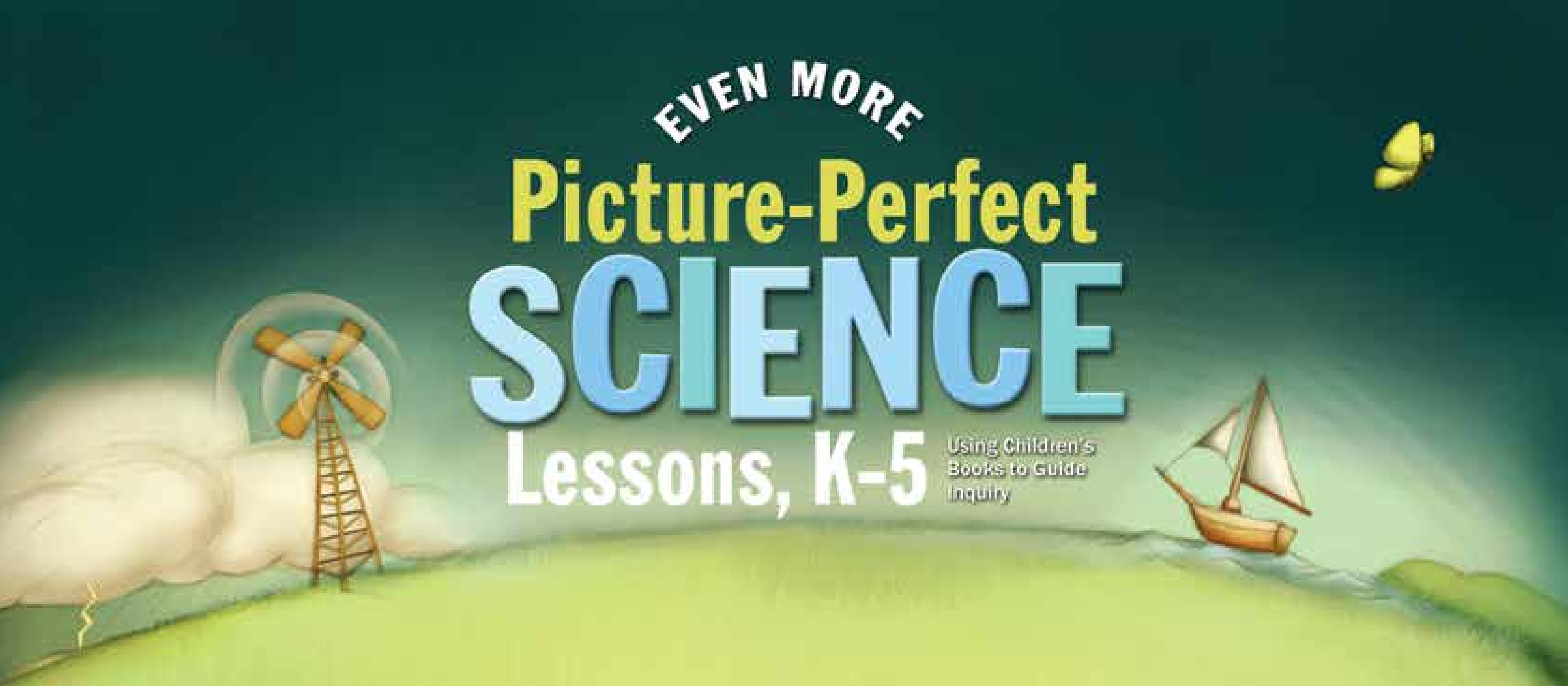
Now he wasn't hungry any more—and he wasn't a little caterpillar any more. He was a big fat caterpillar.

He made a covering, called a chrysalis, around himself. He stayed inside for several days. Then he pushed his way out and…

he was a beautiful butterfly!

Index

Page numbers printed in **boldface** type indicate tables or illustrations.



"The No. 1 compliment we hear from teachers is that the lessons are complete and ready to take back to their classrooms and use." —Karen Ansberry and Emily Morgan, coauthors of the *Picture-Perfect Science* series

Since the debut of the *Picture-Perfect Science* books and workshops more than 10 years ago, authors Emily Morgan and Karen Ansberry have learned one thing for certain: Elementary school teachers are constantly clamoring for even more ways to engage children in reading and science through picture books! To meet that demand, the 15 all-new lessons in *Even More Picture-Perfect Science Lessons* bring you

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Grades K–5

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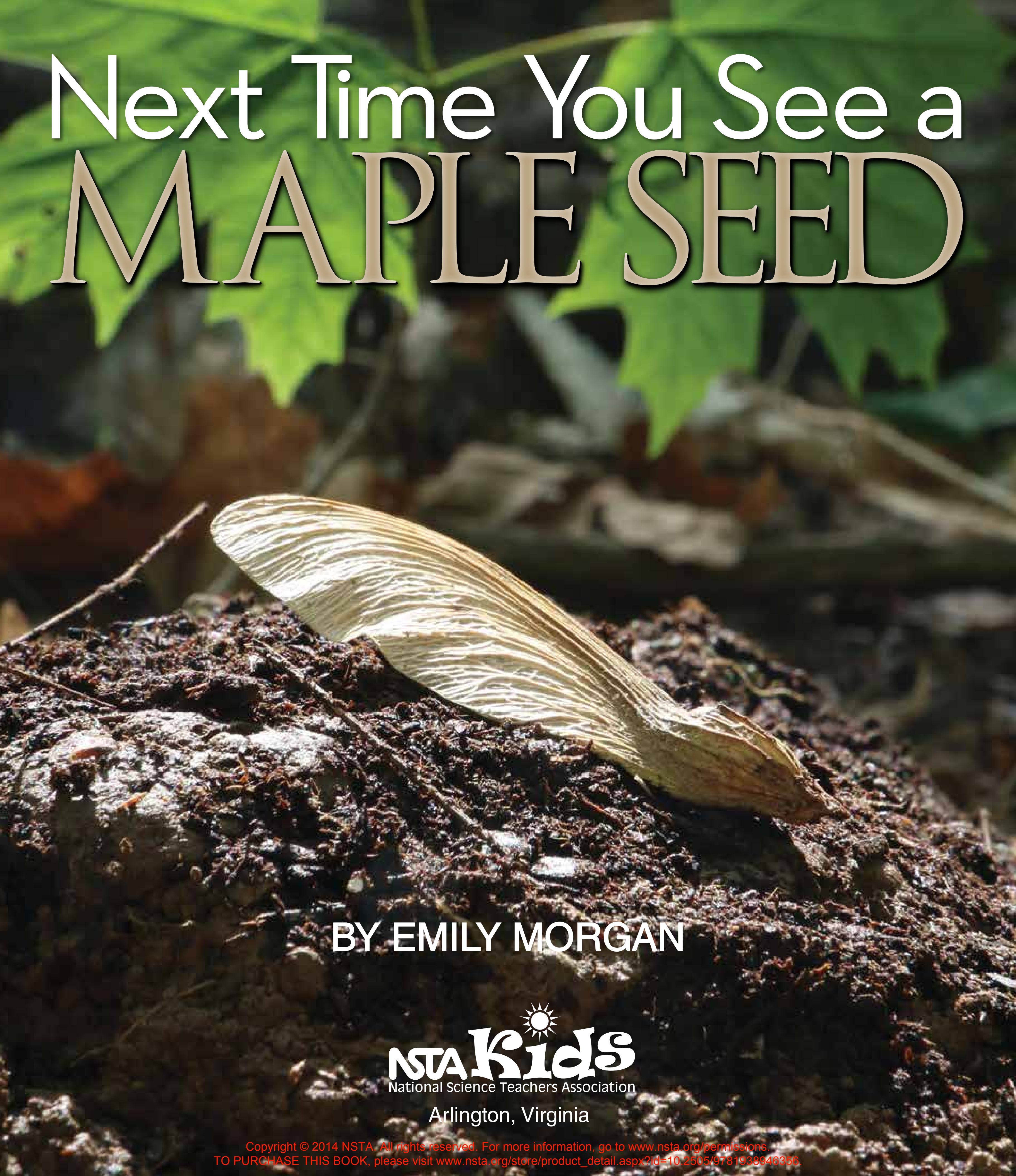
Next Time You See a MAPLE SEED

BY EMILY MORGAN

NSTA Kids
National Science Teachers Association



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NSTA Kids
National Science Teachers Association
Arlington, Virginia

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Claire Reinburg, Director
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Art and Design
Will Thomas Jr., Director

Printing and Production
Catherine Lorrain, Director

National Science Teachers Association
David L. Evans, Executive Director
David Beacom, Publisher

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To my friend and mentor, Dr. Diana Hunn.
Thanks for helping me grow.

A Note to Parents and Teachers

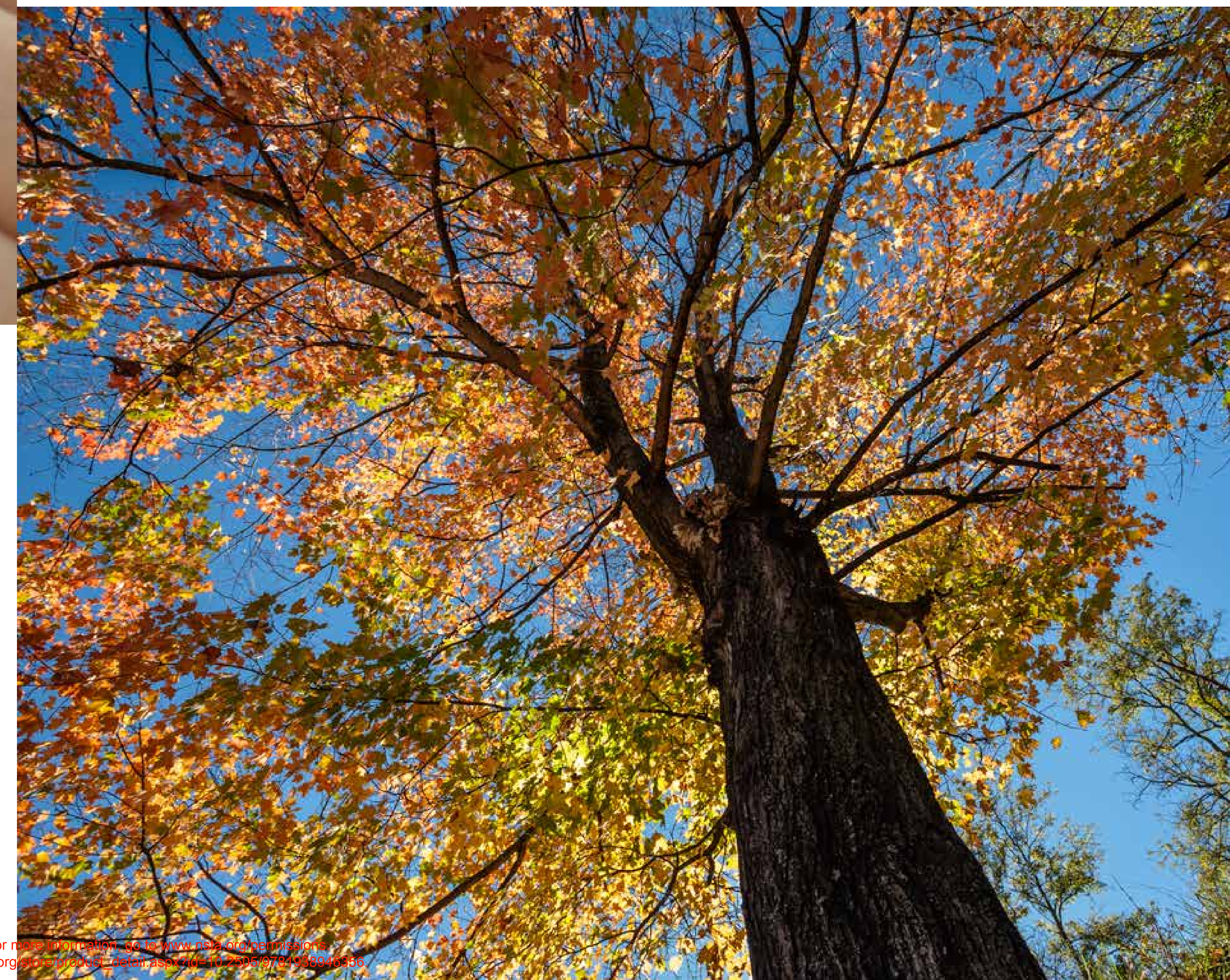
The books in this series are intended to be read with a child *after* he has had some experience with the featured objects or phenomena. For example, go outside together on a spring day and look for maple tree samaras (which we commonly call maple seeds). Gather a pile of them and toss them up in the air. As they fall to the ground, watch them spin through the air like tiny helicopters. Look around to see if you can find the tree that made them. Drop one samara at a time and count the seconds it takes to reach the ground. Look closely at a samara and talk about its shape. Feel the delicate, feathery wing. Break open the round end and discuss what you find inside.

Ask your child what he is wondering about the samaras, and share what you wonder. Then read this book together and discuss new learnings. You will find that new learnings often lead to new questions. Take time to pause and share these wonderings with each other.

The *Next Time You See* books are not meant to present facts to be memorized. They are written to inspire a sense of wonder about nature and foster a desire to learn more about the natural world. Children are naturally fascinated by twirling maple tree samaras, and when they learn about what's inside and why they spin, these whirling springtime regulars become much more remarkable. My wish is that after reading this book, you and your child feel a sense of wonder the next time you see a maple seed.

—Emily Morgan

When you look up at a mature maple tree, it is astonishing to think that tree was once a tiny embryo that fit inside a feathery, winged samara. Have you ever wondered how a small seed becomes a towering tree?



Inside the round, hard part of the samara is the seed, and inside of that seed is an *embryo*. The embryo is the part of the maple seed that can grow into a tree. You might think of it as a baby tree. If you take a samara apart carefully, you can actually observe the tiny tree that is waiting to grow. First, pull off the wing and remove the seed. Then, carefully divide the seed in half and look closely for the tiny maple tree embryo inside.

To begin to grow, a maple seed just needs water and a warm environment. Like most seeds, a maple seed does not need sunlight to sprout. Most seeds sprout in darkness underground. While underground, the embryo uses the material in the rest of the seed for food and grows roots to soak up water. When the leaves finally break through the surface, something truly amazing begins to happen.

Next Time You See a MAPLE SEED

It's fun to toss maple seeds up in the air and watch them spin down to the ground like nature's own helicopters. This book prompts inquisitive kids to learn about these marvels of aerial engineering, including their real name (no, not *whirlybird*), the work they do for maple trees, and how to uncover the little trees waiting to sprout from the seeds. *Next Time You See a Maple Seed* is a mini class in how tall trees grow from these tiny, twirling winged fruits.

Awaken a sense of wonder in a child with the *Next Time You See* series from NSTA Kids. The books will inspire elementary-age children to experience the enchantment of everyday phenomena, such as maple seeds, Moon phases, pill bugs, fireflies, seashells, and sunsets. Free supplementary activities are available on the NSTA website.

