EUREKA!

GRADE 3-5 SCIENCE ACTIVITIES AND STORIES
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# CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FOREWORD</td>
<td>ix</td>
</tr>
<tr>
<td></td>
<td>DEDICATION</td>
<td>xvii</td>
</tr>
<tr>
<td></td>
<td>ACKNOWLEDGMENTS</td>
<td>xvii</td>
</tr>
<tr>
<td></td>
<td>ABOUT THE AUTHORS</td>
<td>xvii</td>
</tr>
<tr>
<td></td>
<td>INTRODUCTION: WHAT WE DID IN THIS BOOK AND WHY</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>ASKING QUESTIONS AND DEFINING PROBLEMS</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>Scientists and Engineers Are THINKERS—Learning About Philo Farnsworth</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>The Boy Who Invented TV: The Story of Philo Farnsworth by Kathleen Krull</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scientists and Engineers Are INSPIRED—Learning About Thomas Edison</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td>Young Thomas Edison by Michael Dooling</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scientists and Engineers Are DILIGENT—Learning About George Washington Carver</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>A Picture Book of George Washington Carver by David A. Adler</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DEVELOPING AND USING MODELS</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>Scientists and Engineers Are IMAGINATIVE—Learning About Annie Jump Cannon</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>Annie Jump Cannon, Astronomer by Carole Gerber</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scientists and Engineers Are VISIONARY—Learning About George Washington Ferris Jr</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Mr. Ferris and His Wheel by Kathryn Gibbs Davis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Scientists and Engineers Are PATIENT—Learning About Gregor Mendel</td>
<td>69</td>
</tr>
<tr>
<td></td>
<td>Gregor Mendel: The Friar Who Grew Peas by Cheryl Bardoe</td>
<td></td>
</tr>
</tbody>
</table>

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PLANNING AND CARRYING OUT INVESTIGATIONS

Recommended Science Teaching Strategy: Effective Questioning

Scientists and Engineers Are OBSERVANT—Learning About Jane Goodall
The Watcher: Jane Goodall’s Life With the Chimps by Jeanette Winter

Scientists and Engineers Are PUZZLERS—Learning About Charles Darwin
Darwin: With Glimpses Into His Private Journal and Letters by Alice B. McGinty

Scientists and Engineers Are INTUITIVE—Learning About Barnum Brown
Barnum’s Bones: How Barnum Brown Discovered the Most Famous Dinosaur in the World by Tracey Fern

ANALYZING AND INTERPRETING DATA

Recommended Science Teaching Strategy: Integration of Science and Mathematics

Scientists and Engineers Are DEDICATED—Learning About Wilson Bentley
Snowflake Bentley by Jacqueline Briggs Martin

Scientists and Engineers Are DREAMERS—Learning About Luke Howard
The Man Who Named the Clouds by Julie Hannah and Joan Holub

Scientists and Engineers Are CURIOUS—Learning About John James Audubon
The Boy Who Drew Birds: A Story of John James Audubon by Jacqueline Davies

USING MATHEMATICS AND COMPUTATIONAL THINKING

Recommended Science Teaching Strategy: Probeware and Digital Media

Scientists and Engineers Are INNOVATIVE—Learning About Ada Byron Lovelace
Ada Byron Lovelace and the Thinking Machine by Laurie Wallmark

Scientists and Engineers Are COURAGEOUS—Learning About Galileo Galilei
Starry Messenger by Peter Sís

Scientists and Engineers Are CONFIDENT—Learning About Jacques Cousteau
Manfish: A Story of Jacques Cousteau by Jennifer Berne
## CONTENTS

### 7

**CONSTRUCTING EXPLANATIONS (SCIENCE) AND DESIGNING SOLUTIONS (ENGINEERING)**

Recommended Science Teaching Strategy: KLEW Charts

193

**Scientists and Engineers Are CLEVER—Learning About Elijah McCoy**

The Real McCoy: The Life of an African-American Inventor by Wendy Towle

195

**Scientists and Engineers Are PERSISTENT—Learning About John Roebling**

The Brooklyn Bridge: The Story of the World’s Most Famous Bridge and the Remarkable Family That Built It by Elizabeth Mann

208

**Scientists and Engineers Are INVENTIVE—Learning About William Kamkwamba**

The Boy Who Harnessed the Wind by William Kamkwamba and Bryan Mealer

218

---

### 8

**ENGAGING IN ARGUMENT FROM EVIDENCE**

Recommended Science Teaching Strategy: Science Talk

235

**Scientists and Engineers Are RISK TAKERS—Learning About Nikola Tesla**

Electrical Wizard: How Nikola Tesla Lit Up the World by Elizabeth Rusch

237

**Scientists and Engineers Are FEARLESS—Learning About Sylvia Earle**

Life in the Ocean: The Story of Oceanographer Sylvia Earle by Claire A. Nivola

249

**Scientists and Engineers Are CREATIVE—Learning About Waterhouse Hawkins**

The Dinosaurs of Waterhouse Hawkins by Barbara Kerley

260

---

### 9

**OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION**

Recommended Science Teaching Strategy: Citizen Science

273

**Scientists and Engineers Are PERSUASIVE—Learning About Rachel Carson**

Rachel Carson and Her Book That Changed the World by Laurie Lawlor

276

**Scientists and Engineers Are PASSIONATE—Learning About Wangari Maathai**

Seeds of Change: Wangari’s Gift to the World by Jen Cullerton Johnson

286

**Scientists and Engineers Are INQUISITIVE—Learning About Carl Sagan**

Star Stuff: Carl Sagan and the Mysteries of the Cosmos by Stephanie Roth Sisson

296
CONTENTS

BEYOND EUREKA! TEACHING HOW SCIENTISTS AND ENGINEERS WORK 309

Recommended Science Teaching Strategy: Concept Mapping .......................................................... 310

Scientists and Engineers Use MODIFICATION ........................................................................ 311
Papa’s Mechanical Fish by Candace Fleming

Scientists and Engineers Use IDEA DEVELOPMENT ................................................................ 321
What Do You Do With an Idea? by Kobi Yamada

Scientists and Engineers Use DESIGN PROCESS ..................................................................... 327
Rosie Revere, Engineer by Andrea Beaty

LESSON GUIDELINES 335

Appendix A: Overview of Featured Books .................................................................................. 339
Appendix B: Timeline of Featured Scientists and Engineers ......................................................... 342
Appendix C: Lesson Connections to the NGSS and the Nature of Science, Grades 3–5 .............. 343
Appendix D: Glossary of Character Traits .................................................................................. 350
Appendix E: Recommended Science Teaching Strategies .......................................................... 351

Index .............................................................................................................................................. 363
Elementary teachers know the challenges of balancing literacy instruction with high-stakes testing and content area instruction. One way to do this is by incorporating literature relating to the content area into the lessons of that content area. In the case of science, the use of trade books to integrate literacy into science instruction is commonly used as a means of maximizing students’ understanding of specific content-related concepts. Some educators, however, have expressed concern that not all books containing science information meet a suitable standard for both science and literature content. Perhaps more troublesome, some studies have demonstrated that science literature books can actually create or increase misconceptions about the content they include (Trundle, Troland, and Pritchard 2008). Should these concerns derail elementary teachers’ selection and use of science trade books in their classrooms? Certainly, the answer is no. However, these concerns do heighten the need for teachers to have a clear understanding of the quality of science trade book content that appropriately conveys the desired information and concepts. Included with such considerations is the need to make trade book selections with very clear and purposeful rationales, having a definite sense for how a book’s content can be used to address specific science messages to students while at the same time providing support for high-quality literacy instruction.

A perusal of many science trade books might quickly reveal that the science content targeted in them can range from concepts (such as lightning, magnets, or volcanoes) to gizmos (such as science equipment and devices) to history (such as science during a specific era) or to other aspects of the discipline. One aspect of science that is sometimes difficult to tease out of trade books is the nature and work of scientists. What are scientists like? What do they do? How do they do it? Who can be a scientist? These are among the questions that arise when a teacher wishes to find a trade book that focuses on scientists. A trade book whose primary focus is on gizmos might mention scientists in passing but is likely going to do a poor job of addressing the actual nature of scientists. In short, it might be difficult for teachers to find high-quality science trade books that focus on the nature and work of scientists. The authors of this book have undertaken the task of helping elementary teachers with this problem. They have carefully identified key elements about the nature and work of scientists that should be considered in trade book selection and then developed and followed a process for assessing trade books to derive a set of books that could best meet the need.

Among those key features about the nature and work of scientists that are included in the authors’ selection process are (1) personal stories about scientists’ lives (who scientists are), (2) portrayal of science as a human endeavor (what inspires scientists’ work), (3) features of the processes scientists use (what we know as the science process skills describing how scientists do what they do), and (4) illustrations of scientists (how they are depicted) within the
books. For many elementary teachers, locating personal stories (who scientists are) is likely to be the easiest of these three things to accomplish. Finding the science processes (how scientists do their work) within the pages of these same books might be a little more difficult but still relatively easy. However, finding trade books that clearly identify science as a human endeavor is more difficult but certainly possible in trade books (Segun 1988; Tapscott 2009). Let’s look briefly at aspects of these last three elements the authors dealt with in this book.