Grades K–6
Lexile® measure: 1040L

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National Science Teachers Association

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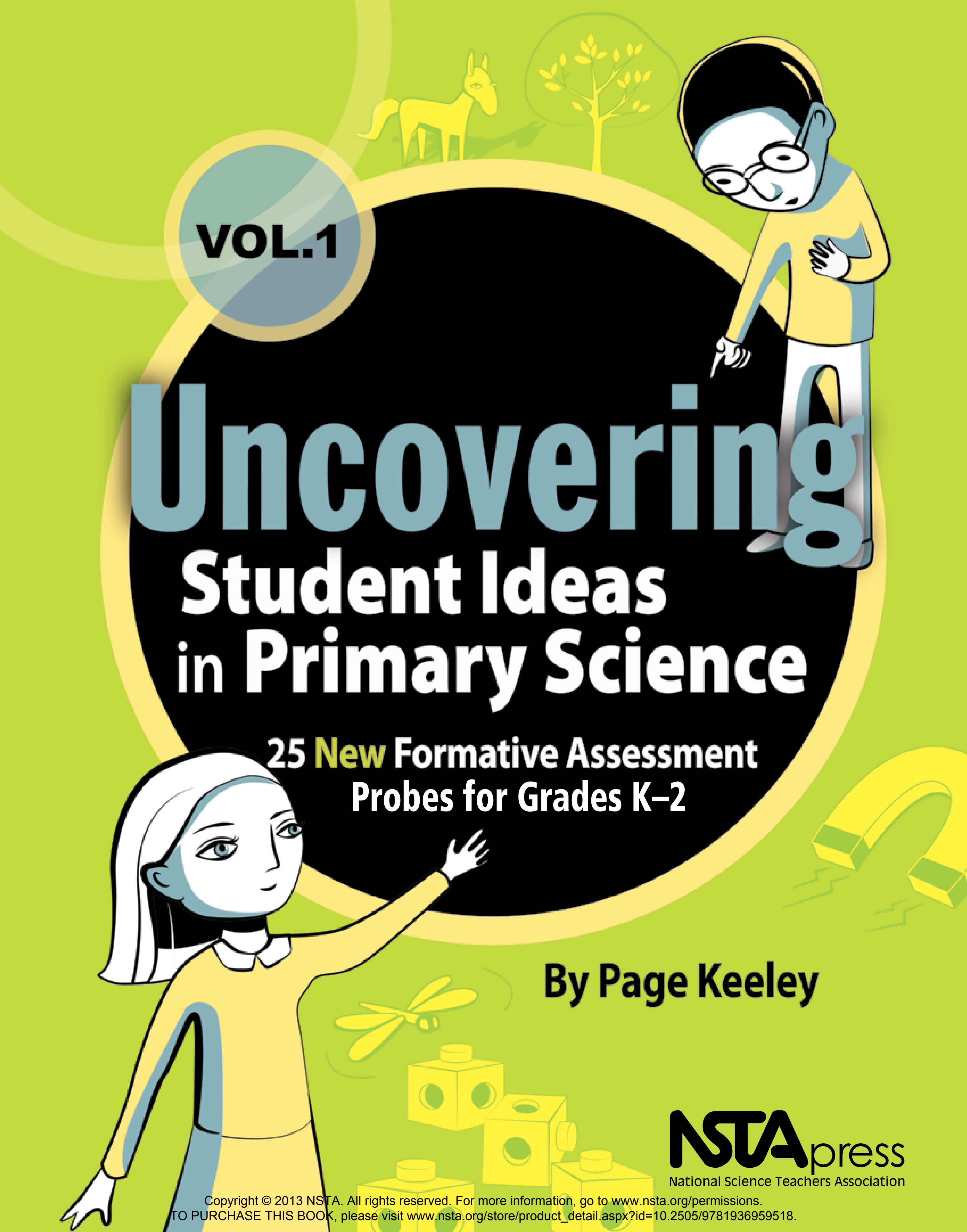


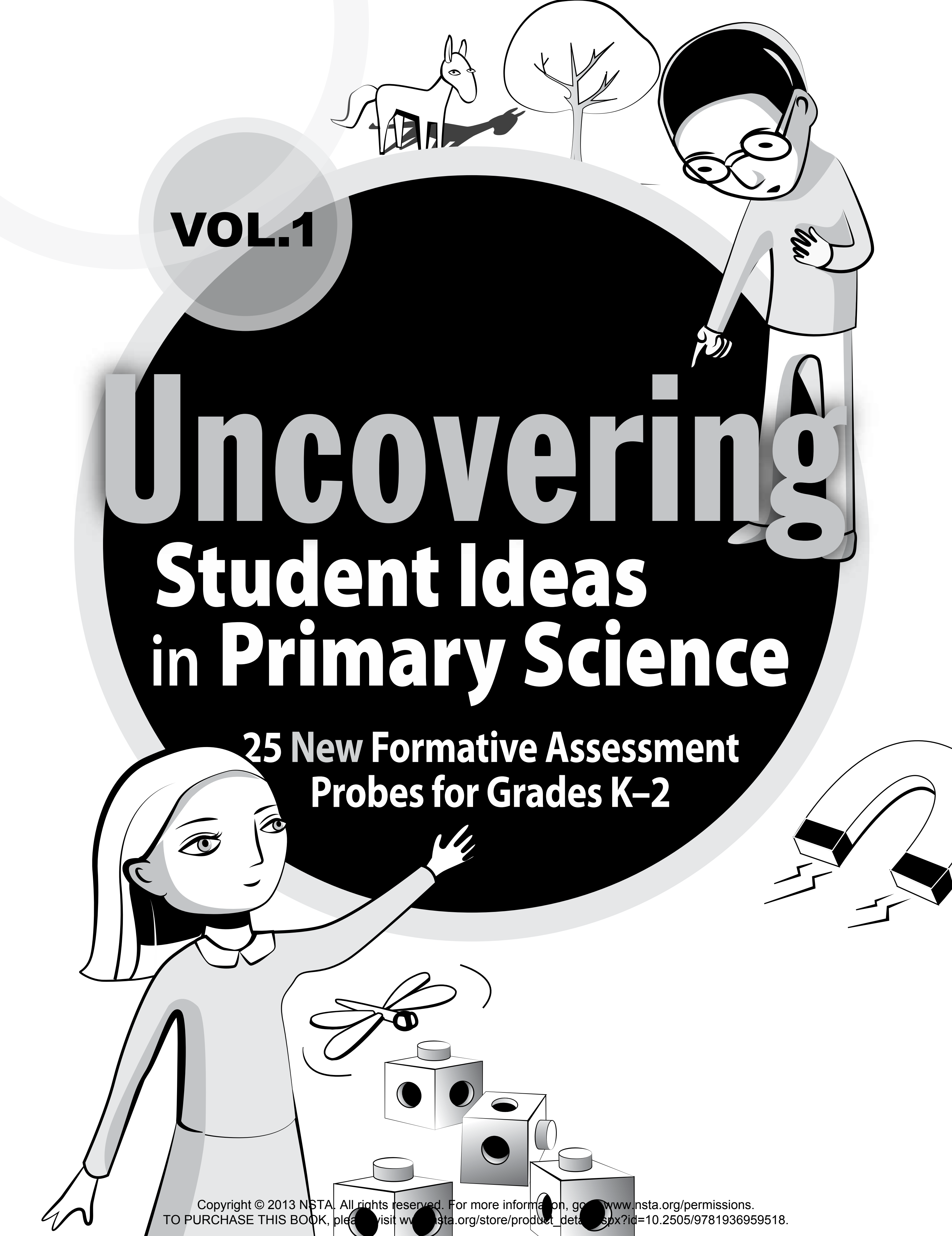
VOL.1

Uncovering Student Ideas in Primary Science

25 New Formative Assessment Probes for Grades K–2

By Page Keeley

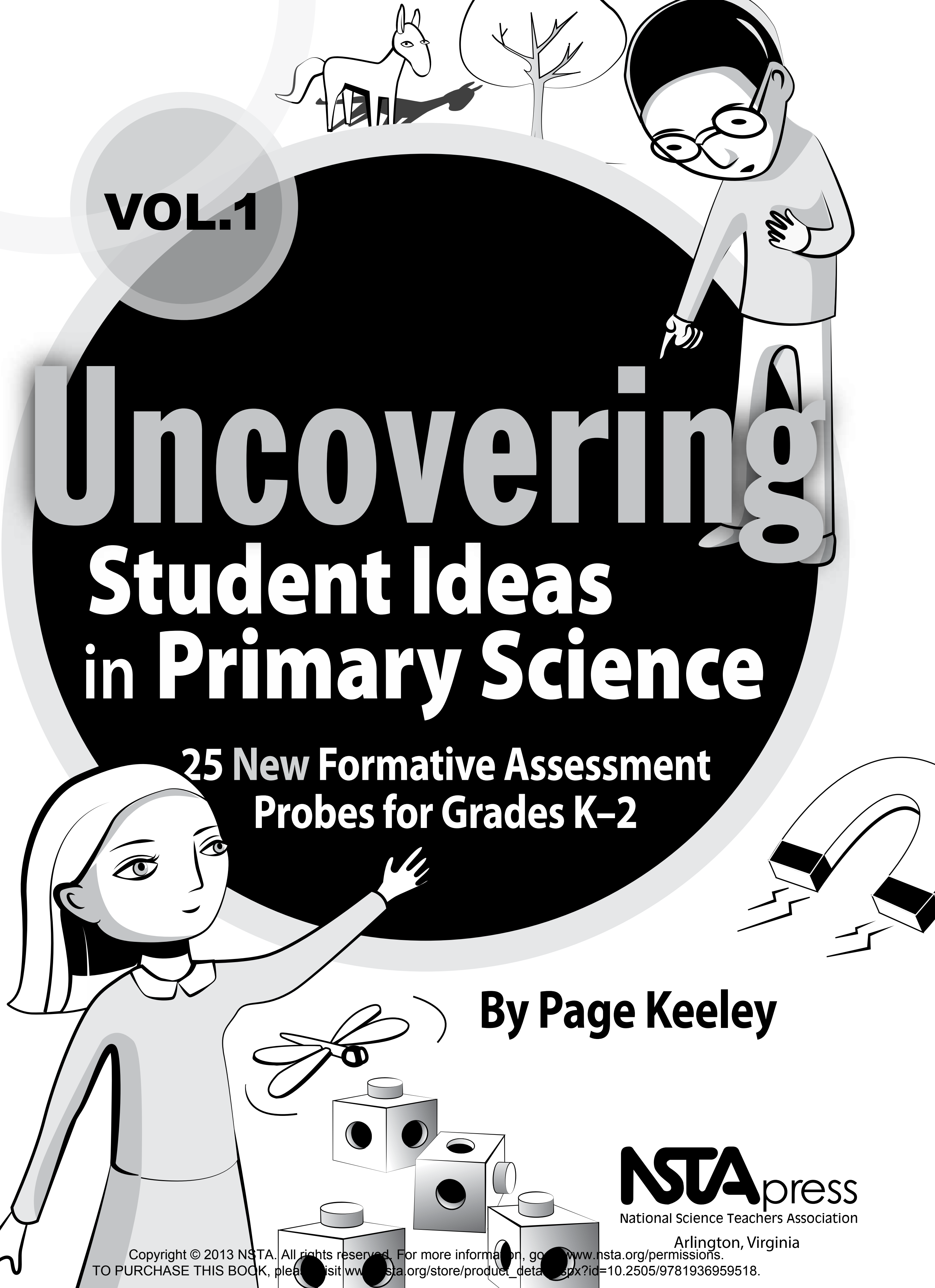
NSTA press
National Science Teachers Association



VOL.1

Uncovering Student Ideas in Primary Science

25 New Formative Assessment Probes for Grades K–2



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Uncovering Student Ideas in Primary Science

25 New Formative Assessment Probes for Grades K–2

By Page Keeley

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Contents

Section 3. Earth and Space Science

Dedication

This book is dedicated to Emma Elizabeth Keeley, Lincoln Wright DeKoster, Court Wilson Brown, Jack Anthony Morgan, Cadence Jane Friend-Gray, and Emeline Leslie Friend-Gray. May you all grow up to have wonderful ideas!

Preface

This is the eighth book in the *Uncovering Student Ideas in Science* series, and the first one that exclusively targets young children's ideas. Like its predecessors, this book provides a collection of formative assessment probes designed to uncover the ideas students bring to their science learning. Each probe is carefully researched to elicit commonly held ideas young children have about phenomena or scientific concepts. A best answer is provided along with distractors designed to reveal research-identified misconceptions held by young children.

A major difference between this book and others in the *Uncovering Student Ideas in Science* series lies in the format of the student pages. The probes in this book use minimal text so that they can be used with children who are just developing their reading and writing skills. Each probe provides a visual representation of the elicited idea using familiar phenomena, objects, and organisms or set in situations that can be duplicated in the classroom. For example, "Is It Living?" elicits students' ideas about living and nonliving things using pictures of familiar objects and organisms. "Big and Small Magnets" uses a concept cartoon format to elicit children's ideas about magnetism, which can then be tested in the classroom using magnets of different sizes. The visuals are designed to capture children's interest and stimulate their thinking. Each probe ends by asking, "What are you thinking?" to draw out students' reasons for their answer choices and encourage "science talk."

Other *Uncovering Student Ideas* Books That Include K–2 Probes

While this book is specifically designed for K–2 students, other books in the series include K–12 probes that can be used or modified for the primary grades. The following is a description of each of the other books in the *Uncovering Student Ideas in Science* series and selected probes that can be used as is or modified for the primary grades:

Uncovering Student Ideas in Science, Volume 1 (Keeley, Eberle, and Farrin 2005)

The first book in the series contains 25 formative assessment probes in life, physical, and Earth and space science. The introductory chapter provides an overview of what formative assessment is and how it is used. Probes from this book that can be used in grades K–2 include:

- "Making Sound"
- "Cookie Crumbles"
- "Is It Matter?" (This probe has been modified for this book.)
- "Is It an Animal?" (This probe has been modified for this book.)
- "Is It Living?" (This probe has been modified for this book.)
- "Wet Jeans"

Uncovering Student Ideas in Science, Volume 2 (Keeley, Eberle, and Tugel 2007)

The second book in the series contains 25 more formative assessment probes in life, physical, and Earth and space science. The introductory chapter of this book describes the link between formative assessment and instruction. Probes from this book that can be used in grades K–2 include:

- "Is It a Plant?" (This probe has been modified for this book.)
- "Needs of Seeds"
- "Is It a Rock?" (version 1)
- "Is It a Rock?" (version 2)
- "Objects in the Sky"

Uncovering Student Ideas in Science, Volume 3 (Keeley, Eberle, and Dorsey 2008)

The third book in the series contains 22 formative assessment probes in life, physical, and Earth and space science, as well as 3 probes about the nature of science. The introductory chapter describes ways to use the probes and student work for professional learning. Probes from this book that can be used in grades K–2 include:

- "Is It a Solid?"
- "Does It Have a Life Cycle?"
- "Me and My Shadow"

Uncovering Student Ideas in Science, Volume 4 (Keeley and Tugel 2009)

The fourth book in the series contains 23 formative assessment probes in life, physical, and Earth and space science, as well as 2 probes that target the crosscutting concepts of models and systems. The introductory chapter describes the link between formative and summative assessment. Probes from this book that can be used with grades K–2 include:

- "Magnets in Water"
- "Moonlight"

Uncovering Student Ideas in Physical Science, Volume 1 (Keeley and Harrington 2010)

The fifth book in the series, and the first in a planned four-book series of physical science probes, contains 45 force and motion formative assessment probes. The introductory chapter describes why students struggle with force and motion ideas and the implications for instruction. Probes from this book that can be used in grades K–2 include:

- "How Far Did It Go?"
- "Rolling Marbles"
- "Talking About Forces"
- "Does It Have to Touch?"
- "Balance Beam"

Uncovering Student Ideas in Life Science, Volume 1 (Keeley 2011)

The sixth book in the series, and the first in a planned three-book series of life science probes, contains 25 life science formative assessment probes. The introductory chapter describes how formative assessment probes are used in a life science context. Probes from this book that can be used in grades K–2 include:

- "Cucumber Seeds"
- "No Animals Allowed"
- "Pumpkin Seeds"
- "Rocky Soil"
- "No More Plants"
- "Chrysalis"

Uncovering Student Ideas in Astronomy (Keeley and Sneider 2011)

The seventh book in the series contains 45 formative assessment probes for astronomy. The introductory chapter describes how formative assessment probes are used to understand students' mental models in astronomy. Probes from this book that can be used in grades K–2 include:

- "Where Do People Live?"
- "Sunrise to Sunset"
- "Seeing the Moon"
- "Sizing up the Moon"
- "Crescent Moon"

Preface

Features of This Book

This book contains 25 probes for the K–2 grade range organized in three sections: Section 1, Life Science (8 probes); Section 2, Physical Science (11 probes); and Section 3, Earth and Space Science (6 probes). The format is similar to the other seven volumes, with a few changes due to the focus on the primary grades. For example, the introduction focuses on young children's ideas in science and the use of "science talk." What follows are descriptions of the features of the Teacher Notes pages that accompany each probe in this book.