Science Process Skills
How do scientists actually do science? Shortly after the launching of the satellite *Sputnik* by the Soviet Union on October 4, 1957, this became a key question for American education to answer. It was important because leaders in our nation realized we needed to do a better job of helping future citizens not only understand science but also how to actually do science. Congress provided millions of dollars in funding to various agencies and universities to develop science curricula that could help teachers accomplish this task. The three major elementary curriculum projects that emerged were Elementary Science Study (ESS), Science Curriculum Improvement Study (SCIS), and Science: A Process Approach (SAPA) (Shymansky 1989). Each of these curricula had at its heart the most significant science concepts and science process skills. The process skills were derived from observations and interviews with actual practicing scientists to assess the procedures they followed when doing their work (i.e., process skills). Hence, one of the aspects of the nature of scientists is the process skills scientists choose to use and how they employ them.

The set of science process skills derived varies depending on the source one reads, but all sets include essentially the same process skills. These skills can be categorized as either basic process skills or integrated process skills. The basic science process skills are the foundational skills upon which all other skills are based. The integrated science process skills are those that can be seen as integrated combinations of two or more of the basic science process skills. Although educators often view the basic science process skills as being taught only at the elementary level, many of them need to be revisited during later grades and at higher levels of sophistication. The essentials about the science process skills are described below.

Basic Science Process Skills
**Observing**
*Observing* is using the senses (or extensions of them) to gather information about an object or event. An example is watching and describing an ice cube as it melts.

**Inferring**
*Inferring* is making a conclusion or interpretation based on observations, whether observed by oneself or others, using reasoning to explain data or information. An example is concluding that the lid of a container filled with water was pushed off the container by the expansion of water as it turned to ice.

**Measuring**
*Measuring* is using both standard and nonstandard measures or estimates to describe dimensions of objects or events in quantitative ways. An example is using a metric ruler to measure the length and width of an ice cube in centimeters.

**Communicating**
*Communicating* is sharing or transferring ideas through spoken, written, graphic, or pictorial form. An example is using graphs to show the
relationship of an ice cube’s melting to time exposed to the air.

**Using Numbers**

*Using numbers* is applying mathematical rules and/or formulas to calculate quantities or determine relationships. An example is calculating the average time for an ice cube to melt in 25 ml of room-temperature water.

**Manipulating Materials**

*Manipulating materials* is handling or treating materials and equipment skillfully and effectively. An example is pouring a liquid from a graduated cylinder into another container when making ice.

**Classifying**

*Classifying* is grouping, ordering, or arranging objects, events, or information into groups or categories based on their properties or the criteria specified in some method or system. An example is placing ice crystals in groups based on their shape.

**Predicting**

*Predicting* is stating an outcome for a future event or condition one expects to exist based on a pattern of evidence derived from observations and measurements. An example is stating that an ice cube will melt within a specified amount of time.

**Developing Vocabulary**

*Developing vocabulary* is using and understanding terminology, specific and unique to uses of words in a discipline, in ways that have meaning. An example is applying working definitions of science concepts in verbal discussions, such as melting or heat exchange for an ice cube.

**Integrated Science Process Skills**

**Questioning**

*Questioning* is using questions to focus inquiry or to determine prior knowledge and establish purposes or expectations for an investigation. An example is formulating a question about how an ice cube wrapped in newspaper will melt.

**Identifying and Controlling Variables**

*Identifying and controlling variables* is identifying and describing the factors that are thought to be constant or changing under differing conditions that can affect the outcome of an experiment, keeping all of them constant except for the one being investigated. An example is identifying the factors that might affect the melting of an ice cube and keeping all of them the same except for the amount of light that shines on the ice cube.

**Defining Operationally**

*Defining operationally* is stating how to measure a variable or stating what a phenomenon is according to the actions or operations to be performed on it. An example is stating that an ice cube has “melted” when there is no solid material left in the cup where the ice cube was kept.

**Recording Data**

*Recording data* is setting down data in writing or some other permanent form (e.g., taking notes, making lists, and entering in data tables) in an organized manner to facilitate analysis to determine whether patterns or relationships exist in the data. An example is recording data about the mass of the ice remaining in an ice cube compared with the time it has been in a cup on the table.

**Formulating Models**

*Formulating a model* is creating a mental or physical model or representation of a process, object, or
event. An example is making a three-dimensional model of the molecules in an ice cube.

**Hypothesizing**

_Hypothesizing_ is stating or constructing a statement that is tentative and testable about what is thought to be the expected outcome of the interaction of two or more variables. An example is stating that if one ice cube is placed in water and another is left in an open container, the one in the water will melt more quickly.

**Experimenting**

_Experimenting_ is conducting procedural steps to test a hypothesis, including asking appropriate questions, stating the hypothesis, identifying and controlling variables, operationally defining variables, designing a “fair test,” and interpreting and then communicating the results. An example is investigating whether hot water or cold water freezes more quickly in a freezer.

**Making Decisions**

_Making decisions_ is drawing conclusions based on the results of experiments or collections of data, including identifying alternatives and choosing a course of action from among them based on the judgment for the selection with justifiable reasons. An example is identifying alternative ways to store ice cubes to avoid causing some of them to melt within a specific amount of time.

**Science as a Human Endeavor**

Science as a human endeavor is a significant component of both the American Association for the Advancement of Science (AAAS) _Benchmarks for Science Literacy_ (Project 2061) (AAAS Benchmarks; 1993), the _National Science Education Standards_ (NSES; NRC 1996), and _A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas_ (Framework; NRC 2012), which delineated how science as a human endeavor is evidenced by the following: (1) being people engaged in science and technology for a long time, (2) those who have contributed throughout history to the knowledge base have been both men and women and of various ethnicities—some of whom make careers in the sciences, and (3) science is an ongoing endeavor that does not end. It would seem logical that educators interested in teaching science would therefore look for ways to help students see science as a human endeavor.

A very human aspect of doing science is engaging in scientific inquiry (Akerson and Hanusc 2005). Scientific inquiry consists of posing questions and then conducting investigations in attempts to find evidence-based answers to them. This is central to the scientific enterprise and necessitates the appropriate development of scientific habits of mind and thinking. Seeing science as a human endeavor helps students develop an image of science going beyond familiar bodies of knowledge, helps them perceive science as something they can engage in successfully, and becomes something to them that is clearly a human endeavor. Abd-El-Khalick, Bell, and Lederman (1998) and Lederman (2007) emphasized that science as a human enterprise is practiced within the context of the culture in which it is situated. Hence, how science and scientists are portrayed in trade books can help contextualize students’ views and understanding about science as a human endeavor.

**Illustrations of Scientists**

Good picture books include colorful images students will want to look at and be able to refer to over and again (House and Rule 2005; Verhalle and Bus 2011; Xiung 2009). Analysis of images differentiates between photographs and other types of illustrations and considers their attributes, qualities, and appropriateness for use
with targeted student age groups. The differentiation between photographs and illustrations is an important consideration because students’ preferences—and subsequent attentiveness to the images in a book—help them comprehend the content being presented (Fang 1996; Glenberg and Langston 1992).

Included in the extant research regarding the impact of illustrations and images on elementary students were examinations of image attributes of color (bold and bright versus muted and pastels), realistic versus conventionalized presentation, sharp versus rounded lines, line drawings versus drawn images, and drawings or paintings versus photographs. Rationales for considering the importance of such elements encompass improvement of reader comprehension and development of specific language. The overall design of visual features and illustrations typically guides the reader in comprehending and linking elements of stories (Andrews, Scharff, and Moses 2002; Wolfenbarger and Sipe 2007). Appropriate and well-done illustrations help children develop a language of science (beyond simple vocabulary) extending to the language of inquiry: observation, logically derived hypothesizing, question posing, and examination of evidence (Pappas 2006). So, it is important to select trade books that have appropriately designed illustrations of scientists that are constructed in ways students prefer. Students’ preferences include such qualities as:

- being realistic and life-like (Rudisill 1952), with life-like realism being more important than color when those aspects are considered separately (King 1967);

- photographs, particularly in color, over drawings and paintings (Rudisill 1952; Simcock and DeLoache 2006);

- being simplified and less complex (French 1952), although they accept more complexity increases with each grade level; and

- being more realistically colored over those either using no color or including colors too bold and not seen in the “real” things represented in the images (Rudisill 1952; Welling 1931). Younger children prefer bright primary colors, while older children tend to prefer softer colors (Andrews, Scharff, and Moses 2002; Stewig 1972). Freeman and Freeman (1933) noted that preschool-age children favored bolder and more life-like colors.

Illustrations in nonfiction picture books play an integral role in how the reader understands the content. They “serve a special comprehension function in that these [visual] elements help readers link information-containing portions of the text” (Donovan and Smolkin 2002, p. 510). Thus, illustrations are an essential component in not only understanding science content but also aiding students’ understanding of science as a human endeavor or something they themselves could engage in.

Illustrations can go a long way in influencing students not only with respect to understanding where scientists work and what they do but also with regard to instilling interest and later engagement in actual career choices (Archer et al. 2010; Shope 2006). Children are very likely to formulate much of their perceptions about scientists from what they see in the illustrations in books. This factor can have a number of implications teachers may not readily consider. For example, the perceptions students hold about scientists may relate to their attitudes toward science and scientists (Finson 2003; Fung 2002). Finson (2003) found that students having more negative attitudes toward science tended to have more stereotypical perceptions of scientists, which in turn led to
a reduced desire to pursue science as a vocation later in life.