Purpose

This section describes the purpose of the probe—what you will find out about your students' ideas when you use the probe. It begins with the overall concept elicited by the probe, followed by the specific idea the probe targets. Before choosing a probe, it is important to be clear about what the probe is designed to reveal. Taking time to read the purpose will help you decide if the probe fits your intended learning target.

Related Concepts

Each probe is designed to target one or more concepts that are appropriate for grades K–2 students. A concept is a one-, two-, or three-word mental construct used to organize the related ideas addressed by the probe and the related national standards. These concepts are also included on the matrix charts that precede the probes on pages 2, 44, and 92.

Explanation

A brief scientific explanation accompanies each probe and provides clarification of the scientific content that underlies the probe. The explanations are designed to help the teacher understand what the "best" or most scientifically acceptable answers are, as well as clarify any misunderstandings about the content. The explanations are not intended to provide detailed background knowledge about the content or designed to be shared with the student. The explanation is for the teacher. In writing these explanations, the author is careful not to make them too technical, as many primary-grade teachers have a limited content background in science. At the same time, the author takes great care not to oversimplify the science. The intent is to provide the information a science novice would need to understand the content related to the probe. If you have a need or desire for additional or deeper explanations of the content, refer to the NSTA resources listed for each section to build or enhance your content knowledge. For example, Bill Robertson's *Stop Faking It! Finally Understanding Science So You Can Teach It* books are excellent resources for furthering your own content understanding.

Curricular and Instructional Considerations for Grades K–2

Unlike the collections in the other books of this series, which address curricular and instructional considerations across the K–12 grade range, these probes are designed for the primary grades, and therefore the curricular and instructional considerations focus only on the K–2 grade span. (*Note:* Several probes are appropriate for the preK level as well.) This section provides a broad overview of the curricular emphasis in the primary science curriculum, the types of instructional experiences appropriate for K–2 students, and the difficulties to be aware of when teaching and learning the concepts related to the probe. This section will sometimes alert teachers to a K–2 idea from *A Framework for K–12 Science Education* (NRC 2012) that in the past has typically been addressed at the upper-elementary or middle-school level but has been moved down to the primary level. For example, static friction and waves are two concepts that typically have not been addressed at the K–2 level but are included in the grades K–2 span in *A Framework for K–12 Science Education.* These are new considerations for curriculum and instruction that teachers of primary science will need to be aware of as they use the probes and design learning experiences for their students. In some cases, the developers of the *Next Generation Science Standards* (*NGSS*) decided to move disciplinary core ideas to a later grade span. This, too, is noted in the Teacher Notes.

Administering the Probe

Suggestions are provided for administering the probe to students, including response methods and ways to use props, demonstrate the probe scenario, make modifications for different learners, or use different formative assessment classroom techniques (FACTs) to gather the assessment data. This section also suggests referring to pages xxviii–xxxiii in the introduction for techniques that can be used to guide "science talk."

Related Ideas in the National Standards

This section lists the learning goals stated in two national documents. One has been used extensively to develop the learning goals in states' standards and curriculum materials: The revised, online version of *Benchmarks for Science Literacy* (AAAS 2009) includes a K–2 grade span. The *National Science Education Standards* (NRC 1996) were released after the original *Benchmarks* and overlap considerably in content. However, they are not included here, as the content is similar and the learning goals target too broad a grade span (K–4). Another referenced document in the teacher notes, *A Framework for K–12 Science Education* (NRC 2012), was used to identify the disciplinary core ideas that informed the development of the K–2 performance expectations in the *NGSS*. Since the *Benchmarks* is one of the primary documents on which most state standards have been based prior to the release of the *NGSS*—which will be adopted by several states—it is still important to look at the related learning goals in this document. The third source of standards referenced is the *NGSS,* which were released shortly before the publication of this book. The Teacher Notes include the related performance expectation, which is the final assessment of student learning and is informed by the disciplinary core ideas listed under the *Framework.* The probes are not designed as summative assessments, so the listed related national standards are not intended to be considered alignments, but rather ideas that are related in some way to the probe. Some targeted probe ideas, such as the concept of living versus nonliving, are not explicitly stated as learning goals in the standards, yet they are important prerequisite ideas to understanding core ideas related to living things. In some cases, the *NGSS* performance expectation may not relate directly to the probe. Because performance expectations are designed for summative assessment purposes and not considered the curriculum or instruction, teachers need to provide experiences for students to learn the underlying ideas and concepts that will deepen the knowledge they will use to demonstrate the performance expectation. Formative assessment reveals the gaps that teachers can address in their instruction to move students toward the intended learning targets.

Related grade 3–5 learning goals, as well as some middle school learning goals, are also included in this section because it is useful to see the related idea that builds on the probe ideas at the next grade level. In other words, primary teachers can see how the foundation they are laying relates to a spiraling progression of ideas as students move from the primary grades to the intermediate elementary level. It may also be useful to teachers in grades 3–5 who may choose to use one of these probes to assess for gaps in students' understanding or misconceptions that are still tenaciously held. Sometimes the listed learning goals from upper grade spans appear to be unrelated to the probe or the K–2 learning goal. It is important to recognize that learning is a progression, and while it may seem unrelated, there is a connection. For example, when K–2 students learn about natural resources, it is in the context of objects and materials that are made from resources obtained from the Earth. The "Is a Brick a Rock?" probe is an example. However, in grade 4, the *NGSS* performance expectation shifts to energy sources and fuels obtained from the Earth. While the grade 4 *NGSS* performance expectation does not directly align with the probe, it is related to the bigger idea that humans use natural reources from the Earth.

Related Research

Each probe is informed by related research. Three comprehensive research summaries commonly available to educators—Chapter 15 in *Benchmarks for Science Literacy* (AAAS 1993), Rosalind Driver's *Making Sense of Secondary Science: Research Into Students' Ideas* (Driver, Squires, Rushworth, and Wood-Robinson 1994), and recent summaries in the *Atlas of Science Literacy, Volume 2* (AAAS 2007)—were drawn on for the research summaries. In addition, recent research is cited where available. Although many of the research citations describe studies that have been conducted in past decades and studied children not only in the United States but in other countries as well, most of the results of these studies are considered timeless and universal. Whether students develop their ideas in the United States or other countries, research indicates that many of these commonly held ideas are pervasive regardless of geographic boundaries and societal and cultural influences. Misconceptions held by students studied in past decades still exist today. Even though your students may have had different experiences and contexts for learning, the descriptions from the research can help you better understand the intent of the probe and the kinds of thinking your students will likely reveal when they respond to the probe. As you use the probes, you are encouraged to seek new and additional published research or engage in your own action research to learn more about students' thinking and share your results with other teachers to extend and build on the research summaries in the teacher notes. To learn more about conducting action research using the probes, read the *Science and Children* article "Formative Assessment Probes: Teachers as Classroom Researchers" (Keeley 2011).

Suggestions for Instruction and Assessment

Uncovering and examining the ideas children bring to their learning is considered diagnostic assessment. Diagnostic assessment becomes formative assessment when the teacher uses the assessment data to make decisions about instruction that will move students toward the intended learning target. Therefore, for the probe to be considered a formative assessment probe, the teacher needs to think about how to best design, choose, or modify a lesson or activity to best address the preconceptions students bring to their learning or misconceptions that might surface or develop during the learning process. As you carefully listen to and analyze your students' responses, the most important next step is to decide on the instructional path that would work best in your particular context based on your students' thinking, the materials you have available, and the different types of learners you have in your classroom.

The suggestions provided in this section have been gathered from the wisdom of teachers, the knowledge base on effective science teaching, and research on specific strategies used to address commonly held misconceptions. These are not lesson plans, but rather brief suggestions that may help you plan or modify your curriculum or instruction to help students learn ideas with which they may be struggling or that are incomplete. It may be as simple as realizing you need to provide an effective context, or there may be a specific strategy or activity that you could use with your students. Learning is a complex process, and most likely no single suggestion will help all students learn. But that is what formative assessment encourages: thinking carefully about the variety of instructional strategies and experiences needed to help students learn scientific ideas. As you become more familiar with the ideas your students have and the multifaceted factors that may have contributed to their misunderstandings, you will identify additional strategies that you can use to teach for deeper understanding. In addition, this section also points out other probes in the *Uncovering Student Ideas in Science* series that can be modified or used as is to further address the concepts targeted by the probe.

Related NSTA Resources

This section provides a list of additional materials that can provide further information on content, curriculum, or instruction related to the probe. For example, Bill Robertson's *Stop Faking It!* series may be helpful in clarifying content with which teachers struggle; Karen Ansberry and Emily Morgan's *Picture-Perfect Science* series may suggest trade books and classroom activities that go together; and Dick Konicek's *Everyday Science Mysteries* series may provide an engaging story context to help students start investigating ideas. Articles from NSTA's *Science and Children* journal may suggest ways to provide primary-grade students the opportunity to learn the content targeted by the probe.

References

References are provided for the standards, cited research, and some of the instructional suggestions given in the Teacher Notes. You might also wish to read the full research summary or access a copy of the research paper or resource cited in the Related Research and Suggestions for Instruction and Assessment sections of the Teacher Notes.

Formative Assessment Probes in the Elementary Classroom

Formative assessment is an essential feature of a learning-focused elementary science environment. To help teachers learn more about using formative assessment probes with elementary students to inform instruction and promote learning, NSTA's elementary science journal, *Science and Children,* publishes my monthly column "Formative Assessment Probes: Promoting Learning Through Assessment." Your NSTA membership provides you with access to all of these journal articles, which have been archived electronically by NSTA. Go to the *Science and Children* page at *www.nsta.org/elementaryschool*. Scroll down to the journal archives and type "Formative Assessment Probes" in the keyword search box. This will pull up a listing of all of my columns. These articles can be saved in your library in the NSTA Learning Center or downloaded as a PDF. The following table lists the journal issue date, title of the column, and topic of the column for the articles that have been published to date. Check back regularly as more articles are added. These articles can also be used by preservice instructors, professional developers, and facilitators of professional learning communities to engage teachers in discussions about teaching and learning related to the probes and the content they teach.

Table 1. List of Articles in the Column "Formative Assessment Probes: Promoting Learning Through Assessment"

Date	Title	Topic
Sept. 2010	"Doing Science"	**Probe: "Doing Science"** "Scientific method": examine how misuse of the "scientific method" influences students' ideas related to the nature of science
Oct. 2010	"'More A-More B' Rule"	**Probe: "Floating Logs"** Floating and sinking: use of intuitive rules to reason about floating and sinking
Nov. 2010	"Does It Have a Life Cycle?"	**Probe: "Does It Have a Life Cycle?"** Life cycles: addressing the limitations of context in the curriculum
Dec. 2010	"To Hypothesize or Not"	**Probe: "Is It a Hypothesis?"** Hypothesis making: reveal misconceptions teachers have about the nature of science that can be passed on to students
Jan. 2011	"How Far Did It Go?"	**Probe: "How Far Did It Go?"** Linear measurement: difficulties students have with measurement particularly with a non-zero starting point
Feb. 2011	"Needs of Seeds"	**Probe: "Needs of Seeds"** Needs of living things: engaging in evidence-based argumentation
March 2011	"The Mitten Problem"	**Probe: "The Mitten Problem"** Energy transfer; insulators: teaching for conceptual change and how children's everyday experience affects their thinking
April 2011	"Is It Living?"	**Probe: "Is It Living?"** Characteristics of living things: examine ways to uncover hidden meanings students have for some words and concepts in science
July 2011	"With a Purpose"	**Probe: various examples** A variety of probes and concepts are used to show purposeful links to various stages in an assessment, instruction, and learning cycle
Sept. 2011	"Where Are the Stars?"	**Probe: "Emmy's Moon and Stars"** Solar system, relative distances: importance of examining students' explanations even when they choose the right answer; the impact representations have on children's thinking
Oct. 2011	"Pushes and Pulls"	**Probe: "Pushes and Pulls"** Forces: examining common preconceptions and use of language to describe forces and motion

Table 1 *(continued)*

Date	Title	Topic
Nov. 2011	"Teachers as Researchers"	**Probe: "Is It an Animal?"** Biological conception of an animal: explore how formative assessment probes can be used to engage in teacher action research
Dec. 2011	"Representing Microscopic Life"	**Probe: "Pond Life"** Single-celled organisms: use of representations to examine students' ideas
Jan. 2012	"Daytime Moon"	**Probe: "Objects in the Sky"** Objects in the sky: challenges the adage "seeing is believing" with "believing is seeing"; examines reasons why children hold on to their strongly held beliefs
Feb. 2012	"Can It Reflect Light?"	**Probe: "Can It Reflect Light?"** Reflection: addressing students' preconceptions with firsthand experiences that support conceptual change
April/May 2012	"Food for Plants: A Bridging Concept"	**Probe: "Food for Plants"** Food, photosynthesis, needs of plants: using bridging concepts to address gaps in learning goals, understanding students' common sense ideas
July 2012	"Where Did the Water Go?"	**Probe: "Where Did the Water Go?"** Water cycle: using the water cycle to show how a probe can be used to link a core content idea, scientific practice, and crosscutting concept
Sept. 2012	"Confronting Common Folklore: Catching a Cold"	**Probe: "Catching a Cold"** Infectious disease, personal health: using a probe to uncover common myths and folklore related to the common cold
Oct. 2012	"Talking About Shadows"	**Probe: "Me and My Shadow"** Sun-Earth system; talk moves: using a formative assessment probe to engage students in productive science talk
Nov. 2012	"Birthday Candles: Visually Representing Ideas"	**Probe: "Birthday Candles"** Light transmission; connection between light and vision: using drawings to support explanations
Dec. 2012	"Mountain Age: Creating Classroom Formative Assessment Profiles"	**Probe: "Mountain Age"** Weathering and erosion: organizing student data using a classroom profile for instructional decisions and professional development
Jan. 2013	"Solids and Holes: A P-E-O Probe"	**Probe: "Solids and Holes"** Floating/sinking; density: using the P-E-O technique to launch into inquiry
Feb. 2013	"Labeling Versus Explaining"	**Probe: "Chrysalis"** Life cycle of a butterfly: reveals how an overemphasis on labeling diagrams with correct terminology may mask conceptual misunderstandings related to the life cycle of a butterfly

Table 1 *(continued)*

Date	Title	Topic
March 2013	"When Equipment Gets in the Way"	**Probe: "Batteries, Bulb, and Wire"** Electrical circuits; lighting a bulb with a battery and a wire: how science kit materials may make it difficult for students to examine the way a complete circuit works
Summer 2013	"Is It a Solid? Claim Cards and Argumentation"	**Probe: "Is It a Solid?"** Matter, solids: using claims and evidence to engage in argumentation

Formative Assessment Reminder

Now that you have the background on this new series, the probes, and the Teacher Notes, we should not forget the formative purpose of these probes. Reminder that a probe is not formative unless you use the information from the probe to modify, adapt, or change your instruction so students have increased opportunities to learn the important scientific ideas necessary for building a strong foundation in the primary grades. As a companion to this book and all the other volumes, NSTA has copublished the book *Science Formative Assessment: 75 Practical Strategies for Linking Assessment, Instruction, and Learning* (Keeley 2008). In this book, you will find a variety of strategies to use along with the probes to facilitate elicitation, support metacognition, spark inquiry, encourage discussion, monitor progress toward conceptual change, encourage feedback, and promote self-assessment and reflection. In addition, be sure to read the suggestions in the introduction before using the probes. The introduction will help you learn more about ways to facilitate productive science discussions in the primary classroom and make links to the *Common Core State Standards* in English language arts. I hope the use of these K–2 probes and the techniques used along with them will stimulate new ways of assessing your students, create environments conducive to learning, and help you discover and use new knowledge about teaching and learning.