Another component influencing student interest and choice is self-efficacy. O’Brien, Kopala, and Martinez-Pons (1999) linked self-efficacy (with respect to a given field) to the probability of an individual choosing a career in that field. Individuals who perceive themselves as being successful or potentially successful engaging in science are those who will have higher science self-efficacy. From this finding, one could reasonably conclude that individuals holding negative perceptions of science or scientists may be less interested in science and less likely to select science courses or pursue science as a career.

The specifics with respect to the NSES (NRC 1996) are as follows:

**Standard Statement 1:** “The long-term and ongoing practice of science and technology is done by many people” (NRC 1996, p. 141).

- The practice of science must include students’ practice and learning. The content of a trade book must be both age- and developmentally appropriate for its intended audience so readers can cognitively connect with what is presented. An example of a book that meets these criteria is *Gregor Mendel: The Friar Who Grew Peas* by Cheryl Bardoe (2006), which tells how Mendel had paired different species of plants to see what offspring (hybrids) would result and then would count the numbers of specific traits that exhibited themselves in each hybrid to determine whether a mathematical pattern would emerge.

- The storytelling aspect of the book is more likely to reflect science as a human endeavor than are presentations of sets of facts. As an example, in *Rachel Carson: Preserving a Sense of Wonder*, Locker and Bruchac (2004) wrote about Carson hearing stories of robin deaths linked to pesticides, leading her to write a story in which the songbirds of the world had disappeared. Carson followed that up with *Silent Spring* in which she explained how every strand within the web of life is connected to the other strands and how the collapse of one endangers all the others.

**Standard Statement 2:** “Both men and women have made significant contributions to science and technology throughout history” (NRC 1996, p. 141).

- A trade book should include images of both males and females inasmuch as this is historically appropriate. In addition, the images of persons included within a trade book should be as nonstereotypical as possible (Farland 2006a; Farland 2006b).

**Standard Statement 3:** “By its nature, science will never be finished. Although much has been learned through inquiry about phenomena, objects, and events, there remains ever more to be discovered and learned” (NRC 1996, p. 141).

- Two things need consideration: (1) accuracy of the science information (Rice and Snipes 1997) and (2) attributes of the processes of science as delineated by the NSES and National Science Teachers Association documents on scientific literacy (Showalter et al. 1974). An example of a trade book that meets the requisites for accuracy of science information is Dan Yaccarino’s (2009) *The Fantastic Undersea Life of Jacques Cousteau*, in which he describes how Cousteau conducted life inventories of sea flora and fauna in books and documentaries and
how that inventory information changed over decades of study.

**Standard Statement 4:** “Many men and women choose science as a vocation and devote their lives to studying it. Many also derive great pleasure from doing so” (NRC 1996, p. 141).

- The story presented in a trade book should illustrate the roles of people engaging in the scientific enterprise. A good example is Jacqueline Briggs Martin’s (1998) *Snowflake Bentley*, in which she describes how a farmer became interested in and persisted in photographing snowflakes over many years until he was able to publish a book about them at the age of 66—and even then he continued his work about them.

**Conclusion**

In writing this book, the authors have been diligent and deliberate in selecting the science trade books that serve as the anchors for each of the chapters. Through careful examination of each of those books, the authors identified the science process skills that were attendant to the work of the person at the focus of each book and then matched those process skills to suggested activities that clearly lead children in their learning of how to apply those essential skills for investigations in science.

Elementary teachers who read and use this book will benefit from the extensive work already completed by the authors. Teachers can be confident that the trade books used as the focus within the chapters are high quality and meet well-established standards for both literacy and science with respect to the nature of scientists. Making use of this book will help teachers save precious time, will help them make science more personable to their students, and will guide them in how to connect the science process skills central to excellent science activities they can select to accompany literature that truly engages students.

**References**


FOREWORD

Dedication

This book is dedicated to the best science teacher I know, who teaches at Eastford Elementary School in Connecticut.
—Donna Farland-Smith

This book is dedicated to my most supportive husband, who has helped me brainstorm, craft, and edit these ideas and lessons from the very beginning.
—Julie Thomas

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About the Authors

Donna Farland-Smith has over a decade of experience in the classroom and previously taught science in all grades K–12. She currently serves as an associate professor of science education in The School of Teaching and Learning at The Ohio State University-Mansfield. Her areas of expertise include teacher education, students’ perceptions of science and scientists, and encouraging girls to explore science and engineering fields. Along with several book chapters and many articles about science education, Farland-Smith has written and published four books that inspire children to understand and appreciate scientists and their work: Jungle Jane (Authentic Perceptions Press, 2002), It Takes Two: The Story of the Watson and Crick Team (Authentic Perceptions Press, 2002), and The Simple Truth About Scientists (Authentic Perceptions Press, 2002). Farland-Smith received a BA in elementary education, a BA in natural science, an MA in science education, and an EdD in mathematics and science education from the University of Massachusetts-Lowell. In 2017, she published the book Many Hands, One Vision: 20 Principles That Built a Children’s Museum and Revitalized a Downtown Community (CreateSpace), which tells about her experience in founding The Little Buckeye Children’s Museum in Mansfield, Ohio.

Julie Thomas is an experienced elementary classroom teacher and elementary gifted-program coordinator. Now a research professor of science education in the College of Education and Human Sciences at the University of Nebraska-Lincoln, Thomas...
focuses her efforts on elementary science—for teachers and their students. She has led both state-funded and federally funded projects and has published research about children’s science learning and teacher professional development. Thomas’s accomplishments include collaborative efforts such as No Duck Left Behind, a partnership with waterfowl biologists to promote wetland education efforts; and Engineering Is Everywhere (E2), a partnership with a materials engineer to develop a time-efficient model for STEM career education. Throughout her teaching career, Thomas has been active in professional associations such as the School Science and Mathematics Association, for which she is a past executive director; the National Science Teachers Association, for which she has authored articles in the journal Science and Children and has served on the Awards Committee and Nominations Committee; and the Council for Elementary Children International, for which she is a past president.
Imaginative (adj.): creative or having the ability to think of unique ideas

Lesson: Starlight—Light From the Sun

Description

In this lesson, students will learn about how scientist Annie Jump Cannon observed variations in the brightness of stars and explored behaviors of light from the Sun.

Objectives

Students will consider how the character trait of being imaginative helped Annie Jump Cannon develop a classification system for stars and explore the nature of reflected light.

• Before starting the lesson, students will make a two-dimensional (2-D) foldable model of their place in the solar system.

• As a class, students will make a model to show the position of Earth and the solar system within the Milky Way galaxy.

• Students will hear the story Annie Jump Cannon, Astronomer by Carole Gerber and discuss how it relates to the word imaginative.

• Students will explore the behaviors and benefits of luminous and reflected light.

• To conclude the lesson, students will engage in a light-tag activity to further explore the behavior of reflected light.
Learning Outcomes

Students will (1) make a science notebook entry to explain what it means to be imaginative and why being imaginative is an important trait for scientists and engineers and (2) demonstrate their understanding of the behavior and benefits of reflected light.

Connections to the NGSS and the Nature of Science, Grades 3–5

Disciplinary Core Ideas

**ESS1.A: THE UNIVERSE AND ITS STARS**

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

**PS3.B: CONSERVATION OF ENERGY AND ENERGY TRANSFER**

- Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.

- Light also transfers energy from place to place.

**PS4.B: ELECTROMAGNETIC RADIATION**

- An object can be seen when light reflected from its surface enters the eyes.

Science and Engineering Practices

*Asking Questions and Defining Problems:* A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world works and which can be empirically tested. Asking questions and defining problems in grades 3–5 builds from grades K–2 experiences and progresses to specifying qualitative relationships.

- Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.

- Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.

*Developing and Using Models:* A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling in 3–5 builds on K–2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.
• Develop and/or use models to describe and/or predict phenomena.
• Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.

Crosscutting Concepts

Patterns: Observed patterns in nature guide organization and classification and prompt questions about relationships and causes underlying them.
• Similarities and differences in patterns can be used to sort, classify, communicate and analyze simple rates of change for natural phenomena and designed products.
• Patterns can be used as evidence to support an explanation.

Scale, Proportion, and Quantity: In considering phenomena, it is critical to recognize what is relevant at different size, time, and energy scales, and to recognize proportional relationships between different quantities as scales change.
• Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods.
• Standard units are used to measure and describe physical quantities such as weight, time, temperature, and volume.

Nature of Science Connections

Scientific Investigations Use a Variety of Methods
• Science methods are determined by questions.
• Science investigations use a variety of methods, tools, and techniques.

Science Knowledge Is Based on Empirical Evidence
• Science findings are based on recognizing patterns.
• Science uses tools and technologies to make accurate measurements and observations.

Science Is a Way of Knowing
• Science is both a body of knowledge and processes that add new knowledge.

Science Is a Human Endeavor
• Men and women from all cultures and backgrounds choose careers as scientists and engineers.
• Most scientists and engineers work in teams.
• Creativity and imagination are important to science.
SCIENCE ADDRESSES QUESTIONS ABOUT THE NATURAL AND MATERIAL WORLD

• Science findings are limited to questions that can be answered with empirical evidence.

Source: NGSS Lead States 2013.

Overview
In this lesson, students learn how Annie Jump Cannon invented a model for classifying stars based on the stars’ temperatures and shared her classification system with others in her science community. This challenged the way people thought about female astronomers. Through the featured book, students learn that men and women from all backgrounds choose careers as scientists and engineers. The character trait imaginative references Cannon’s meticulous and creative attempts to organize the starlight behaviors she observed. Students also share ideas about women being scientists. In the hands-on exploration, students explore the nature of reflected light.

Materials
You will need a supply of 9 in. × 14 in. or 8.5 in. × 11 in. colored paper in seven colors, enough for one color set for each student; and one copy of the featured book, Annie Jump Cannon, Astronomer, by Carole Gerber (ISBN 978-1589809116). Each group of students will need one rock, a cup of water, a piece of aluminum foil, a piece of white paper, and a small plastic bag. Each student will need a set of colored papers prepared ahead by the teacher, a glue stick, his or her science notebook, a flashlight, safety glasses or goggles, and a small acrylic mirror (e.g., 3 in. × 5 in.). Note: Acrylic mirrors minimize the safety risks of glass mirrors. Sheets of mirrored acrylic are available online and in most building supply stores and can be cut to any size.

Safety Notes
(1) Personal protective equipment should be worn during the setup, hands-on, and takedown segments of the activity. (2) Immediately wipe up spilled water—it creates a slip-and-fall hazard. (3) Wash hands with soap and water upon completing this activity.
Setting the Context

Engage

Ask students whether they have ever wondered how humans fit in the universe; that is, where we are relative to galaxies, the universe, and the solar system. Ask, “Which is larger, a galaxy, the universe, or a solar system?” Help students build a model of the universe so they appreciate how they actually fit into the big picture.

1. Before class, prepare the colored paper sets for students, planning for all students to create their stacks in the same color sequence. Leave the sheets of the first color of paper whole. For each subsequent color, cut the sheet to be 1 in. shorter and 1 in. narrower than for the previous color.

2. Provide each student with one set of precut colored paper and a glue stick. Have students stack the seven paper sheets by descending size (see Figure 3.1) and glue them in place.

3. Help students label their models. First, have them label the bottommost paper “Universe” (the outermost location in the universe model) and the topmost paper “Home” (the innermost location in the universe model). Students might instead use the city name and/or street addresses for the innermost label. Involve students in a conversation about which colors in this model represent the Milky Way galaxy, the solar system, Earth, North America, the United States, and their state. Prompt students with questions about relative size; for example, ask, “If the universe is the biggest, what fits inside it?” It is sometimes easier to begin with the home city and expand outward. You might use the book My Place in Space by Robin and Sally Hirst to help your students think about the smaller and larger components of this model.

4. Prompt students to connect their models to the classification of the stars by asking, “Where would the stars be found?” and “How might scientists find out the temperature of a star?” Guide the discussion to the idea that collecting data about space is challenging because stars are far away.

Figure 3.1

Example of a Student’s Stacked-Paper Model of the Universe

This model helps students conceptualize the relative sizes of the various parts of the universe and their location within it. See Zike 2004 for more information.
Guided Reading
Inform students that by reading *Annie Jump Cannon, Astronomer*, they will be learning about how stars are classified and about the work of Annie Jump Cannon, a scientist who was especially imaginative. Introduce the book by asking, “Can you describe the person on the front cover? What seems to be happening on the front cover?” Read the story aloud. Encourage students to notice and think about the challenges Cannon faced as a female astronomer. The questions below may be used to guide students’ attention to detail as you read. (Page numbers reference unnumbered book pages, beginning with the title page as page 1.)

1. **Pages 3–5:** When she was young, Annie Jump Cannon enjoyed stargazing with her mother. How did Cannon and her mother know what stars they were looking at? Cannon and her mother climbed onto the roof of their house and matched their view of the night sky to her mother’s school star charts. This was how Cannon learned the names of the visible constellations.

2. **Pages 6–10:** Cannon enrolled in a nearby boys’ school after they began admitting girls and graduated at the top of her class. How did Cannon happen to then enroll in Wellesley College? Annie’s father had toured Wellesley on a business trip and was impressed that Wellesley, a women’s college, offered the same courses as all-male universities.

3. **Pages 12–15:** Cannon loved attending Wellesley College, especially the laboratory experiments in her science classes. What challenges did she encounter as a student? During her sophomore year, Cannon had scarlet fever and developed an ear infection that left her partially deaf. Despite that, she graduated with her class.

4. **Pages 16–18:** After her mother died, Cannon remembered how much she had enjoyed studying the stars with her mother, so she returned to Wellesley to study astronomy. How did Cannon’s astronomy studies set the course for her career? While at Wellesley, Cannon arranged a way to use the telescope at the Harvard College Observatory.

5. **Pages 19–21:** The director of Harvard College Observatory hired Cannon to help photograph and classify all the stars in the sky; however, Cannon soon learned that she would not actually be photographing stars. How did astronomers take photographs of the stars? Why did Cannon not photograph stars? Astronomers used a special system to photograph the stars. They attached prisms to telescopes that separated the light from each star into different wavelengths, similarly to how raindrops separate sunlight into a rainbow. Cannon did not take photographs of the stars because only the male astronomers were allowed to. Women could only be assistants who worked as “human
computers” to examine the photographic plates (spectrographs) to analyze the type of light from each star. Women were paid one-fourth the amount that men were paid.

6. **Pages 24–28:** Cannon had sharp eyes and a good memory and soon became the fastest computer—she could classify three stars per minute. How did she identify a problem with the classification system? The computers used magnifying glasses to examine the spectrographs. They used the dark lines on the spectrographs to determine what the star was made of and how hot it was and then ranked the stars (named according to letters of the alphabet) on the basis of their spectral characteristics. Cannon noticed, for example, that the O stars (the brightest) were the hottest and the A stars were the third hottest. So, she developed a shorter, more accurate star classification system that organized the classes of stars from hottest to coolest—O, B, A, F, G, K, M. Her system is still used today and is remembered by the mnemonic “Oh Be A Fine Guy/Girl, Kiss Me.”
7. **Pages 26–29:** Introduce a discussion of the importance of Cannon’s model for classifying stars in ranked order from hottest to coolest by asking the following questions. How did Cannon become known as “the census taker of the stars”? Why is this system needed, and why is it important to science? How does this science activity of re-creating Cannon’s classification system on a model help you think about Cannon’s imaginative model for classifying the stars? This is a complex model, and students are expected to understand only that she saw patterns in both the spectra and the temperatures of stars and that she reorganized the alphabetical lettering system (OBAFGKM) to classify stars from hottest (O) to coolest (M).

### Making Sense

#### Explore

Begin by holding a discussion about rainbows to help students recall their knowledge of refraction—the bending and separating of light into a spectrum of colors. Although refraction is not the lesson focus, this discussion will help students connect the lesson to Annie Jump Cannon’s interest in and research about stars. Initiate the discussion by asking, “When do we see rainbows?” “What are the colors of the rainbow?” and “What causes rainbows?” Rainbows appear when rain and sunlight interact in a specific manner. When sunlight passes through water droplets, the droplets act like prisms and refract (bend) the various wavelengths of light that make up white light, which we then see as a spectrum of colors—red, orange, yellow, green, blue, indigo, and violet (ROYGBIV). Cannon worked with images collected through telescopes equipped with prisms and recognized that the different classes of stars emitted light composed of particular wavelengths, which could be distinguished by their refraction through the prisms.

Extend the discussion to students’ experience of light from the Sun and other stars. Ask, “What do we know about the light that comes from the Sun, which is one of the largest stars in our galaxy?” Encourage students to share personal experiences and observations of the nature of light from the Sun (e.g., what sunlight feels like on their skin, that sunlight passes through clouds and windows, and that blocking sunlight produces shadows). Then, inform students that they will conduct an exploration of how the Sun’s light behaves when it strikes various objects. This exploration focuses on reflection, the bouncing of light rays off an object, which allows us to see the object. It is organized in two parts and will work best in a darkened classroom with the lights off and the shades drawn. The steps of the exploration are as follows:

1. Organize students into table groups and provide each group with a rock, a cup of water, a piece of aluminum foil, a piece of white paper, and a small plastic bag. Each student will need a flashlight. Invite students to examine each item and predict what will happen when they shine a flashlight on it. Encourage students to think of the flashlight as the Sun. Guide their thinking
by asking, “What will happen to the light when it hits this object?” “Where will the light go?” and “Will the light rays pass through, be blocked, or be reflected?” Have students record their predictions in their science notebooks; encourage them to create a chart so they can record both their predictions and their test results. Then, allow some time for students to use their flashlights to test their predictions. Students should find that the opaque objects (rock and paper) will block some light and cast a shadow; the shiny object (aluminum foil) will reflect or redirect some of the light; and the clear objects (water and plastic bag) will allow most or all of the light to pass through. Note that all the objects actually reflect some light, although this will not be obvious to your students. This fine point may become clear in the “Extend” and “Explain” sections that follow.

2. Have students work in pairs. Provide each pair with a flashlight and a small acrylic mirror. Begin with the guiding question, “What happens when the Sun’s light reflects off a mirror?” Prompt students to think of their flashlight as the Sun, and invite them to work together to observe what happens when they shine their flashlight on the mirror. They should easily observe a reflected light beam if they lay the flashlight on the table and shine it into a mirror held perpendicular to the table so that some of the light spills onto the table. Once they recognize the line of reflected light, ask, “How can you change the line of reflected light?” Challenge students to record their data by creating three diagrams in their science notebooks. Each diagram should include an arrow to show the direction of the reflected (outgoing) light. Students may need to adjust the angle of the mirror and the distance between the flashlight and the mirror. Once students have completed their three diagrams, ask, “What pattern do you see?” Students should be able to explain that light reflecting from the mirrors travels in a straight line and that the angle of reflection changes when the position of the mirror changes.