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About the Author

Page Keeley recently retired from the Maine Mathematics and Science Alliance (MMSA), where she was the Senior Science Program Director for 16 years, directing projects and developing resources in the areas of leadership, professional development, linking standards and research on learning, formative assessment, and mentoring and coaching. She has been the PI and Project Director of three National Science Foundation–funded projects, including the Northern New England Co-Mentoring Network, PRISMS (Phenomena and Representations for Instruction of Science in Middle School), and Curriculum Topic Study: A Systematic Approach to Utilizing National Standards and Cognitive Research. In addition to NSF projects, she has directed state MSP projects, including TIES K–12: Teachers Integrating Engineering Into Science K–12 and a National Semi-Conductor Foundation grant, Linking Science, Inquiry, and Language Literacy (L-SILL). She also founded and directed the Maine Governor's Academy for Science and Mathematics Education Leadership, a replication of the National Academy for Science and Mathematics Education Leadership, of which she is a Cohort 1 Fellow.

Page is the author of 14 national bestselling books, including four books in the *Curriculum Topic Study* series, 8 volumes in the *Uncovering Student Ideas in Science* series, and both a science and mathematics version of *Formative Assessment: 75 Practical Strategies for Linking Assessment, Instruction, and Learning.* Currently, she provides consulting services to school districts and organizations throughout the United States on building teachers' and school districts' capacity to use diagnostic and formative assessment. She is a frequent invited speaker on formative assessment and teaching for conceptual change.

Page taught middle and high school science for 15 years before leaving the classroom in 1996. At that time, she was an active teacher leader at the state and national levels. She served two terms as president of the Maine Science Teachers Association and was a District II NSTA Director. She received the Presidential Award for Excellence in Secondary Science Teaching in 1992, the Milken National Distinguished Educator Award in 1993, the AT&T Maine Governor's Fellow in 1994, the National Staff Development Council's (now Learning Forward) Susan Loucks-Horsley Award for Leadership in Science and Mathematics Professional Development in 2009, and the National Science Education Leadership Association's (NSELA) Outstanding Leadership in Science Education Award in 2013. She has served as an adjunct instructor at the University of Maine, was a science literacy leader for the AAAS/Project 2061 Professional Development Program, serves on several national advisory boards, and is the Region A Director for NSELA. She is a science education delegation leader for the People to People Citizen Ambassador Professional Programs,

About the Author

leading trips to South Africa in 2009, China in 2010, India in 2011, and China again in 2013.

Prior to teaching, she was a research assistant in immunology at The Jackson Laboratory of Mammalian Genetics in Bar Harbor, Maine. She received her B.S. in life sciences from the University of New Hampshire and her master's degree in science education from the University of Maine. In 2008, Page was elected the 63rd president of the National Science Teachers Association (NSTA), the world's largest professional organization of science educators.

Introduction

"The having of wonderful ideas is what I consider the essence of intellectual development." —Eleanor Duckworth

K–2 Probes as Assessments for Learning

Imagine a first-grade classroom where Miss Ortega's students are sitting in a circle on the science rug to have a science talk about living things. Miss Ortega uses the pictures from the "Is It Living?" probe to have the children share their ideas about which things are living and which things are not living. As Miss Ortega shows the pictures and names the organisms or objects, she has each student turn to his or her partner to talk about ideas. They then discuss each picture as a whole class, with students sharing the rules they used to decide if something is living or nonliving.

At one point, the class is evenly divided about whether a seed is living or nonliving. Shalika argues, "The seed is not living because it can't move. The cat moves and it is alive, so I think living things have to move." Mac disagrees: "A tree is alive, but it can't move around like a cat. I think some things can be living and not move, so maybe a seed is alive." Oscar offers a new idea: "But seeds grow into plants." Miss Ortega asks Oscar to say more about that, and he adds a clarification: "Things that are living can grow. A seed grows into a plant, so that makes it living." Cora argues that some living things stop growing: "My dad is living, but he is done growing. I think you can stop growing and still be living."

Miss Ortega lists two ideas the children have proposed so far: moving and growing. She asks the class if there are other ways to decide if something is living. Albert offers a new idea: "Living things have to eat, so if it eats, then it is alive." Kenny looks puzzled and asks a question to seek clarification: "But what about fire? It grows bigger when it eats wood." Rania responds, "Yeah, it moves around, too. Fire can move through a whole forest!"

The discussion continues for several minutes. The children are deeply involved in sharing their ideas, listening attentively to each other, seeking clarification from the teacher or other students when needed, constructing explanations to use in their arguments, and evaluating the ideas and arguments of others. Throughout the discussion, they are using and practicing speaking and listening skills.

Miss Ortega makes sure that all the children have an opportunity to make claims and express their thinking. Throughout the year, they have been working on claims and evidence during their science time. Her students know that a claim is the statement that answers the probe question, and to share their thinking, they must provide reasons, including evidence, for their claim. As the children are talking, Miss Ortega is carefully listening and making a list of the class's best ideas so far, which she will post on a chart for students to see and refer to while they visit the learning stations she will set up for the children to explore claims and ideas that support their claims. She notes the extent to which students are using scientific ideas or whether they are drawing on their own alternative conceptions or prior experiences.

By taking the time to find out what her students think about characteristics of living things, Miss Ortega collects valuable assessment data that she will use to plan lessons that will confront her students with their ideas and help them resolve some of the inconsistencies between their ideas and the scientific explanation she will guide them toward developing. By taking their ideas seriously and not correcting students' initial misconceptions, Miss Ortega is promoting learning by giving her students the opportunity to use scientific practices as they listen to each other's ideas, justify their own reasoning, and evaluate the validity of each other's arguments. This is the essence of formative assessment where good instruction and assessment are inextricably linked. Formative assessment is an approach to teaching in which students develop deeper conceptual understanding through the development of their own thinking and talking through their ideas, while simultaneously providing a window for the teacher to examine students' thinking and determine next steps based on where the learners are in their conceptual development.

Facilitating this type of approach to learning may sound demanding, and it seems it would be much simpler to just give students the information or engage in a hands-on activity. However, research shows that children learn best when they first surface their ideas before launching into investigations, activities, readings, and other opportunities to learn (Bransford, Brown, and Cocking 1999). Students have to do the thinking; the activity cannot do it for them, nor is the learning in the materials themselves. Surfacing initial ideas and recognizing when their ideas are changing as they construct new understandings is a powerful way to teach and learn. It is the explanation of the probe—not the answer selections the students choose from—that provides important assessment data and supports learning. One of the most effective ways to help students construct new understandings and simultaneously develop reasoning skills (that works particularly well with the formative assessment probes) is to provide children with the opportunity to interact in pairs, small groups, and as a whole class, where they listen to each other's ideas and have to justify their own. Communicating ideas in science is a central feature of using the formative assessment probes and one of the *Next Generation Science Standards (NGSS)* scientific practices. The probes not only provide insights for the teacher about students' understanding or misunderstanding of core ideas in science but also provide a treasure trove of data about students' use of scientific and engineering practices. For example, P-E-O (Predict-Explain-Observe) probes provide an opportunity for young children to make an initial claim (prediction), provide an explanation for their initial claim, test the claim, gather evidence (the data) from the observations, analyze the data to see if they support or refute the initial claim, and propose a new claim and explanation if the observations did not match the initial claim. See Table 2 for examples of ways the formative assessment probes support learning of the practices in the *NGSS*.

This book provides 25 highly engaging formative assessment probes that elicit preconceptions, support the development of young children's understanding of K–2 core disciplinary ideas, and encourage the use of scientific practices in the *NGSS*. However, before you skip ahead and use the probes, read through the rest of this introduction to learn more about children's ideas in science and science talk so that you can best use these probes to inform your teaching and support learning.

Table 2. Link Between K–2 Formative Assessment Probes and the *NGSS* Scientific and Engineering Practices

NGSS Scientific and Engineering Practice	K–2 Probes as Assessments for Learning	Examples
Practice 1: Asking questions and defining problems	The probe begins with an interesting question. Students ask additional questions to seek understanding and determine what they already know or need to know to make a claim and construct explanations to the probe.	**Probe 16, "Do the Waves Move the Boat?"** Students may ask questions of each other and the teacher about water waves. They use the probe question to further explore the science that can provide an explanatory answer to the probe.
Practice 2: Developing and using models	Some probes involve the use of models to develop explanations of the phenomenon. As the teacher listens to children's ideas, he or she is thinking about the best model to use to help them understand the probe phenomenon.	**Probe 24, "What Lights Up the Moon?"** As the teacher listens to students, he notices several students think there is a light glowing inside the moon. He thinks about how he can have the children model the reflection of sunlight using a white ball and a flashlight.
Practice 3: Planning and carrying out investigations	Some probes (P-E-O probes) can be used to launch an investigation and require children to think about how they can best make observations and collect data to test the claims they made in response to the probe.	**Probe 19, "Big and Small Magnets"** Students test their claims using a variety of big and small magnets. They decide how they will determine strength using paper clips, make observations, and record their data.
Practice 4: Analyzing and interpreting data	To support a claim with evidence when using a P-E-O probe, students collect, analyze, and interpret the data to derive meaning.	**Probe 18, "Rubber Band Box"** Students make rubber band box guitars like the one in the probe context and test their ideas about sound. They analyze their data to determine how pitch is related to the thickness of the rubber band.
Practice 5: Using mathematics and computational thinking	Students count and use numbers to find or describe patterns related to the probe. They also use measurement and measurement instruments such as thermometers, rulers, and weighing scales to gather data.	**Probe 12, "Snap Blocks"** Students count the individual blocks and make predictions about how the weight of the blocks snapped together compares to the total weight of the individual blocks weighed together. They try this several times using different numbers of snap blocks, weigh them on a scale, record their data, and notice that the pattern shows the weight is always the same.
Practice 6: Constructing explanations and designing solutions	Every probe requires students to construct an initial explanation (their personal theory) to support their claim (answer choice) and revise their explanations as they gather new evidence and information.	**Probe 10, "Watermelon and Grape"** The initial theory proposed by the class is that large things sink and small things float. After testing a variety of objects, students revise their initial explanation to explain that size alone does not determine whether an object floats or sinks.

Table 2 *(continued)*

NGSS Scientific and Engineering Practice	K–2 Probes as Assessments for Learning	Examples
Practice 7: Engaging in argument from evidence	All the probes are used in a talk format that requires students to explain and defend their reasoning to others and promotes careful listening so that other students can build on a line of reasoning or offer alternative explanations. Together, the class searches for the best explanation from the comments and evidence offered during science talk.	**Probe 1, "Is It Living?"** As in the scenario at the beginning of this chapter, the teacher engages the students in science talk, explaining and defending their reasons for why something is or is not considered living. Later, after the teacher has provided opportunities for students to investigate their ideas, they will engage again in science talk, providing new evidence to support or revise their initial arguments.
Practice 8: Obtaining, evaluating, and communicating information	Following up the use of a probe often involves students seeking additional information that may come from trade books, videos, and other sources to provide information that supports their claims or provides new information to help them change their claim. Students must also be able to communicate information clearly to each other, which sometimes involves the use of drawings and other visual ways to share the information they obtain.	**Probe 6, "Do They Need Air?"** Many students claimed that animals that live in water do not need air, so the teacher obtained several trade books and video clips for children to learn about animals that live in water and how they meet their needs. She also brought in a goldfish that students could observe. Children revisit the probe and explain ways different animals get air and draw pictures of land and water animals, showing different structures they use to get air.

Young Children's Ideas

Children develop ideas about their natural world well before they are taught science in school. For example, many young children think that things like hats, coats, blankets, sweaters, or mittens warm us up by generating their own heat. This makes sense to children because when they put on a sweater or wrap themselves up in a blanket, they get warmer. They have not yet learned that heat moves from warmer to cooler and that materials such as a mitten can slow down the loss of body heat. In other instances, children are novice learners in science and have not yet gained enough background knowledge or been formally introduced to scientific principles to be able to explain a concept scientifically. For example, young children may think that only organisms with fur and four legs are considered animals because they do not yet have enough knowledge about the scientific meaning of animal—such as having to acquire food from the environment—to recognize that organisms such as worms, insects, and even humans are considered animals in a scientific sense.

Some of the ideas young children have may be consistent or partially consistent with the science concepts that are taught. For example, they know when you drop an object, it falls to the ground. They are already developing ideas consistent with the idea of gravity. But often there is a significant gap between children's explanations for natural phenomena or concepts and the explanations that are developed through "school science." For example, failure to recognize that weight is conserved when a whole object is broken into individual pieces illustrates a significant gap between children's ideas about what happens to the total weight of an object when it is changed in some way and the understanding of conservation of matter with "parts and wholes" that is developed in the science class.

Many studies have been conducted of children's commonly held ideas about natural phenomena and science concepts. Most notable among the researchers of children's ideas is Dr. Rosalind Driver and her research group from the University of Leeds in England. This group has contributed extensively to our understanding of commonly held ideas children have about science that may affect their learning. The research into commonly held ideas, which is often referred to by practitioners as misconceptions, has enabled teachers to predict what their own students are likely to think about a phenomenon and how they might respond to an assessment that probes their thinking. The assessment probes in this book were developed from examining the research on children's ideas in science, particularly Driver's contributions (Driver, Squires, Rushworth, and Wood-Robinson 1994). As you use these probes, it is highly likely that your students' ideas will mirror the findings that are described in the Related Research Summaries part of the Teacher Notes that accompany each of the probes. While you may be surprised to find that your students hold many of these alternative ideas, it is important for you to realize that these are highly personal and make sense to the student. Merely correcting them does not make them go away. Students must have access to instructional experiences that will challenge their thinking and help them construct models and explanations that bridge the gap between their initial ideas and the scientific understandings that are achievable at their grade level.