Explain
Encourage students to summarize their understanding of the different ways the Sun’s light (modeled by the flashlight) behaved when it struck opaque, shiny, and clear objects and the relationship between the angle of the mirror and the line of reflection. Note: There is a rule for mirror reflections—that the angle of the incidence equals the angle of the reflection—but this is not the point in this lesson. Rather, this lesson introduces the concept of a definite line of light that reflects from the mirror.

Extend
Organize a light-tag activity. Darken the classroom (turn the lights off and draw the shades) and seat students in two facing rows. Each pair of facing rows is a group. Give a flashlight to a student seated at the end of a row and give small acrylic mirrors to the other students. The goal is for the group members with mirrors to adjust
Figure 3.2
One Way to Organize Students in Rows for Light Tag

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### Table 3.1

#### Rubric for Assessing Student Science Notebook Entries for Starlight—Light From the Sun

<table>
<thead>
<tr>
<th>Content</th>
<th>Not Yet</th>
<th>Beginning</th>
<th>Developing</th>
<th>Secure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Opaque Objects</strong></td>
<td>Student did not include information about the rock and paper blocking some light and casting a shadow.</td>
<td>Student included some information about the rock and paper blocking some light and casting a shadow.</td>
<td>Student included much information about the rock and paper blocking some light and casting a shadow.</td>
<td>Student included much information about the rock and paper blocking some light and casting a shadow and a clear explanation for that phenomenon.</td>
</tr>
<tr>
<td><strong>Shiny Objects</strong></td>
<td>Student did not include information about the aluminum foil reflecting or redirecting some light.</td>
<td>Student included some information about the aluminum foil reflecting or redirecting some light.</td>
<td>Student included much information about the aluminum foil reflecting or redirecting some light.</td>
<td>Student included much information about the aluminum foil reflecting or redirecting some light and a clear explanation for that phenomenon.</td>
</tr>
<tr>
<td><strong>Clear Objects</strong></td>
<td>Student did not include information about the water and plastic bag allowing the light to pass through them.</td>
<td>Student included some information about the water and plastic bag allowing the light to pass through them.</td>
<td>Student included much information about the water and plastic bag allowing the light to pass through them.</td>
<td>Student included much information about the water and plastic bag allowing the light to pass through them and a clear explanation for that phenomenon.</td>
</tr>
<tr>
<td><strong>Mirror</strong></td>
<td>Student did not produce three diagrams with an arrow showing the direction of the reflected (outgoing) light.</td>
<td>Student produced three diagrams but they did not all have an arrow showing the direction of the reflected (outgoing) light.</td>
<td>Student produced three diagrams and all had an arrow showing the direction of the reflected (outgoing) light.</td>
<td>Has three diagrams that include an arrow to show the direction of the reflected (outgoing) light. Highlights the relationship between the angle of incidence and the angle of reflection.</td>
</tr>
</tbody>
</table>
Index

Page numbers printed in bold type indicate tables, figures, or illustrations.

A
Ada Byron Lovelace and the Thinking Machine (Wallmark), 159, 163–166, 340
Ada Lovelace Day website, 170
age-appropriate content, trade book selection, 336
Airboat Race lesson, 159–172
description and overview, 159, 163
learning outcomes, 159
making sense, 166–171, 172
evaluate, 170–171, 172
explain, 168, 170
explore, 166–168, 167, 169
extend, 170, 171
materials, 163
NGSS and Nature of Science connections, 160–162
objectives, 159
safety notes, 163
setting the context, 163–166
engage, 163
guided reading, 163–166
analyzing and interpreting data
about, 119
integration of science and mathematics, 119–120, 356–357
See also Sandhill Crane Migration lesson; Sizing Up Snowflakes lesson; Water Cycle in a Bag lesson
Annie Jump Cannon, Astronomer (Gerber), 49, 52, 54–56, 339
Aqua Lung, 182, 187–188
Arbor Day and Earth Day lesson, 286–295
description and overview, 286, 289
learning outcomes, 287
making sense, 292–295
evaluate, 294–295, 295
explain, 294
explore, 292, 293
extend, 294
materials, 289
NGSS and Nature of Science connections, 287–289
objectives, 286
setting the context, 289–292
engage, 289–290
guided reading, 290–292
argument from evidence. See engaging in argument from evidence
asking questions and defining problems about, 9
designating makerspaces, 9–10, 352–353, 354, 355
See also Edison's Three Questions lesson; How Are Fruits and Vegetables Different? lesson; Thinking and Tinkering lesson
assessment rubrics
Airboat Race lesson, 172
Arbor Day and Earth Day lesson, 295
Building Dinosaurs lesson, 271
Chirping Crickets lesson, 92
Digging Up Dinosaurs lesson, 117
Edison's Three Questions lesson, 34
Electric Action lesson, 248
Exploring Suspension Bridges lesson, 217
Food Delivery Design Challenge, 320
Gravity Versus Microgravity lesson, 307
How Are Fruits and Vegetable Different? lesson, 45
How Do Submersibles Work? lesson, 191
Inventing a Solution lesson, 232
M is for Motion lesson, 181
Mysterious Sawfish lesson, 259
New Uses lesson, 285
Pass It Along lesson, 78
Puzzling Potatoes lesson, 103
Racing Against Friction lesson, 207
Rosie Revere, Engineer lesson, 333
Round and Round We Go! lesson, 68
INDEX

Sandhill Crane Migration lesson, 155
Sizing Up Snowflakes lesson, 130
Starlight—Light From the Sun lesson, 59
Thinking and Tinkering lesson, 21
Water Cycle in a Bag lesson, 140
What Do You Do With an Idea? lesson, 326
Audubon, John James, 141, 145, 146–148, 147, 152, 153–154, 342
See also Sandhill Crane Migration lesson

Babbage, Charles, 164–166
Ballard, Bob, 258
Barnum’s Bones (Fern), 104, 108–110, 339
Bentley, Wilson, 121, 124, 125–126, 127, 128–129, 342
See also Sizing Up Snowflakes lesson

Big Beast Book (Booth), 269
bioinspiration, 229
bird banding, 145–146
book overview
SE learning-cycle format, 5
chapters and lessons structure, 2, 7–8
character traits of featured scientists, 3
children’s views of scientists, 6–7, 7
Eureka! title, 1–2
NGSS connections, 2–3
recommended science teaching strategies, 3–4
safety considerations, 5–6
The Boy Who Drew Birds (Davies), 141, 145, 146–148, 340
The Boy Who Harnessed the Wind (Kamkwamba and Mealer),
218, 222, 223–225, 340
The Boy Who Invented TV (Krull), 11, 13, 339
brainstorming. See What Do You Do With an Idea? lesson
bridges. See Exploring Suspension Bridges lesson
The Brooklyn Bridge (Mann), 208, 211, 212–214, 212, 340
Brown, Barnum, 104, 107, 108–110, 109, 116, 342
See also Digging Up Dinosaurs lesson
Building Dinosaurs lesson, 260–272
description and overview, 260, 264
learning outcomes, 260
making sense, 267–270, 271
evaluate, 270, 271
explain, 267, 269
explore, 267, 268, 269
extend, 269–270
materials, 264
NGSS and Nature of Science connections, 261–263
objectives, 260

C

Calyx (research vessel), 186, 187
Cannon, Annie Jump, 49, 52, 54–56, 55, 58, 342
See also Starlight—Light From the Sun lesson
Carson, Rachel, 276, 279, 280–281, 281, 283, 284, 342
See also New Uses lesson
Carver, George Washington, 35, 37, 38–39, 40, 44, 342
See also How Are Fruits and Vegetables Different? lesson
clear (Mysterious Sawfish lesson), 249, 250, 253, 254, 258
glossary of, 350
imaginative (Starlight—Light From the Sun lesson), 49, 50, 52, 58
innovative (Airboat Race lesson), 159, 163, 170–171
inquisitive (Gravity Versus Microgravity lesson), 296, 297, 300, 302, 305–306
inspired (Edison’s Three Questions lesson), 22–23, 33–34
intuitive (Digging Up Dinosaurs lesson), 104, 105, 108, 115, 116
inventive (Inventing a Solution lesson), 218, 219, 222, 224, 230
observant (Chirping Crickets lesson), 83, 85, 90, 91
passionate (Arbor Day and Earth Day lesson), 286, 287, 289, 290, 292, 294
patience (Pass It Along lesson), 69, 71, 72, 77–78