Another important feature of children's ideas in science is that children learn best when knowledge is socially constructed. Much like the way science is done in the real world, children need opportunities to share their thinking, justify the reasons for their ideas, and listen to the ideas of others. Children also need to be aware of the range of ideas others have about the same phenomenon or concept and be able to evaluate them in light of their own ideas and the evidence presented. Scientific theories develop through interaction with other scientists; children's ideas develop through interaction with their classmates and the teacher. The probes provide ample opportunities for children to think through and talk about their ideas with others. Animated science talk and argumentation are the hallmarks of a formative assessment–centered learning environment in which the probes are effectively being used.

Children's Learning Experiences

Hands-on science has not always been minds-on science. The opportunity to ask questions, manipulate materials, and conduct investigations—a major emphasis of inquiry-based science—has not always resulted in deeper conceptual learning. That is because the learning is not in the materials or investigations themselves, but in the sense children make out of their experiences as they use the materials to perform investigations, make observations, and construct explanations. Perhaps the pendulum swung too far to the hands-on side in the last decade or so of elementary inquiry-based science. Inquiry without inquiry for conceptual change did little to help students give up their strongly held alternative ideas. One way to support inquiry for conceptual change is to start with uncovering children's ideas before launching into an investigation. To design probes for this book that could be used to support or enhance children's learning experiences, the following features for developing and using a probe were considered:

- Promoting curiosity and stimulating children's thinking
- Drawing out alternative ideas that could be investigated in the classroom

- Linking to previous experiences in or out of school
- Using familiar objects, phenomena, and situations
- Reducing dependency on reading text
- Improving developmental appropriateness
- Relating to core ideas in the *NGSS* or the *Benchmarks for Science Literacy*
- Supporting the use of the scientific and engineering practices such as constructing explanations and engaging in argument from evidence
- Using models and representations to develop explanations
- Encouraging sense making and reflection on how ideas have changed

Effective teaching and learning do not just happen; they are carefully planned. Using the probes to inform the design of learning experiences for children involves the recognition that children already have ideas about the natural world that they bring with them to their learning experiences. This is significant when planning instructional experiences, particularly when combined with a constructivist view of learning in which the student must take an active role in constructing meaning for himself or herself. When children's existing ideas are acknowledged as you incorporate their ideas from the probes into the lessons, learning takes place as children change their ideas through experiences that allow them to test or discuss their ideas and support them with evidence, in much the same way that scientists develop theories. This may involve supporting an initial idea, modifying an idea, or rejecting an idea in favor of an alternative explanation. Whichever it is, the student needs to "own it," which means the reasoning must be done by the student (not the teacher, although he or she can guide it).

Formative Assessment Probes and Science Talk

> When I first tried listening quietly and taking notes about what I heard students saying as they worked, my insight into their learning was phenomenal! I actually stopped talking and just listened. The data I collected showed some incorrect conceptions as well as understanding. It often opened windows into how a student had learned. The rich data I gathered helped me determine which next steps I needed to take to further learning. (Carlson, Humphrey, and Reinhardt 2003, p. 37)

This quote from an elementary teacher reveals the power of careful listening as students talk about their science ideas. The probes in this book differ from the collection of 215 other formative assessment probes in the *Uncovering Student Ideas* series because they are designed to be used in a talk format rather than having students write explanations to support their answer choice (however, they certainly can be combined with writing, especially with science notebooks). Even the formats used in this book highlight the importance of science talk. For example, you will see that several of the probes in this book use a cartoon format in which the characters share their ideas with each other and the student selects the character whose idea best matches his or her own (e.g., "Sink or Float?"). This format models what we want to encourage children to do: share their claims with one another and provide evidence that supports these claims. The author intentionally uses this format to help students recognize the importance of sharing ideas without passing judgment initially on whether they are right or wrong.

Whether you use the science workshop approach, science conferences, small-group discussions, pair talk, or other ways to involve students in science talk, the probes provide an interesting question that serves to elicit children's initial ideas and draw out their reasons for their thinking. Assessment data is gathered by carefully listening to students, and, when possible, audio-recording dialogue, taking notes, or transcribing parts of conversations as you listen will provide a treasure trove of data you can use to design instruction focused on where the learners are in their understanding.

The first step in using science talk for formative assessment is to ask questions that will capture students' interest, provoke thinking, and encourage explanations that will help you gain insight into their reasoning and understanding. Sometimes it can be challenging for teachers to know what type of question will elicit children's ideas that can provide rich information about a core concept they will be learning. This has been done for you in this book! Each probe is a question specifically designed to draw out children's ideas that will not only support their learning but also inform your teaching. Use the probe as your starting point for learning more about your students' ideas. New questions will spring from the probe and spark further conversation.

Sometimes a probe is used to develop an investigative question and launch into inquiry. Some probes provide an opportunity for students to make predictions and explain the reasons for their prediction before they make observations during their investigations. This type of probe is called a P-E-O (Predict-Explain-Observe) probe, and examples include, but are not limited to, "Snap Blocks" (p. 59), "Marble Roll" (p. 71), and "Seeds in a Bag" (p. 25) (Keeley 2008). P-E-O probes provide an opportunity for children to practice verbal communication to articulate their thoughts prior to the investigation and make their thinking visible to others. In addition, it provides an opportunity for children to discuss the best way to test their ideas and then test them, supporting the *NGSS* scientific practice of designing and carrying out investigations.

Productive classroom talk using a formative assessment probe before launching into an investigation also has the benefit of leading to deeper engagement in the content before and during the investigation. As students collect, analyze, and share their data, they compare their findings with their initial claims and evidence and may become aware of the discrepancies between their own or others' ideas from the evidence gathered during the investigation. For example, the probe "When Is the Next Full Moon?" provides an opportunity for students to make and test a prediction about how long it takes to see a full Moon again (length of a lunar cycle). They examine reasons for their predictions before beginning an investigation that provides the data they need to understand the repeated pattern of Moon phases, a disciplinary core idea in the *NGSS* as well as a crosscutting concept of patterns and cycles. The probe can be revisited again after students have had an opportunity to make sense of their data and use it to explain the lunar cycle. By following the probe with a scientific investigation, the students have actual data from their investigation to construct a scientific explanation to support their new or revised claim. As they engage in talk and argument again with the same probe, the context of the probe—combined with the scientific knowledge they gained through their investigation—provide an opportunity for them to build stronger, evidence-based arguments.

Talk Moves

One of the best resources I recommend that every teacher of elementary science read and become familiar with is *Ready, Set, Science! Putting Research to Work in K–8 Classrooms*

(Michaels, Shouse, and Schweingruber 2008). Since this book is published through our federal taxpayer–supported National Academies of Science, it is available for free as a PDF on the National Academies Press website (*www.nap.edu*), where you can download a copy of the book. It is also available for purchase through the NSTA bookstore. Chapter 5, "Making Thinking Visible: Talk and Argument," is an excellent read for you to deepen your understanding of the role of talk and argument in science as you use the probes in this book.

As students grapple with the ideas elicited by the probes in this book, the role of the teacher is to facilitate productive science talk in ways that will move students' thinking forward and help them clarify and expand on their reasoning. One of the ways to do this is through the use of "talk moves" (Keeley 2012). Table 3 shows six productive talk moves adapted from *Ready, Set, Science!* (Michaels, Shouse, and Schweingruber 2008) that can be used with the formative assessment probes in this book.

Table 3. Talk Moves and Examples

Talk Move (from *Ready, Set, Science!* [Michaels, Shouse, and Schweingruber 2008])	Example of Using the Talk Move with a Formative Assessment Probe
Revoicing	• "So let me see if I've got your thinking right. You're agreeing with Amy because _____?" • "Let me see if I understand. You are saying _____?"
Asking students to restate someone else's reasoning	• "Can you repeat in your own words what Latisha just said about why she agrees with Jamal?" • "Is that right, Latisha? Is that what you said?"
Asking students to apply their own reasoning to someone else's reasoning	• "Do you agree or disagree with Emma's reason for agreeing with Morrie, and why?" • "Can you tell us why you agree with what Sam said? What is your reasoning?"
Prompting students for further participation	• "Would someone like to add on to the reasons why some of you chose Fabian as the person you most agree with in the probe?" • "What about others—what would you like to add to these ideas so far?" • "What do others think about the ideas we have shared so far? Do you agree or disagree?"
Asking students to explicate their reasoning	• "Why do you agree with Penelope?" • "What evidence helped you choose Fabian as the person you most agree with in the probe?" • "Say more about that."
Using wait time	• "Take your time. We'll wait." • "I want everyone to think first, and then I will ask you to share your thinking."

Revoicing

Sometimes it is difficult to understand what the student is trying to say when they struggle to put their thoughts into words. If you, as the teacher, have difficulty understanding what the student is saying, then the students listening are apt to have even greater difficulty. Clarity in expressing ideas is often needed when encouraging young children to share their thinking. Therefore, this move not only helps the child clarify his or her thinking but also provides clarity for the listeners as well—both teacher and students. By revoicing the child's idea as a question, the teacher is giving the child more "think time" to clarify his or her ideas. It is also a strategy for making sure the student's idea is accessible to the other students who are listening and following the discussion.

Asking Students to Restate Someone Else's Reasoning

While the move above (revoicing) is used by the teacher, this move has the students reword or repeat what other students share during the probe discussion. It should then be followed up with the student whose reasoning was repeated or reworded. The benefit to using this talk move during discussions about the science probe ideas is that it gives the class more think time and opportunity to process each student's contribution to the science talk. It also provides another version of the explanation that may be an easier version for the children to understand. This talk move is especially useful with English language learners. As a formative assessment talk move, it provides the teacher with additional clarification of student ideas. Additionally, it acknowledges to the students that the teacher as well as the students in the class are listening to one another.

Asking Students to Apply Their Own Reasoning to Someone Else's Reasoning

The probes encourage students to make a claim and share their reasoning for their claim. This talk move is used with the probes to make sure students have had time to evaluate the claim based on the reasoning that was shared by a student. It helps students zero in and focus on the reasoning. Note that the teacher is not asking the other students whether they merely agree or disagree with someone's claim; they also have to explain why. This talk move helps students compare their thinking to someone else's and, in the process, helps them be more explicit in their own reasoning.

Prompting Students for Further Participation

After using revoicing to clarify the different ideas that emerge during discussion of the probe, the teacher prompts others in the class to contribute by agreeing, disagreeing, or adding on to what was already shared. This talk move encourages all students to evaluate the strength of each other's arguments. It promotes equitable and accountable discussion.

Asking Students to Explicate Their Reasoning

This talk move encourages students to go deeper with their reasoning and be more explicit in their explanations. It helps them focus on the evidence that best supports their claim and build on the reasoning of others.

Using Wait Time

This is actually a silent move, rather than a talk move. One of the hardest things for teachers to do is to refrain from not commenting immediately on children's responses. There are two types of wait time that should be used when engaging students in probe discussions. The first is for the teacher to wait at least five seconds after posing a question so the students have adequate think time. The second is for the teacher, as well as the students, to practice waiting at least five seconds before commenting on a students' response. This strategy is especially important to use with English language learners as well as students who may be shy or reluctant to contribute ideas in front of the whole class. By waiting, even though silence can be agonizing, the teacher supports students' thinking and reasoning by providing more time for them to construct an explanation or evaluate the arguments of others. This strategy provides greater inclusivity for all students in the class to participate in productive science talk by acknowledging the time they need to think through their ideas.

All of these talk moves can be used with the probes in various combinations to facilitate productive science talk in which all the students are accountable for each other's learning and the teacher is able to extract valuable formative assessment data to further plan instruction and support learning. However, to use these moves effectively, it is important to establish the conditions for a respectful learning environment. To do that, teachers should set group norms or ground rules for engaging in productive talk and equitable participation so that students will listen to and talk with one another respectfully and courteously as they use the probes. It is important for them to know that a scientific argument has a different meaning in science than in real life. In science, we argue to examine our ideas and seek understanding rather than argue to win with our point of view. Examples of norms you might establish in your classroom for science talk may include but are not limited to the following:

- Listen attentively as others talk.
- Make sure you can hear what others are saying.
- Speak so others can hear.
- Argue to learn, not to win.
- Criticize the reasoning, not the person.
- Make only respectful comments.

Communicating and listening to scientific ideas contribute to language development, an important goal of teaching in the primary grades, and is consistent with the *Common Core State Standards, ELA* (NGAC and CCSSO 2010). See Table 4 for examples of ways the formative assessment probes support the *Common Core* literacy standards for speaking and listening for primary students.

Formative assessment that supports productive scientific discussions takes time to develop and needs a lot of practice. As you incorporate these probes into your science lessons, I hope you will see the value in productive science talk that emanates from using these probes. By using these probes in talk formats with primary students, you are not only developing conceptual understanding of the life, physical, Earth, and space ideas for grades K–2 included in the *NGSS*, but also revealing and clarifying the ideas they bring to their learning, which you can use to improve and enhance your science teaching. Making students' ideas visible as you use these probes will help you build more effective lessons and support young students in using the scientific and engineering practices in sophisticated ways that show young learners are capable of far more than we often ask of them. In a nutshell, it's about teaching science well and giving your students the best possible start to be successful learners of science as they progress through school!

Table 4. Linking Formative Assessment Probes to the *Common Core* Speaking and Listening Standards

Common Core State Standards (Grades K, 1, and 2)	Formative Assessment Probes
◆ SL.K.1, 1.1, 2.1: Participate in collaborative conversations with diverse partners about kindergarten, grade 1, and grade 2 topics and texts with peers and adults in small and larger groups.	The probes are designed to be used in a talk format in small or large groups discussing ideas with the teacher and with each other about a science topic.
◆ SL.K.2: Confirm understanding of a text read aloud or information presented orally or through other media by asking and answering questions about key details and requesting clarification if something is not understood. ◆ SL.1.2: Ask and answer questions about key details in a text read aloud or information presented orally or through other media. ◆ SL.2.2: Recount or describe key ideas or details from a text read aloud or information presented orally or through other media.	As students talk about and share their ideas related to the probe, they ask questions about and discuss key details related to the probe context or answer choices. They may ask for clarification about the probe context or the answer choices or clarification of each other's explanations as they share their ideas through speaking and listening.
◆ SL.K.3: Ask and answer questions in order to seek help, get information, or clarify something that is not understood. ◆ SL.1.3: Ask and answer questions about what a speaker says in order to gather additional information or clarify something that is not understood. ◆ SL.2.3: Ask and answer questions about what a speaker says in order to clarify comprehension, gather additional information, or deepen understanding of a topic or issue.	Students ask questions about the probe task. They also ask questions of each other and seek clarification of explanations as they share their claims and provide their reasons for their claims. After students have had the opportunity to revisit the probe after the teacher has designed learning experiences, students ask and answer questions to deepen their understanding of the concepts elicited by the probe.
◆ SL.K.4: Describe familiar people, places, things, and events and, with prompting and support, provide additional detail. ◆ SL.1.4: Describe people, places, things, and events with relevant details, expressing ideas and feelings clearly. ◆ SL.2.4: Tell a story or recount an experience with appropriate facts and relevant, descriptive details, speaking audibly in coherent sentences.	The probes provide a context for discussing familiar phenomena, objects, and processes related to a science core idea. Students are encouraged to share their prior experiences connected to the probe and prompted by the teacher to provide details and further information.
◆ SL.K.5: Add drawings or other visual displays to descriptions as desired to provide additional detail. ◆ SL.1.5: Add drawings or other visual displays to descriptions when appropriate to clarify ideas, thoughts, and feelings. ◆ SL.2.5: Create audio recordings of stories or poems; add drawings or other visual displays to stories or recounts of experiences when appropriate to clarify ideas, thoughts, and feelings.	Students are encouraged to use drawings or other visual symbols, where appropriate, to support their ideas, clarify their responses, and communicate relevant details related to the probe.
◆ SL.K.6: Speak audibly and express thoughts, feelings, and ideas clearly. ◆ SL.1.6 and SL2.6: Produce complete sentences when appropriate to task and situation in order to provide requested detail or clarification.	Probes provide an engaging context for students to practice speaking clearly in complete sentences to support their ideas and emerging understanding of science.

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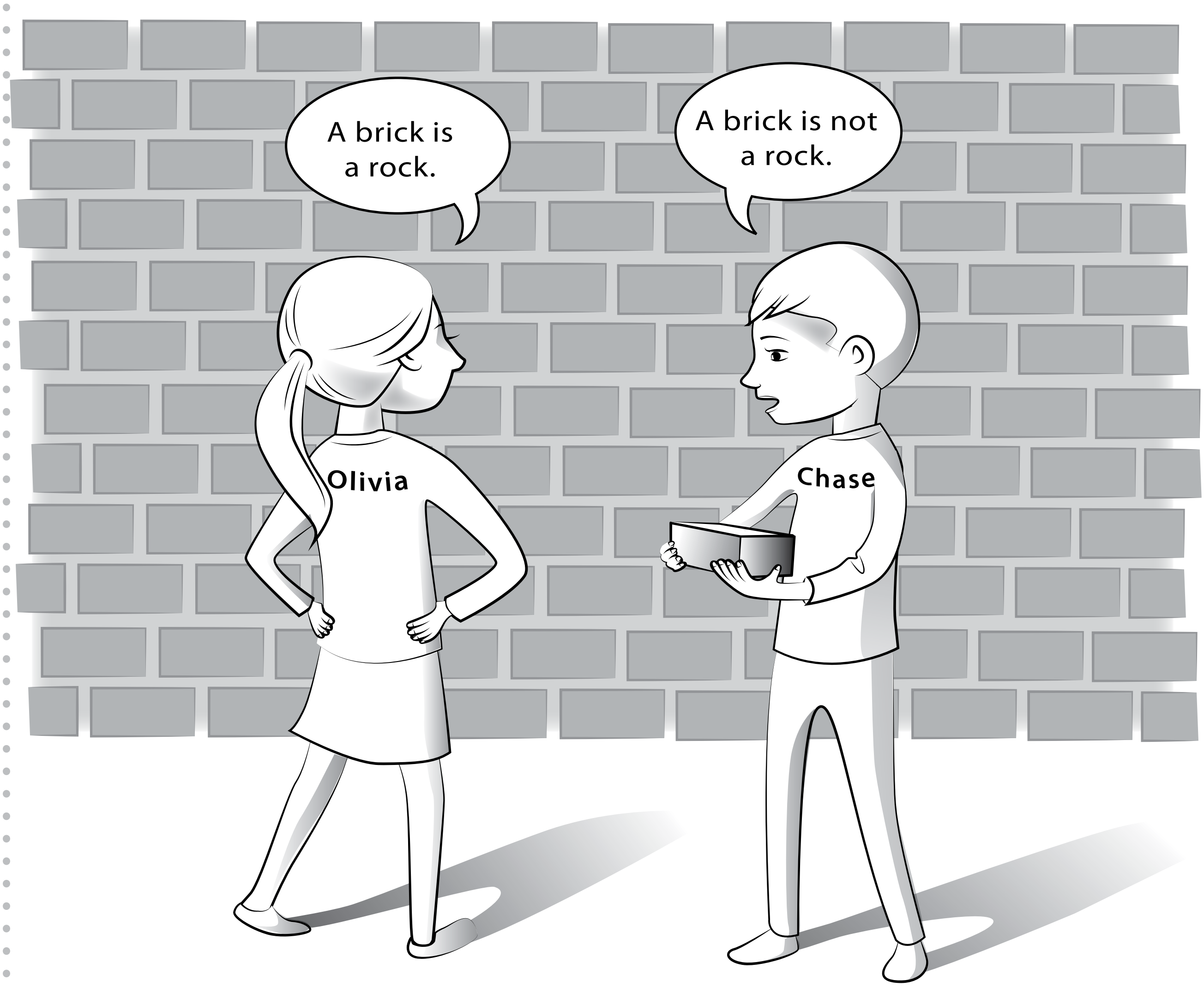
Is a Brick a Rock?



What are you thinking?

Is a Brick a Rock?

Teacher Notes

Purpose
The purpose of this assessment probe is to elicit children's ideas about rocks. The probe is designed to determine if children can distinguish between rocklike materials made by humans and rocks that have a geologic origin.

Related Concepts
rocks, Earth materials, human-made materials

Explanation
Chase has the better answer: "A brick is not a rock." Bricks are objects made by humans from Earth materials such as clay, lime and sand, or dried mud. They are often fired in a kiln. Rocks are a solid mass of mineral (a naturally occurring inorganic substance with a definite chemical composition) or mineral-like matter that occurs naturally on our planet and is formed by geologic processes. Rocks can be composed of one type of mineral or mixtures of two or more minerals. Bricks are also mixtures containing rock material, but they do not form naturally. Although bricks may contain some rock material, they are reshaped and recombined through a human manufacturing process, not a geologic process.

Curricular and Instructional Considerations for Grades K–2
Observing properties and classifying objects by their properties is an important part of the elementary science curriculum. Young children should become familiar with a variety of natural and human-made materials in their environment, describe the materials' properties, and classify them as natural or human made. They should develop an understanding that humans need materials from their environment and many of the materials humans use to build houses, roads, and other things come from the Earth. The focus is on natural resources used to make materials or build objects. At the grades 3–5 level, the focus on natural resources begins to move toward energy resources.

Administering the Probe
Ask children if they have ever seen a brick or things made from bricks. Show children an actual brick or pictures of structures made from bricks before they share their ideas related to the probe. Have children circle or color the person with whom they agree the most and explain why they agree with that person. Explain to students that they should select the person whose idea best matches their thinking, not whose features they like most. See pages xxviii–xxxiii in the introduction for techniques used to guide "science talk" related to the probe.

Related Ideas in *Benchmarks for Science Literacy* (AAAS 2009)

K–2 Structure of Matter
- Objects can be described in terms of their properties. Some properties, such as hardness and flexibility, depend upon what material the object is made of, and some properties, such as size and shape, do not.

3–5 Processes That Shape the Earth
- Rock is composed of different combinations of minerals.

3–5 Materials and Manufacturing

- Humans have produced a wide variety of materials, such as steel, plastic, and nylon, that do not appear in nature.

Related Core Ideas in *A Framework for K–12 Science Education* (NRC 2012)

K–2 ESS3.A: Natural Resources

- Humans use natural resources for everything they do.

3–5 ESS3.A: Natural Resources

- All materials, energy, and fuels that humans use are derived from natural sources.

Related *Next Generation Science Standards* (Achieve Inc. 2013)

Kindergarten: Earth and Human Activity

- K-ESS3-1: Use a model to represent the relationship between the needs of different plants or animals (including humans) and the places they live.

Grade 4: Earth and Human Activity

- 4-ESS3-1: Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.

Related Research

- The word *rock* is used in many different ways, contributing to the confusion of what it means in a geologic sense (Freyberg 1985).
- In studies by Happs (1982, 1985), students had difficulty making the distinction between natural things and those created or altered by humans. For example, some students considered a brick to be a rock because part of it comes from natural material (Driver, Squires, Rushworth, and Wood-Robinson 1994).

Suggestions for Instruction and Assessment

- A related probe, "Is It a Rock? Version 2," can be modified for use at this grade level (Keeley, Eberle, and Tugel 2007).
- This probe uses a format called "Opposing Views" and can also be used with a strategy called "Lines of Argumentation" (Keeley, in press). Have children sit in two lines that face each other—one line for those who selected Olivia and another line for those who selected Chase. Have students engage in argumentation—making a claim and justifying their claim with reasoning for why they think a brick is or is not a rock. If an argument is compelling enough to change a student's thinking, he or she can move to the other line.
- Take time to elicit students' ideas about what they think a rock is. Develop an operational definition before introducing the scientific definition of *rock*.
- Compare and contrast naturally formed rocks with objects that are "rocklike" and formed by humans (e.g., bricks, tiles, cement, clay pots), as well as objects that are shaped from rock (e.g., figurines carved out of rock, granite countertops, gravestones, statues).
- Use this probe as a nice tie-in to the *T* in STEM: technology. Science deals with our natural world (rocks); technology uses the application of science to modify our natural world to fulfill a human need (making clay pots out of rock). Furthermore, you can tie in the *E* (engineering) to show how engineers solve problems to meet human needs through a design process. (How can

materials be combined to make a clay pot that is hard to break?)

Related NSTA Resources

Ansberry, K., and E. Morgan. 2012. Rock solid science. In *Teaching science through trade books,* ed. C. A. Royce, E. Morgan, and K. Ansberry, pp. 229–233. Arlington, VA: NSTA Press.

Brkich, K. 2012. Science shorts: Is concrete a rock? *Science and Children* 50 (4): 80–82.

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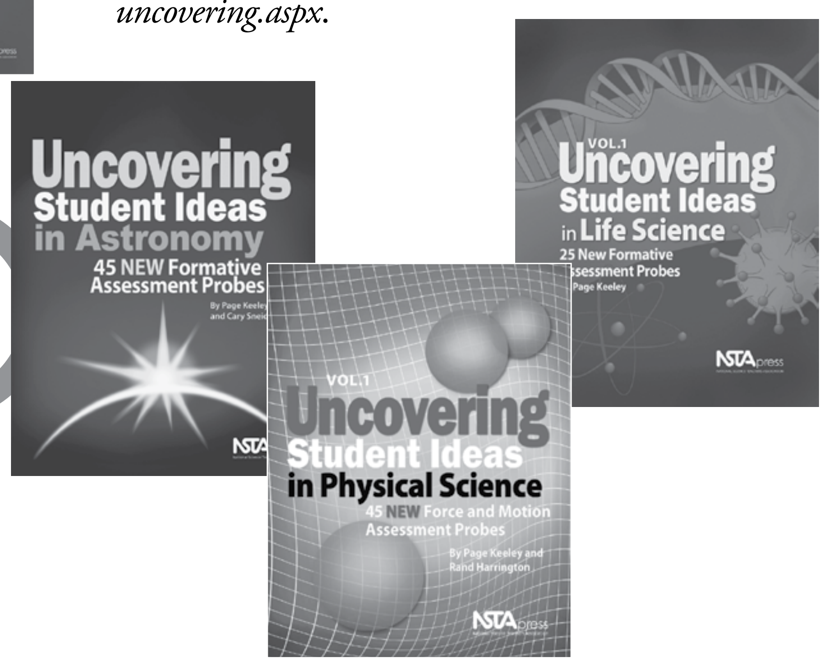

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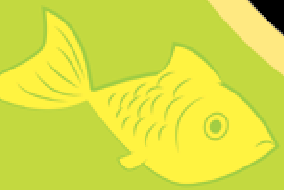

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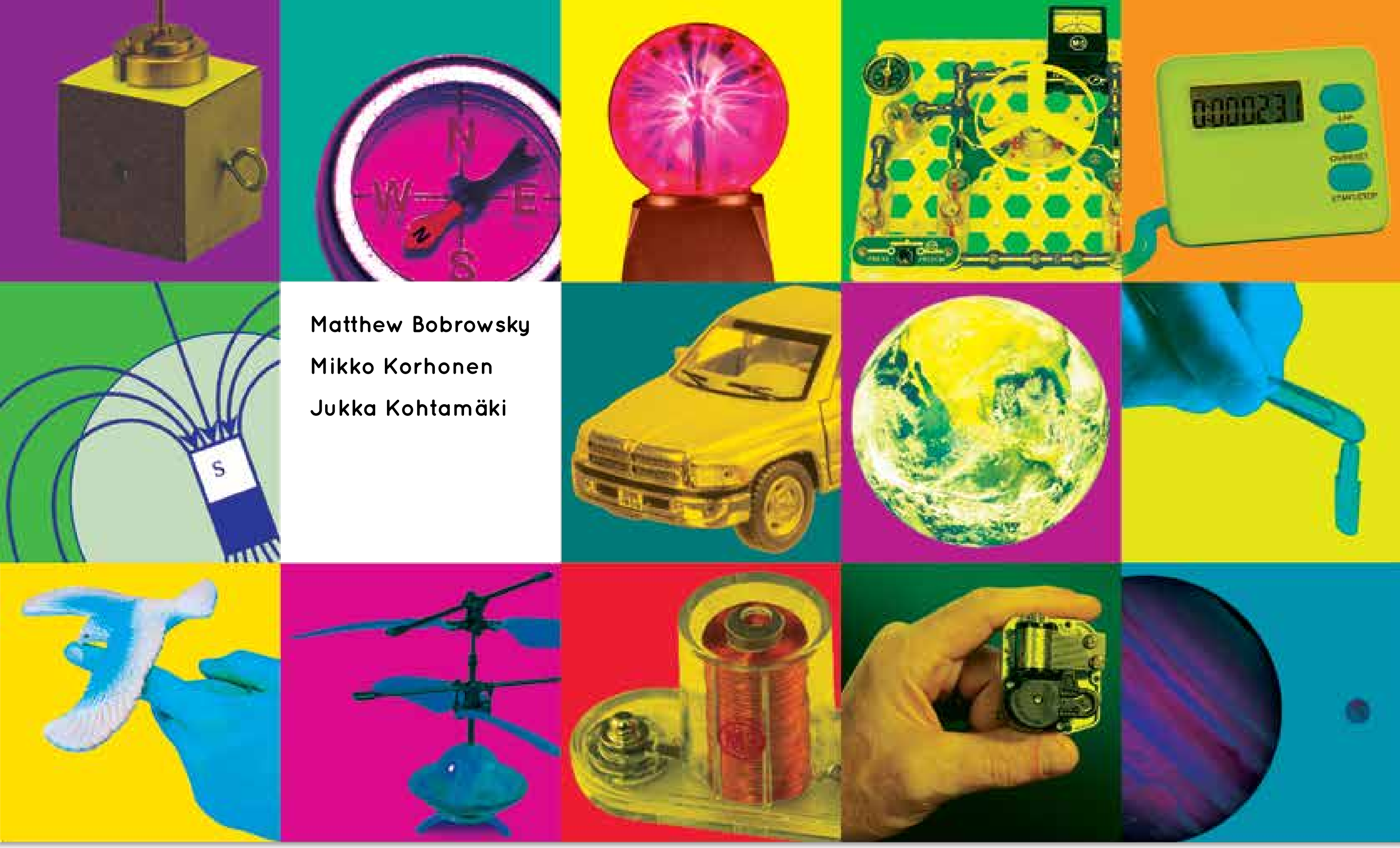

Matthew Bobrowsky
Mikko Korhonen
Jukka Kohtamäki

USING PHYSICAL SCIENCE

GADGETS & GIZMOS

GRADES 3–5

PHENOMENON-BASED LEARNING

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ABOUT THE AUTHORS

MATTHEW BOBROWSKY, PHD

Dr. Matt Bobrowsky has been involved in scientific research and science education for several decades. Currently at Delaware State University, he previously served as Director of the Physics Demonstration Facility at the University of Maryland—a collection of over 1,600 science demonstrations. Also at the University of Maryland, Matt was selected as a Faculty Mentor for the Fulbright Distinguished International Teachers Program, where he met Mikko Korhonen.