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persistent (Exploring Suspension Bridges lesson), 208, 209, 211, 216
persuasive (New Uses lesson), 276, 277, 279, 280, 284
puzzler (Puzzling Potatoes lesson), 93–94, 96, 102
risk taker (Electric Action lesson), 237, 240, 243, 247
thinker (Thinking and Tinkering lesson), 11, 13, 19–20
visionary (Round and Round We Go! lesson), 60, 63, 67
Chemistry Matters (AIMS Education Foundation), 120
Chirping Crickets (Berger), 90
Chirping Crickets lesson, 83–92
description and overview, 83, 84
learning outcomes, 83
making sense, 88–91, 92
evaluate, 90–91, 92
explain, 89
explore, 88, 89, 90
extend, 90
materials, 86, 86
NGSS and Nature of Science connections, 84–85
objectives, 83
safety notes, 86
setting the context, 86–88
engage, 86
guided reading, 86–88
citizen science, 273–275, 359–360
clever (character trait), 195, 196, 198, 199, 205–206
clouds. See Water Cycle in a Bag lesson
concept mapping, 310, 327, 329, 331, 332, 333, 360, 361
confident (character trait), 182, 186, 191
constructing explanations (science) and designing solutions (engineering)
about, 193
KLEW charts, 193–194, 199, 211, 223, 358, 359. See also Exploring Suspension Bridges lesson; Inventing a Solution lesson; Racing Against Friction lesson
content
Airboat Race lesson, 171, 172
Arbor Day and Earth Day lesson 295, 295
Building Dinosaurs lesson, 270, 271
Chirping Crickets lesson, 91, 92
Edison's Three Questions lesson, 34, 34
Electric Action lesson, 247–248, 248
Exploring Suspension Bridges lesson, 216, 217
Gravity Versus Microgravity lesson, 306, 307
How Are Fruits and Vegetables Different? lesson, 44, 45
Inventing a Solution lesson, 230–231, 231, 232
M is for Motion lesson, 181, 181
Mysterious Sawfish lesson, 259, 259
New Uses lesson, 284, 285
Pass It Along lesson, 78, 78
Puzzling Potatoes lesson, 102, 103
Racing Against Friction lesson, 206–207, 207
Round and Round We Go! lesson, 68, 68
Sandhill Crane Migration lesson, 154, 155
Sizing Up Snowflakes lesson, 130, 130
Starlight—Light From the Sun lesson, 58, 59
Thinking and Tinkering lesson, 20, 20
Water Cycle in a Bag lesson, 140, 140
courageous (character trait), 173, 176, 177, 180–181
Cousteau, Jacques, 182, 186, 187–188, 188, 191, 342
See also How Do Submersibles Work? lesson
Creating Snowflakes activity, 125, 128
creative (character trait), 260, 264, 269, 270
Crime Scene Investigations (Walker and Wood), 77
crosscutting concepts
Airboat Race lesson, 162
Arbor Day and Earth Day lesson, 288
Building Dinosaurs lesson, 262
Chirping Crickets lesson, 84
Digging Up Dinosaurs lesson, 106
Edison's Three Questions lesson, 24
Electric Action lesson, 239
Exploring Suspension Bridges lesson, 210
Gravity Versus Microgravity lesson, 299
How Are Fruits and Vegetables Different? lesson, 36
How Do Submersibles Work? lesson, 184
Inventing a Solution lesson, 221
M is for Motion lesson, 175
Mysterious Sawfish lesson, 251
New Uses lesson, 278
Pass It Along lesson, 70
Puzzling Potatoes lesson, 95
Racing Against Friction lesson, 197
Rosie Revere, Engineer lesson, 329
Round and Round We Go! lesson, 62
Sandhill Crane Migration lesson, 143
Sizing Up Snowflakes lesson, 123
Starlight—Light From the Sun lesson, 51
summary table, 347–348
Thinking and Tinkering lesson, 12
Water Cycle in a Bag lesson, 133
What Do You Do With an Idea? lesson, 322
curiosity (character trait), 141, 142, 145, 146, 153–154
INDEX

D
Darwin, Charles, 93, 96, 98–99, 98, 100–101, 102, 342
See also Puzzling Potatoes lesson
Darwin (McGinty), 93, 96, 98–99, 98

DDT insecticide, 279

dedication (character trait), 121, 122, 124, 125–126, 128, 129
design
engineering design process, 17–18, 17
See also Food Delivery Design Challenge; Rosie Revere, Engineer lesson; What Do You Do With an Idea? lesson
designating makerspaces, 9–10, 352–353, 354, 355
Design for a Livable Planet (Naar), 283
Desmos graphing tool, 157–158, 170, 171
developing and using models
about, 47
Ferris wheel model, 65–66, 66, 68
graphic organizers as models, 47–48, 355, 355
stacked-paper model of the universe, 53, 53
See also Building Dinosaurs lesson; Pass It Along lesson; Round and Round We Go! lesson; Starlight—Light From the Sun lesson
Digging Up Dinosaurs lesson, 104–117
description and overview, 104, 108
learning outcomes, 105
making sense, 110–116, 117
evaluate, 115–116, 117
explain, 114–115
explore, 110, 111–112, 113, 114
extend, 115
materials, 108
NGSS and Nature of Science connections, 105–107
objectives, 104
setting the context, 108–110
engage, 108
guided reading, 108–110
diligence (character trait), 35, 44
dinosaurs. See Building Dinosaurs lesson; Digging Up Dinosaurs lesson
The Dinosaurs of Waterhouse Hawkins (Kerley), 260, 264–267, 340
disciplinary core ideas
Airboat Race lesson, 160
Arbor Day and Earth Day lesson, 287
Building Dinosaurs lesson, 261
Chirping Crickets lesson, 84
Digging Up Dinosaurs lesson, 106
Edison's Three Questions lesson, 23
Electric Action lesson, 238
Exploring Suspension Bridges lesson, 209
Food Delivery Design Challenge, 312
Gravity Versus Microgravity lesson, 297
How Are Fruits and Vegetables Different? lesson, 36
How Do Submersibles Work? lesson, 183
Inventing a Solution lesson, 219–220
M is for Motion lesson, 174
Mysterious Sawfish lesson, 250–251
New Uses lesson, 277
Pass It Along lesson, 70
Puzzling Potatoes lesson, 94
Racing Against Friction lesson, 196
Rosie Revere, Engineer lesson, 328
Round and Round We Go! lesson, 61
Sandhill Crane Migration lesson, 142
Sizing Up Snowflakes lesson, 122
Starlight—Light From the Sun lesson, 50
summary table, 343–346
Thinking and Tinkering lesson, 12
Water Cycle in a Bag lesson, 132
What Do You Do With an Idea? lesson, 321–322
dreamer (character trait), 131, 132, 135, 139–140

E
Earle, Sylvia, 182, 190, 249, 253–254, 255, 258–259, 342
See also Mysterious Sawfish lesson
Earth Day. See Arbor Day and Earth Day lesson
The Edge of the Sea (Carson), 281
edible plant parts diagram, 39, 40, 42
Edison's Three Questions lesson, 22–34
description and overview, 22, 25
learning outcomes, 23
making sense, 29–34
evaluate, 33–34, 34
explain, 29, 30, 32, 32
explore, 29, 30, 31
extend, 32–33
materials, 25–26
NGSS and Nature of Science connections, 23–24
objectives, 22
safety notes, 25
setting the context, 26–28
engage, 26–27, 27
guided reading, 27–28
Edison, Thomas, 22, 25, 25, 27–28, 33, 242, 342
See also Edison's Three Questions lesson
effective questioning, 81–82, 355–356, 356
egg-drop challenge, 193
Electric Action lesson, 237–248
   description and overview, 237, 240
   learning outcomes, 237
   making sense, 243–248
      evaluate, 247–248, 248
      explain, 244
      explore, 243–244, 243, 244
      extend, 245–246, 245
   materials, 240
   NGSS and Nature of Science connections, 237–239
   objectives, 237
   safety notes, 240
   setting the context, 241–243
      engage, 241–242
      guided reading, 242–243
   Electrical Wizard (Rusch), 237, 240, 242–243, 244, 340
   energy phase demonstration, 26–27, 27
   engaging in argument from evidence about, 235
   science talk, 235–236, 359
   See also Building Dinosaurs lesson; Electric Action lesson;
      Mysterious Sawfish lesson
   engineering design process (EDP)
      process chart, 17–18, 17
   See also Food Delivery Design Challenge; Rosie Revere,
      Engineer lesson; What Do You Do With an Idea? lesson
   environment. See Arbor Day and Earth Day lesson; Gravity
      Versus Microgravity lesson; New Uses lesson
   evidence. See engaging in argument from evidence
   explicit questioning, 9
Exploring Suspension Bridges lesson, 208–217
   description and overview, 208, 211
   learning outcomes, 209
   making sense, 214–216, 217
      evaluate, 216, 217
      explain, 214–215
      explore, 214, 215
      extend, 215
   materials, 211
   NGSS and Nature of Science connections, 209–210
   objectives, 208
   safety notes, 211
   setting the context, 211–214
      engage, 211
      guided reading, 212–214
F
Farnsworth, Philo, 11, 13, 15–17, 15, 19–20, 342
   See also Thinking and Tinkering lesson
   fearless (character trait), 249, 250, 253, 254, 258
Ferris, Jr., George Washington, 60, 63–65, 65, 67, 342
   See also Round and Round We Go! lesson
Food Delivery Design Challenge, 311–320
   description and overview, 311, 315
   learning outcomes, 311
   making sense, 317–320
      evaluate, 320, 320
      explain, 319, 319
      explore, 317–318, 317, 318
      extend, 319–320, 320
   materials, 315
   NGSS and Nature of Science connections, 312–314
   objectives, 311
   safety notes, 315
   setting the context, 315–316
      engage, 315
      guided reading, 315–316
   force-fitting, 229–230
Ford, Henry, 33
fossils. See Digging Up Dinosaurs lesson
friction. See Racing Against Friction lesson
G
Galilei, Galileo, 173, 176–177, 178, 180, 342
   See also M is for Motion lesson
Genetic Science Learning Center website, 72
Genetic traits, 77
Goodall, Jane, 83, 85, 86–88, 87, 90, 91, 342
   See also Chirping Crickets lesson
graphic organizers as models, 47–48, 355, 355
Gravity Versus Microgravity lesson, 296–308
   description and overview, 296, 300
   learning outcomes, 297
   making sense, 303–306, 307
      evaluate, 305–306, 307
      explain, 303, 305
      explore, 303, 304, 305
      extend, 305
   materials, 300
   NGSS and Nature of Science connections, 297–299
   objectives, 296
   safety notes, 300
   setting the context, 301–302
      engage, 301–302
INDEX