Matt has taught physics, astronomy, and astrobiology both in the classroom and online. He has written K–12 science curricula and serves on the Science Advisory Committee for the Howard County Public School System in Maryland. Matt has conducted countless professional development workshops for science teachers and special presentations for students, speaking on a variety of topics beyond physics, such as the scale of the universe, life in the universe, misconceptions about science among students and the public, the process of science, and science versus pseudoscience.

He is often asked to be an after-dinner speaker or keynote speaker at special events. Matt is a "Nifty Fifty" speaker for the USA Science & Engineering Festival and a Shapley Lecturer for the American Astronomical Society. Matt has received a number of awards for teaching excellence from the University of Maryland, including the Stanley J. Drazek Teaching Excellence Award (given to the top 2 instructors out of ~800) and the Board of Regents' Faculty Award for Excellence in Teaching (given to the top 3 instructors out of ~7,000). Matt's teaching is always innovative because he uses pedagogical techniques that are based on current science education research and known to be effective.

In his research, Matt has been involved in both theoretical and observational astronomy. He developed computer models of planetary nebulae—clouds of gas expanding outward from aging stars—and has observed them with telescopes on the ground as well as with the Hubble Space Telescope. One of the planetary nebulae that Matt investigated is the Stingray Nebula, which he discovered using Hubble.

MIKKO KORHONEN

Mikko Korhonen obtained a master's degree from Tampere Technical University in Finland, where he studied physics, mathematics, and pedagogics. Since then, he has been teaching physics, mathematics, and computer science at various schools in Finland. He has also developed a number of educational programs that brought some of his students to top scientific facilities in the world, including the Nordic Optical Telescope (NOT) observatory in La Palma, Spain, the CERN laboratory at the Franco-Swiss border, and the LATMOS laboratory in France. Most recently, some of his students have attended the Transatlantic Science School, which Mikko founded.

Mikko has written numerous other educational publications, including a book of physics experiments, manuals of physics problems with answers, an article on mathematics and logic for computer science, and two books with Jukka Kohtamäki on using toys to teach physics, one at the middle school and one at the high school level.

Mikko has obtained numerous grants and awards for his school and students, including awards from the NOT science school and the Viksu science competition prize, as well as individual grants from the Finnish National Board of Education and the Technology Industries of Finland Centennial Foundation, and grants for his "physics toys" project. His students are also award winners in the Finnish National Science Competition. Mikko received one of the Distinguished Fulbright Awards in Teaching, which brought him to the University of Maryland for a semester, where he worked with Matt Bobrowsky. Most recently, Mikko received the award of Distinguished Science Teacher in 2013 by the Technology Industries of Finland Centennial Foundation.

JUKKA KOHTAMÄKI

Jukka Kohtamäki obtained his master of science degree from Tampere University of Technology in Finland and since then has been teaching grades 5–9 at the Rantakyla Comprehensive School, one of the largest comprehensive schools in Finland. Jukka has participated in long-term professional development teaching projects and projects involving the use of technology in learning, as well as workshops that he and Mikko Korhonen conducted for Finnish science teachers. His writing includes teaching materials for physics and computer science, and he has written two books with Mikko on using toys to teach physics, one at the middle school and one at the high school level.

Jukka is a member of the group under the National Board of Education that is writing the next physics curriculum in Finland. He is also participating in writing curricula in chemistry and natural science (which is a combination of biology, geology, physics, chemistry, and health education). His goals are to get students engaged in lessons, to have them work hands on and minds-on, to encourage creativity in finding solutions, and to get students to discuss natural phenomena using the "language of physics." In 2013, Jukka received the Distinguished Science Teacher Award from the Technology Industries of Finland Centennial Foundation.

"The most beautiful thing we can experience is the mysterious. It is the source of all true art and science."

— Albert Einstein

AN INTRODUCTION TO PHENOMENON-BASED LEARNING

The pedagogical approach in this book is called phenomenon-based learning (PBL), meaning learning is built on observations of real-world phenomena—in this case of some fun toys or gadgets. The method also uses peer instruction, which research has shown results in more learning than traditional lectures (Crouch and Mazur 2001). In the PBL approach, students work and explore in groups: Exercises are done in groups, and students' conclusions are also drawn in groups. The teacher guides and encourages the groups and, at the end, verifies the conclusions. With the PBL strategy, the concepts and the phenomena are approached from different angles, each adding a piece to the puzzle with the goal of developing a picture correctly portraying the real situation.

PBL is not so much a teaching method as it is a route to grasping the big picture. It contains some elements that you may have seen in inquiry-based, problem-based, or project-based learning, combined with hands-on activities. In traditional science teaching, it's common to divide phenomena into small, separate parts and discuss them as though there is no connection among them (McNeil 2013). In our PBL approach, we don't artificially create boundaries within phenomena. Rather, we try to look at physical phenomena very broadly.

PBL is different from project-based or problem-based learning. In project-based learning, the student is given a project that provides the context for learning. The problem with this is that the student is not necessarily working on the project out of curiosity but simply because they are required to by the teacher. To avoid having students view the project as a chore or just a problem that they have to solve, we employ PBL: The student's own curiosity becomes the driver for learning. The student explores not by trudging through a problem to get to the correct answer but by seeing an interesting phenomenon and wanting to understand what's going on. This works because interest and enthusiasm do not result from the content alone; they come from the students themselves as they discover more about a phenomenon. Personal experience with a phenomenon is always more interesting and memorable than a simple recitation of facts (Jones 2007; Lucas 1990; McDade 2013).

The goal in project-based learning is for the students to produce a product, presentation, or performance (Moursund 2013). PBL does not have that requirement; students simply enjoy exploring and discovering. This is the essence of science, and it is consistent with the philosophy of the *Next Generation Science Standards* (*NGSS*). Rather than simply memorizing facts that will soon be forgotten, students are doing real science. They are engaged in collaboration, communication, and critical thinking. Through this, students obtain a deeper understanding of scientific knowledge and see a real-world application of that knowledge—exactly what was envisioned with the *NGSS*. This is why, at the end of each chapter, we provide a list of relevant standards from the *NGSS*, further emphasizing our focus on the core ideas and practices of science, not just the facts of science.

The objective of PBL is to get the students' brains working with some phenomenon and have them discussing it in groups. A gizmo's functions, in most cases, also make it possible for teachers to find common misconceptions that students may harbor. It is important to directly address misconceptions

> *"Most of the time my students didn't need me; they were just excited about a connection or discovery they made and wanted to show me."*
>
> —Jamie Cohen (2014)

because they can be very persistent (Clement 1982, 1993; Nissani 1997). Often the only way to remove misconceptions is to have students work with the problem, experiment, think, and discuss, so that they can eventually experience for themselves that their preconception is not consistent with what they observe in the real world.

We must also keep in mind that students can't build up all the scientific laws and concepts from scratch by themselves. Students will definitely need some support and instruction. When doing experiments and learning from them, the students must have some qualitative discussions (to build concepts) and some quantitative work (to learn the measuring process and make useful calculations). Experience with combining the two reveals the nature of science.

PBL encourages students to not just think about what they have learned but to also reflect on how they acquired that knowledge. What mental processes did they go through while exploring a phenomenon and figuring out what was happening? PBL very much lends itself to a **K**-**W**-**L** approach (what we **K**now, what we **W**ant to know, and what we have **L**earned). K-W-L can be enhanced by adding an H for "How we learned it" because once we understand that, we can apply those same learning techniques to other situations.

When you first look at this book, it might seem as if there is not very much textual material. That was intentional. The idea is to have more thinking by the students and less lecturing by the teacher. It is also important to note that the process of thinking and learning is not a race. To learn and really get the idea, students need to take time to think … and then think some more—so be sure to allow sufficient time for the cognitive processes to occur. For example, the very first experiment (using a toy car) can be viewed in just a few minutes, but in order for students to think about the phenomenon and really get the idea, they need to discuss the science with other group members, practice using the "language of science," and internalize the science involved—which might take 20 minutes. During this time, the students may also think of real-life situations in which the phenomenon plays a significant role, and these examples can be brought up later during discussions as an entire class.

HOW TO USE THIS BOOK

This book can be used in many ways. It can be used as a teacher's guide or as material for the students. In the hands of the teacher, the introductions and the questions can be used as the basis for discussions with the groups before they use the gadgets, that is, as a motivational tool. The teacher can ask where we see or observe the phenomenon in everyday life, what the students know about the matter prior to conducting the activities, and so on. The explorations can also be used to spark curiosity about a particular area of science and to encourage students to explore and learn.

Exactly how you present the material depends a lot on your students. Here's one approach: Have students work in groups. Studies have shown this to be a good way for them to learn. Have the students discuss with each other—and write down in their science notebooks—what they already know about the gadget and about the phenomenon it demonstrates. If they don't yet know what phenomenon the gadget shows, you can just have them carry out the steps provided for exploring that gadget. As they perform the exploration, they should write questions they think of about the gadget or the science involved. If the students are having trouble with this, you can get more specific and ask them, for instance, what they would need to know in order to understand what's going on; or ask where else they have seen something like this. Having students formulate questions themselves is part of PBL and also part of an inquiry approach. Asking questions is also how scientists start out an investigation. Be sure to give the groups plenty of time to attempt to answer their questions themselves.

It's great to let the students pursue the questions they raise and to encourage investigations into areas that they find interesting. This is part of "responsive teaching," and also part of PBL. If, after a good amount of time, the students are unable to come up with their own questions, you can start to present the questions in the book—but resist the temptation to just have students go down the list of questions. That is more structure than we want to have in view of our goal of presenting learning as exploration and inquiry. A good use of the questions would be to help guide your interaction with the groups as they explore a phenomenon.

Students can then work in groups to answer the questions, doing more experimentation as needed. The important point is that they won't learn much by simply being told an answer. Much more learning takes place if they can, through experimentation and reasoning, come up with some ideas themselves. Students may come up with an idea that is incorrect; rather than immediately correcting them, guide them toward an experiment or line of reasoning that reveals an inconsistency. It is not a bad thing if the students' first ideas are incorrect: This allows them to recognize that, through the process of science, it is possible to correct mistakes and come away with a better understanding—which is one of the main points of PBL.

While the student groups are investigating, you, the teacher, should be moving among them, monitoring conversations to determine whether the students are proceeding scientifically, for example, by asking questions or discussing ways to answer the questions—perhaps using the gadget, through debate, or even by doing web searches. This monitoring is part of the assessment process, as explained further in the Learning Goals and Assessment section.

After students have made a discovery or figured out something new, have them reflect on the mental process they went through to achieve that discovery or understanding. This reflection—sometimes referred to as metacognition—helps students recognize strategies that will be helpful for other challenges in the future. The combination of guidance and metacognition is consistent with a modern learning cycle leading to continuous increases in students' content knowledge and process skills.

LEARNING GOALS AND ASSESSMENT

The most important learning goal is for students to learn to think about problems and try a variety of approaches to solve them. Nowadays, most students just wait for the teacher to state the answer. The aim here is for students to enjoy figuring out what's going on and to be creative and innovative.

Combining this with other objectives, a list of learning goals might look something like this:

By the end of these lessons, students will

- think about problems from various angles and try different strategies;
- demonstrate process skills, working logically and consistently;
- collaborate with others to solve problems;
- use the language of science;
- reflect on the thinking processes that helped them to acquire new knowledge and skills in science; and
- view science as interesting and fun.

You will also notice that there are no formal quizzes or rubrics included. There are other ways to evaluate students during activities such as these. First, note that the emphasis is not on getting the "right" answer. Teachers should not simply provide the answer or an easy way out—that would not allow students to learn how science really works. When looking at student answers, consider the following: Are the students basing their conclusions on evidence? Are they sharing their ideas with others in their group? Even if a student has the wrong idea, if she or he has evidential reasons for that idea, then that student has the right approach. After all members of a group are in agreement and tell you, the teacher, what they think is happening, you can express doubt or question the group's explanation, making the students describe their evidence and perhaps having them discuss it further among themselves. Student participation as scientific investigators and their ability to give reasons for their explanations will be the key indicators that the students understand the process of science.

The PBL approach lends itself well to having students keep journals of their activities. Students should write about how they are conducting their experiment (which might differ from one group to another), ideas they have related to the phenomenon under investigation (including both correct and incorrect ideas), what experiments or observations showed the incorrect ideas to be wrong, answers to the questions supplied for each exploration, and what they learned as a result of the activity. The teacher can encourage students to form a mental model—perhaps expressed as a drawing—of how the phenomenon works and why. Then the students can update this model in the course of their investigations. Students' notebooks or journals will go a long way to helping the teacher see how the students' thinking and understanding have progressed. If there is a requirement for a written assessment, the journal provides the basis for that. As a further prompt for writing or discussion, encourage students to form a "bridge to the future" by asking questions such as "Where could we use this phenomena?" and "How could this be useful?" Students might also want to make a video of the experiment. This can be used for later reference as well as to show family and friends. Wouldn't it be great if we could get students talking about science outside the classroom?

A few of the questions asked of the students will be difficult to answer. Here again, students get a feel for what it's like to be a real scientist exploring uncharted territory. A student might suggest an incorrect explanation. Other students in the group might offer a correction, or if no one does, perhaps further experimentation, along with guidance from the teacher, will lead the students on the right course. Like scientists, the students can do a literature search (usually a web search now) to see what others know about the phenomenon. (Doing web searches also involves learning to recognize when a site is reputable and when it is not.) Thus there are many ways for a misconception to get dispelled in a way that will result in more long-term understanding than if the students are simply told the answer. Guidance from the teacher could include providing some ideas about what to observe when doing the experiment or giving some examples from other situations in which the same phenomenon takes place. Although many incorrect ideas will not last long in group discussions, the teacher should actively monitor the discussions, ensuring that students do not get too far off track and are on their way to achieving increased understanding. We've provided an analysis of the science behind each exploration to focus your instruction.

By exploring first and getting to a theoretical understanding later, students are working like real scientists. When scientists investigate a new phenomenon, they aren't presented with an explanation first—they have to figure it out. And that's what students do in PBL. Real scientists extensively collaborate with one another; and that's exactly what the students do here as well—work in groups. Not all terms and concepts are extensively explained; that's not the purpose of this book. Again, like real scientists the students can look up information as needed in, for example, a traditional science book. What we present here is the PBL approach, in which students explore first and are inspired to pursue creative approaches to answers—and have fun in the process!

PBL IN FINLAND

The Finnish educational system came into the spotlight after the Programme of International Student Assessment (PISA) showed that Finnish students were among the top in science literacy proficiency levels. In 2009, Finland ranked second in science and third in reading out of 74 countries. (The United States ranked 23rd and 17th, respectively.) In 2012, Finland ranked 5th in science and 6th in reading. (The United States ranked 28th and 24th, respectively.) Finland is now seen as a major international leader in education, and its performance has been especially notable for its significant consistency across schools. No other country has so little variation in outcomes among schools, and the gap within schools between the top- and bottom-achieving students is quite small as well.

Finnish schools seem to serve all students well, regardless of family background or socioeconomic status. Recently, U.S. educators and political leaders have been traveling to Finland to learn the secret of their success.

The PBL approach is one that includes responsive teaching, progressive inquiry, project-based learning, and in Finland at least, other methods at the teachers' discretion. The idea is to teach bigger concepts and useful thinking skills rather than asking students to memorize everything in a textbook.

AUTHORS' USE OF GADGETS AND GIZMOS

One of the authors (M.B.) has been using gizmos as the basis of teaching for many years. He also uses them for illustrative purposes in public presentations and school programs. The other two authors (M.K. and J.K.) have been using PBL—and the materials in this book—to teach in Finland. Their approach is to present scientific phenomena to students so that they can build ideas and an understanding of the topic by themselves, in small groups. Students progress from thinking to understanding to explaining. For each phenomenon there are several different viewpoints from which the student can develop a big-picture understanding as a result of step-by-step exploration. The teacher serves only as a guide who leads the student in the right direction. PBL is an approach that is not only effective for learning but is also much more fun and interesting for both the teacher and the students.

SAFETY NOTES

Doing science through hands-on, process, and inquiry-based activities or experiments helps to foster the learning and understanding of science. However, in order to make for a safer experience, certain safety procedures must be followed. Throughout this book, there are a series of safety notes that help make PBL a safer learning experience for students and teachers. In most cases, eye protection is required. Safety glasses or safety goggles noted must meet the ANSI Z87.1 safety standard. For additional safety information, check out NSTA's "Safety in the Science Classroom" at *www.nsta.org/pdfs/SafetyInTheScienceClassroom.pdf.* Additional information on safety can be found at the NSTA Safety Portal at *www.nsta.org/portals/safety.aspx.*

Disclaimer: Safety of each activity is based in part on use of the recommended materials and instructions. Selection of alternative materials for these activities may jeopardize the level of safety and therefore is at the user's own risk.

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4

AIR PRESSURE

As you learned earlier, gravity affects all objects. This includes air molecules—the small particles that make up air. Gravity pulls the molecules toward the ground, and the molecules push on the ground. We call that pushing *air pressure* or *atmospheric pressure*. Near the ground there are more molecules and they are squeezed together more tightly, the air pressure is higher near sea level and lower up on a high mountain.

Air pushes in all directions because air molecules are constantly moving in all directions. The molecules bump into, or collide, with each other and with everything they touch. In a container, the air molecules collide with the walls. These collisions cause a force that pushes the walls outwards: You see this when the rubber expands as you blow up a balloon.

In the following experiments you will learn about air pressure. You may have seen terms such as *high pressure*, *excess pressure*, *low pressure*, and *underpressure*. Let's find out what they mean!

4 Let's Explore!

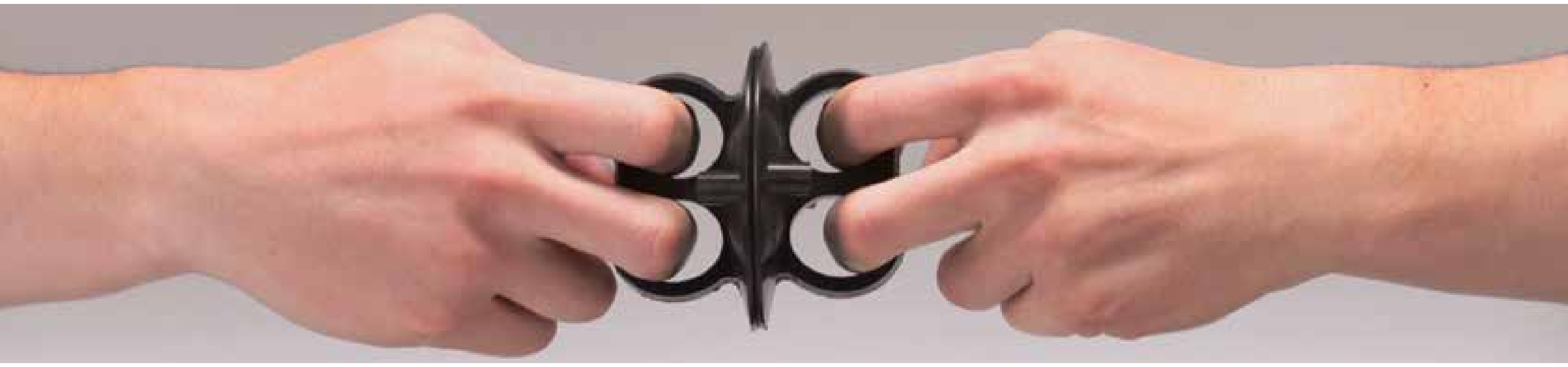

FIGURE 4.1: Atmospheric Pressure Cups

SAFETY NOTES

- Wear safety glasses or goggles.
- To prevent injury, make sure arms are in an area free of any objects when pulling the suction cups apart.

IMPRESSIVE PRESSURE

We do not really feel the atmospheric pressure and the forces it creates. One reason for this is that we are used to these forces. Another reason is that the pressure is pushing equally on all parts of us, inside and out. In the following experiments with the Atmospheric Pressure Cups (Figure 4.1), you will get an idea of how strong the forces are.

1. What are the gadgets you have? How do they work?
2. Compress the cups against each other. Then pull the cups apart. They are probably very tight, so be careful!
3. There is an easier way to separate the two halves. Can you discover it?
4. Place a piece of cloth between the cups.
5. How do the cups work if there is some cloth between them? Why is that?
6. Try lifting different objects using the pressure cups. Take notes on things you can and cannot lift with them.
7. How does the kind of surface affect how well the pressure cups work? What is the same about the materials you are able to lift with the pressure cup? What is the same about the materials you are not able to lift?
8. Why do the two pressure cups stay together?

PRESSURE POWER

Air pressure squeezes every object. Let's see what happens if we remove the pressure with the Vacuum Pumper and Chamber (Figure 4.2).

1. You have a container and a pumper. Find out how the pump works.
2. Before attaching the pump to the container, find out which way the air moves while you are pumping. Which way is it?
3. You were given something to put in the container. It might be a balloon, a half-filled water balloon, a marshmallow, shaving foam, whipped cream, or something else.
4. What do you see in each of these cases? What happens while you pump? Why?

SAFETY NOTE

- Wear safety glasses or goggles.
- Never stand over or near the water rocket while it is being pressurized or launched.
- Stay clear of the stake—it presents a potential impalement hazard.
- Only perform this experiment outside in an open field, never inside.

FIGURE 4.2: Vacuum Pumper and Chamber

SAFETY NOTES

- Wear safety glasses or goggles.
- Before launching the rocket, make sure everyone is at a safe distance.
- Never stand over or near the water rocket while it is being pressurized or launched.
- Stay clear of the stake—it presents a potential impalement hazard.
- Only perform this experiment outside in an open field, never inside.

ROCKET!

This experiment must be done outdoors in a field with open sky. You will see the effect of gravitation and excess pressure. It may be surprising how high the Air-Powered Projectile (Figure 4.3) rises, so before launching the rocket, the area nearby must be made safe.

1. First, your teacher will launch the Air-Powered Projectile straight up. After the rocket lands, look at it closely. Explain what happened.
2. Then, select one of the wedges (triangular blocks) and place it under the launch pad. Try to guess where the rocket will land. Each group can estimate its own landing spot and mark it on the ground before the rocket is launched again.
3. Which angle of the launch pad do you think will make the rocket fly the farthest distance? Test your predictions.

FIGURE 4.3: Air-Powered Projectile

What's Going On?

TABLE 4.1

PRESSURE IN DIFFERENT PLACES IN DIFFERENT UNITS

When measuring pressure, several different units can be used: atmospheres (atm), bars (bar), kiloPascals (kPa), and pounds per square inch (PSI).

	Units			
Pressure location	**atm**	**bar**	**kPa**	**PSI**
Air pressure at sea level	1	1.01	101	14.7
Car tire	3.18	3.22	322	46.7
Bike tire	5.08	5.15	515	74.7
Basketball	1.54	1.57	157	22.7
Air at top of Mount Everest, 8,800 meters above sea level	0.332	0.337	34	5
Mars atmosphere	0.00592	0.00600	0.600	0.087
Venus atmosphere	90.5	91.7	9170	1330

Additional info: For the car tire, bike tire, and basketball, the reading on the pressure gauge is the amount by which the pressure is greater than the surrounding air pressure of 14.7 PSI. For example, the pressure gauge on the bike tire will read 60 PSI, while the actual pressure in the tire is 74.7 PSI.

IMPRESSIVE PRESSURE

With the Pressure Cups (Figure 4.4), it's easy to explore the forces caused by atmospheric pressure. Pressing the cups together squeezes the air out from between them. When you start to pull the cups apart, the space between the cups gets larger, but the number of air molecules remains the same, meaning the molecules are now more spread out. As a result, the molecules don't hit the cups as often, so the pressure between the cups is lower. The air pressure outside the cups is still the same—higher than the pressure inside—so it pushes the cups together.

Letting the air leak out from between the cups equalizes the pressure between the inside and the outside of the cups. With cloth between the cups, air molecules leak out because they can pass through the cloth. This allows the pressure inside and outside of the cups to be the same. This is also the case when the surface of an object you are trying to lift is rough. All the things that the cups can lift are smooth. All the things that the cups won't lift are rough.

FIGURE 4.4: Pressure Cups

As an extension, note that the same ideas about pressure apply to any fluid (liquid or gas), not just air. For instance, think about how an octopus attaches itself to glass under water.

PRESSURE POWER

With the Vacuum Pumper and Chamber (Figure 4.5) it is easy to observe the effects that air pressure has. To see what air pressure can do, you need to create differences in pressure. That means making one place have less air pressure than another place. With the chamber and pump, it is easy and safe to do.

You probably noticed that the pump makes air come out of the container. It is working in the reverse manner of a normal pump. Instead of adding air, as a pump does when used to add air to a bicycle tire, this pump makes the air move out of the chamber.

Molecules colliding in the chamber cause the air pressure there. The air pressure in the chamber is lower because you removed some air from it. With fewer molecules, there are also fewer collisions. Fewer collisions means lower pressure. This lower pressure is sometimes called *underpressure*, meaning that the pressure inside is lower than the normal, outside air pressure.

You also noticed that items that contain air, such as marshmallows, air balloons, or different kind of foams tend to expand in the chamber. Let's discuss the marshmallow demonstration first. When you start pumping, you remove the air from around the marshmallow. The air pressure is lower now: It

FIGURE 4.5: Vacuum Pumper and Chamber

doesn't push as hard on the marshmallow. When the pressure in the chamber is lower, the small air bubbles trapped inside the marshmallow start to expand because the air pressure from those air bubbles is greater than the air pressure outside the marshmallow. When you let the air flow back to the chamber, the marshmallow shrinks to a smaller size than when it started. That's because when it expanded, some of its stretchy parts got broken, causing it to collapse to a smaller size.

With the other foams or a balloon, something similar happens. The air trapped inside the foam or balloon expands when the pressure in the chamber is low.

Question for discussion: What makes dirt go into a vacuum cleaner?

ROCKET!

The two experiments involved underpressure. With the rocket, you saw what can happen if there is excess pressure.

The pressure in the rocket's launch tube gets higher when you pump air into it. The black plastic cover will hold a certain amount of pressure. Once the pressure exceeds that amount, the cap pops and the compressed air comes out and expands, launching the rocket. The compressed air pushes the rocket up.

The Air-Powered Projectile (Figure 4.6) will fly pretty far. With different plastic covers, you can adjust the launching pressure and the distance that the rocket flies. The rocket flies farthest when the pressure is highest and when the launch angle is about 45 degrees.

Air compressed in a balloon pushes on the balloon when you let it go. Do you see how the balloon is like a rocket?

Large rockets do not have air coming out the back, but use other gases. Rockets will work with any kind of compressed gas. The photo to the right shows the rocket that first took humans to the Moon in 1969. Would you like to ride in a rocket?

FIGURE 4.6: Air-Powered Projectile

Web Resources

An activity that shows students air pressure at work.
www.canteach.ca/elementary/physical6.html

Just as in the rocket exploration, students learn about projectile motion by firing various objects in this simulation. You can set the angle, initial speed, and mass, and add air resistance. Make it a game by trying to hit a target.
Info: *http://phet.colorado.edu/en/simulation/projectile-motion*
Simulation: *http://phet.colorado.edu/sims/projectile-motion/projectile-motion_en.html*

Marshmallow man in a vacuum.
www.videojug.com/film/marshmallow-man-in-a-vacuum

Air pressure pushes an egg into a bottle.
www.youtube.com/watch?v=crWA2FkmHnI

A slow-motion version of the egg being pushed into the bottle.
www.youtube.com/watch?v=OqKwxytsvvQ&noredirect=1

Shaving cream in vacuum
physics.wfu.edu/demolabs/demos/avimov/fluids/shaving_cream_vacuum/shaving_cream.MPG

Relevant Standards

Note: The Next Generation Science Standards *can be viewed online at* www.nextgenscience.org/next-generation-science-standards.

The performance expectations in third grade help students formulate answers to questions such as: "How do equal and unequal forces on an object affect the object?"

[In the performance expectations for all elementary grades], students are expected to demonstrate grade-appropriate proficiency in asking questions and defining problems; developing and using models, planning and carrying out investigations, analyzing and interpreting data, constructing explanations and designing solutions, engaging in argument from evidence, and obtaining, evaluating, and communicating information.

PERFORMANCE EXPECTATION

3-PS2-1

Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

DISCIPLINARY CORE IDEA

PS2.A: Forces and Motion

- Each force acts on one particular object and has both strength and a direction. An object at rest typically has multiple forces acting on it, but they add to give zero net force on the object. Forces that do not sum to zero can cause changes in the object's speed or direction of motion. (Boundary: Qualitative and conceptual, but not quantitative addition of forces are used at this level.)

CROSSCUTTING CONCEPT

[Also in all elementary grades:] The crosscutting concepts of patterns; cause and effect; energy and matter; systems and system models; interdependence of science, engineering, and technology; and influence of engineering, technology, and science on society and the natural world are called out as organizing concepts for these disciplinary core ideas.

Cause and Effect

- Cause and effect relationships are routinely identified.

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USING PHYSICAL SCIENCE

GADGETS & GIZMOS

GRADES 3–5

PHENOMENON-BASED LEARNING

"The most beautiful thing we can experience is the mysterious. It is the source of all true art and science." — Albert Einstein

The authors say there are three good reasons to buy this book:

1. To improve your students' thinking skills and problem-solving abilities

2. To acquire easy-to-perform experiments that engage students in the topic

3. To make your physics lessons waaaaay more cool

What student—or teacher—can resist the chance to experiment with Velocity Radar Guns, Running Parachutes, Super Solar Racer Cars, and more? The 30 experiments in *Using Physical Science Gadgets and Gizmos, Grades 3–5*, let your elementary school students explore a variety of phenomena involved with speed, friction and air resistance, gravity, air pressure, electricity, electric circuits, magnetism, and energy.

The phenomenon-based learning (PBL) approach used by the authors—two Finnish teachers and a U.S. professor—is as educational as the experiments are attention-grabbing. Instead of putting the theory before the application, PBL encourages students to first experience *how* the gadgets work and then grow curious enough to find out *why*. Working in groups, students engage in the activities not as a task to be completed but as exploration and discovery using curiosity-piquing devices and doohickeys.

The idea is to motivate young scientists to go beyond simply memorizing science facts. *Using Physical Science Gadgets and Gizmos* can help them learn broader concepts, useful thinking skills, and science and engineering practices (as defined by the *Next Generation Science Standards*). And—thanks to those radar guns and race cars—both your students and you will have some serious fun.

Grades 3–5

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