guided reading, 302
The Green Consumer (Makower), 283
green improvements, 283
Gregor Mendel (Bardoe), 69, 72–74, 336, 339

guided reading
Airboat Race lesson, 163–166
Arbor Day and Earth Day lesson, 290–292
Building Dinosaurs lesson, 264–267
Chirping Crickets lesson, 86–88
Digging Up Dinosaurs lesson, 108–110
Edison's Three Questions lesson, 27–28
Electric Action lesson, 242–243
Exploring Suspension Bridges lesson, 212–214
Food Delivery Design Challenge, 315–316
Gravity Versus Microgravity lesson, 302
How Are Fruits and Vegetables Different? lesson, 38–39
How Do Submersibles Work? lesson, 182–192
Inventing a Solution lesson, 218–233
M is for Motion lesson, 177
Mysterious Sawfish lesson, 253–255
New Uses lesson, 280–281, 283
Pass It Along lesson, 72–74
Puzzling Potatoes lesson, 98–99
Racing Against Friction lesson, 199–201
Rosie Revere, Engineer lesson, 330–331
Round and Round We Go lesson, 64–65
Sandhill Crane Migration lesson, 146–148
Sizing Up Snowflakes lesson, 125–126
Starlight—Light From the Sun lesson, 54–56
Thinking and Tinkering lesson, 15–17
Water Cycle in a Bag lesson, 135–136
What Do You Do With an Idea? lesson, 323–324

H
Harlen, Wynne, 10
Have You Seen Mary? (Kurrus), 152
Hawkins, Waterhouse, 260, 264–267, 265, 270, 342
See also Building Dinosaurs lesson
Heloise's Hints for a Healthy Planet (Heloise), 283
Howard, Luke, 131, 135, 136, 137, 140, 342
See also Water Cycle in a Bag lesson
How Are Fruits and Vegetables Different? lesson, 35–46
description and overview, 35, 37
learning outcomes, 36
making sense, 40–46
evaluate, 44, 45
explain, 42–43, 43
explore, 39, 40–42, 41, 42
extend, 43
materials, 37
NGSS and Nature of Science connections, 36–37
objectives, 35
safety notes, 37
setting the context, 38–39
engage, 38
guided reading, 38–39
How the Dinosaur Got to the Museum (Hartland), 115
How Do Birds Find Their Way? (Gans), 148
How Do Submersibles Work? lesson, 182–192
description and overview, 182, 186
learning outcomes, 182
making sense, 188–191
evaluate, 191, 191
explain, 190
explore, 188–190, 189
extend, 190
materials, 186
NGSS and Nature of Science connections, 183–185
objectives, 182
safety notes, 186
setting the context, 186–188
engage, 186–187
guided reading, 187–188

I
illustrations, trade book selection, 336, 337
imaginative (character trait), 49, 50, 52, 58
implicit questioning, 9
"In-Flight Education Downlinks," 305
information. See obtaining, evaluating, and communicating information
inheritance. See Pass It Along lesson
innovative (character trait), 159, 163, 170–171
inquisitive (character trait), 296, 297, 300, 302, 305–306
inspired (character trait), 22–23, 33–34
integration of science and mathematics, 119–120, 356–357
intuitive (character trait), 104, 105, 108, 115, 116
Inventing a Solution lesson, 218–233
description and overview, 218, 222
learning outcomes, 219
making sense, 225–231, 232
evaluate, 230–231, 230, 231
explain, 229
explore, 225–226, 226, 227, 228–229, 228, 229
extend, 229–230
materials, 222
NGSS and Nature of Science connections, 219–222
objectives, 218
safety notes, 222
setting the context, 223–225
engage, 223
guided reading, 223–225
inventive (character trait), 218, 219, 222, 224, 230
The Inventor's Secret (Slade), 22, 33
It Looked Like Spilt Milk (Shaw), 139
J
Jericho Historical Society, 129
K
Kamkwamba, William, 218, 222, 223–225, 225, 230, 342
See also Inventing a Solution lesson
Kid Wind Project, 230
KLEW charts, 193–194, 199, 211, 223, 358, 359
L
lesson guidelines
planning your own lessons, 337
trade book selection, 335–337
Life in the Ocean (Nivola), 249, 253–254, 340
light beam experiment, 29, 32, 32
lima bean plant embryo, 42–43, 43
Lovelace, Ada Byron, 159, 163–166, 165, 170, 342
See also Airboat Race lesson
M
Maathai, Wangari, 286, 289, 290–292, 291, 294, 342
See also Arbor Day and Earth Day lesson
makerspaces, designating makerspaces, 9–10
Manfish (Berne), 182, 186, 187–188, 336, 340
The Man Who Named the Clouds (Hannah and Holub), 131, 135–136, 339
"Mass vs. Weight: Stretching Mass" lesson, 303, 304, 305, 305
mathematics. See using mathematics and computational thinking
McCoy, Elijah, 195, 196, 198, 199–201, 200, 204–206, 342
See also Racing Against Friction lesson
McCoy, Mary, 201
Mendel, Gregor, 69, 72–74, 74, 342
See also Pass It Along lesson
Merlin Bird ID app, 152
migration. See Sandhill Crane Migration lesson
M is for Motion lesson, 173–181
description and overview, 173, 176
learning outcomes, 173
making sense, 177–181
evaluate, 180–181, 181
explain, 179–180
explore, 177–179, 179, 180
extend, 180, 181
materials, 176
NGSS and Nature of Science connections, 174–175
objectives, 173
setting the context, 176–177
engage, 176
guided reading, 177
Mistakes That Worked (Jones), 18
models. See developing and using models
Mr. Ferris and His Wheel (Davis), 60, 63, 64–65, 339
My Place in Space (Hirst and Hirst), 53
Mysterious Sawfish lesson, 249–259
description and overview, 249, 253
learning outcomes, 250
making sense, 255–259
evaluate, 258–259, 259
explain, 256, 257–258, 257
explore, 255–257, 256, 257
extend, 258
materials, 253
NGSS and Nature of Science connections, 250–252
objectives, 249
setting the context, 253–255
engage, 253
guided reading, 253–255
Mystery Tube activity, 245–246, 245
N
NASA (National Aeronautics and Space Administration), 300, 301, 303, 305
Nashua River, 284
National Council of Teachers of English (NCTE), 335
National Science Teachers Association (NSTA), 335
Nation of Makers website, 10
Nature of Science connections
Airboat Race lesson, 162
Arbor Day and Earth Day lesson, 288–289
Building Dinosaurs lesson, 262–263
Chirping Crickets lesson, 85
Digging Up Dinosaurs lesson, 107
Edison's Three Questions lesson, 24
Electric Action lesson, 239
<table>
<thead>
<tr>
<th>Lesson/Activity</th>
<th>Page(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploring Suspension Bridges</td>
<td>210</td>
</tr>
<tr>
<td>Food Delivery Design Challenge</td>
<td>314</td>
</tr>
<tr>
<td>Gravity Versus Microgravity lesson</td>
<td>299</td>
</tr>
<tr>
<td>How Are Fruits and Vegetables Different?</td>
<td>37</td>
</tr>
<tr>
<td>How Do Submersibles Work?</td>
<td>185</td>
</tr>
<tr>
<td>Inventing a Solution</td>
<td>221–222</td>
</tr>
<tr>
<td>M is for Motion</td>
<td>175</td>
</tr>
<tr>
<td>Mysterious Sawfish</td>
<td>252</td>
</tr>
<tr>
<td>New Uses lesson</td>
<td>279</td>
</tr>
<tr>
<td>Pass It Along lesson</td>
<td>71</td>
</tr>
<tr>
<td>Puzzling Potatoes lesson</td>
<td>95–96</td>
</tr>
<tr>
<td>Racing Against Friction</td>
<td>197–198</td>
</tr>
<tr>
<td>Rosie Revere, Engineer lesson</td>
<td>329</td>
</tr>
<tr>
<td>Round and Round We Go! lesson</td>
<td>62</td>
</tr>
<tr>
<td>Sandhill Crane Migration lesson</td>
<td>144</td>
</tr>
<tr>
<td>Sizing Up Snowflakes</td>
<td>123–124</td>
</tr>
<tr>
<td>Starlight—Light From the Sun lesson</td>
<td>51–52</td>
</tr>
<tr>
<td>summary table, 348–349</td>
<td></td>
</tr>
<tr>
<td>Thinking and Tinkering lesson</td>
<td>13</td>
</tr>
<tr>
<td>Water Cycle in a Bag</td>
<td>134</td>
</tr>
<tr>
<td>What Do You Do With an Idea? lesson</td>
<td>322</td>
</tr>
<tr>
<td>New Uses lesson</td>
<td>277–278</td>
</tr>
<tr>
<td>New Uses lesson</td>
<td>276–285</td>
</tr>
<tr>
<td>description and overview</td>
<td>276, 279</td>
</tr>
<tr>
<td>making sense, 282, 283–284, 285</td>
<td></td>
</tr>
<tr>
<td>evaluate, 284, 285</td>
<td></td>
</tr>
<tr>
<td>explain, 283</td>
<td></td>
</tr>
<tr>
<td>explore, 282, 283</td>
<td></td>
</tr>
<tr>
<td>extend, 284</td>
<td></td>
</tr>
<tr>
<td>materials, 279</td>
<td></td>
</tr>
<tr>
<td>NGSS and Nature of Science connections</td>
<td>277–279</td>
</tr>
<tr>
<td>objectives, 276</td>
<td></td>
</tr>
<tr>
<td>setting the context, 280–283</td>
<td></td>
</tr>
<tr>
<td>engage, 280</td>
<td></td>
</tr>
<tr>
<td>guided reading, 280–281, 283</td>
<td></td>
</tr>
<tr>
<td>NGSS (Next Generation Science Standards)</td>
<td>connections</td>
</tr>
<tr>
<td>Airboat Race lesson</td>
<td>160–162</td>
</tr>
<tr>
<td>analyzing and interpreting data, 119</td>
<td></td>
</tr>
<tr>
<td>Arbor Day and Earth Day lesson</td>
<td>287–288</td>
</tr>
<tr>
<td>asking questions and defining problems, 9</td>
<td></td>
</tr>
<tr>
<td>book overview, 2–3</td>
<td></td>
</tr>
<tr>
<td>Building Dinosaurs lesson</td>
<td>261–262</td>
</tr>
<tr>
<td>Chirping Crickets lesson</td>
<td>84</td>
</tr>
<tr>
<td>constructing explanations (science) and designing solutions (engineering), 193</td>
<td></td>
</tr>
<tr>
<td>developing and using models, 47</td>
<td></td>
</tr>
<tr>
<td>Digging Up Dinosaurs lesson</td>
<td>105–106</td>
</tr>
<tr>
<td>Edison's Three Questions lesson</td>
<td>23–24</td>
</tr>
<tr>
<td>Electric Action lesson</td>
<td>238–239</td>
</tr>
<tr>
<td>engaging in argument from evidence, 235</td>
<td></td>
</tr>
<tr>
<td>Exploring Suspension Bridges lesson</td>
<td>209–210</td>
</tr>
<tr>
<td>Food Delivery Design Challenge</td>
<td>312–314</td>
</tr>
<tr>
<td>Gravity Versus Microgravity lesson</td>
<td>297–299</td>
</tr>
<tr>
<td>How Are Fruits and Vegetables Different?</td>
<td>36–37</td>
</tr>
<tr>
<td>How Do Submersibles Work?</td>
<td>183–184</td>
</tr>
<tr>
<td>Inventing a Solution</td>
<td>219–221</td>
</tr>
<tr>
<td>M is for Motion</td>
<td>174–175</td>
</tr>
<tr>
<td>Mysterious Sawfish</td>
<td>250–251</td>
</tr>
<tr>
<td>New Uses lesson</td>
<td>277–278</td>
</tr>
<tr>
<td>obtaining, evaluating, and communicating information, 273</td>
<td></td>
</tr>
<tr>
<td>planning and carrying out investigations, 81</td>
<td></td>
</tr>
<tr>
<td>Puzzling Potatoes lesson</td>
<td>94–95</td>
</tr>
<tr>
<td>Racing Against Friction</td>
<td>196–197</td>
</tr>
<tr>
<td>Rosie Revere, Engineer lesson</td>
<td>328–329</td>
</tr>
<tr>
<td>Sandhill Crane Migration lesson</td>
<td>142–143</td>
</tr>
<tr>
<td>Sizing Up Snowflakes</td>
<td>122–123</td>
</tr>
<tr>
<td>Starlight—Light From the Sun lesson</td>
<td>50–51</td>
</tr>
<tr>
<td>summary table, 343–348</td>
<td></td>
</tr>
<tr>
<td>teaching how scientists and engineers work, 309</td>
<td></td>
</tr>
<tr>
<td>Thinking and Tinkering lesson</td>
<td>12</td>
</tr>
<tr>
<td>trade book selection, 336</td>
<td></td>
</tr>
<tr>
<td>using mathematics and computational thinking, 157–158</td>
<td></td>
</tr>
<tr>
<td>Water Cycle in a Bag</td>
<td>132–133</td>
</tr>
<tr>
<td>What Do You Do With an Idea? lesson</td>
<td>321–322</td>
</tr>
<tr>
<td>NOAA website, 190</td>
<td></td>
</tr>
<tr>
<td>nostrums. See Mysterious Sawfish lesson</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td></td>
</tr>
<tr>
<td>observant (character trait), 83, 85, 90, 91</td>
<td></td>
</tr>
<tr>
<td>Observing Snow Crystals activity, 124, 126–127</td>
<td></td>
</tr>
<tr>
<td>obtaining, evaluating, and communicating information about, 273</td>
<td></td>
</tr>
<tr>
<td>citizen science, 273–275, 359–360</td>
<td></td>
</tr>
<tr>
<td>See also Arbor Day and Earth Day lesson; Gravity Versus Microgravity lesson; New Uses lesson</td>
<td></td>
</tr>
<tr>
<td>Ocean Floor Mapping activity, 188–190, 189</td>
<td></td>
</tr>
<tr>
<td>Ocean (Woodward), 258</td>
<td></td>
</tr>
<tr>
<td>On the Wing (Lerner), 148</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td></td>
</tr>
<tr>
<td>paleontologists, 108</td>
<td></td>
</tr>
<tr>
<td>Papa's Mechanical Fish (Fleming), 309, 311, 315–316, 341</td>
<td></td>
</tr>
<tr>
<td>passionate (character trait), 286, 287, 289, 290, 292, 294</td>
<td></td>
</tr>
</tbody>
</table>
Pass It Along lesson, 69–79
  description and overview, 69, 72
  learning outcomes, 69
  making sense, 75–79
    evaluate, 77–78, 79
    explain, 76
    explore, 75, 76
    extend, 76
  materials, 72
  NGSS and Nature of Science connections, 70–71
  objectives, 69
  safety notes, 72
  setting the context, 72–74
    engage, 72
    guided reading, 72–74
  patent, 199
  patience (character trait), 69, 71, 72, 77–78
  pendulums. See M is for Motion lesson
  persistent (character trait), 208, 209, 211, 216
  persuasive (character trait), 276, 277, 280, 284
  planning and carrying out investigations
    about, 81
    effective questioning, 81–82, 355–356, 356
    See also Chirping Crickets lesson; Digging Up Dinosaurs
      lesson; Puzzling Potatoes lesson
  Platte River, 150, 150, 152
  Preserving Snow Crystals activity, 125, 127–128
  probeware and digital media, 157–158, 177–180, 179, 180, 182, 188–190, 189, 357–358
  problems. See asking questions and defining problems
  Project Budburst, 274–275
  Project FeederWatch, 274
  puzzler (character trait), 93–94, 96, 102
  Puzzling Potatoes lesson, 93–103
    description and overview, 93, 96
    learning outcomes, 94
    making sense, 100–102, 103
      evaluate, 102, 103
      explain, 101
      explore, 100, 100
      extend, 101
    materials, 96
    NGSS and Nature of Science connections, 94–96
    objectives, 93
  safety notes, 96–97
  setting the context, 97–99
    engage, 97, 97
    guided reading, 98–99

Q
  questions. See asking questions and defining problems

R
  Rachel Carson and Her Book That Changed the World
    (Lawlor), 276, 279, 280–281, 283, 335, 341
  Racing Against Friction lesson, 195–207
    description and overview, 195, 198
    learning outcomes, 196
    making sense, 201–207
      evaluate, 205–207, 207
      explain, 204–205
      explore, 201, 201, 202, 203–204, 203
      extend, 205
    materials, 198–199
    NGSS and Nature of Science connections, 196–198
    objectives, 195–196
    safety notes, 199
    setting the context, 199–201
    engage, 199
    guided reading, 199–201
  rainbows, 56
  The Real McCoy (Towle), 195, 198, 199–201, 340
  Rearing Horse (sculpture), 269–270
  refraction of light, 29, 32, 32
  ringing (bird banding), 145–146
  risk taker (character trait), 237, 240, 243, 247
  A River Ran Wild (Cherry), 284
  Roebling, Emily, 211, 212, 213, 216
  Roebling, John, 208, 218, 212–214, 213, 215, 216, 342
    See also Exploring Suspension Bridges lesson
  Roebling, Washington, 211, 212–214, 216
  Rosie Revere, Engineer (Beaty), 309–310, 327, 329, 330–331, 341
  Rosie Revere, Engineer lesson, 327–333
    description and overview, 327, 330
    learning outcomes, 327
    making sense, 331, 332, 333
      evaluate, 332, 333
      explain, 332
      explore, 331, 332
      extend, 332
    materials, 329
INDEX

NGSS and Nature of Science connections, 328–329
objectives, 327
setting the context, 329–331
engage, 329–330, 330
guided reading, 330–331
Round and Round We Go! lesson, 60–68
description and overview, 60, 63
learning outcomes, 60
making sense, 65–68
evaluate, 67–68, 68
explain, 67
explore, 65–66, 66
extend, 67
materials, 63
NGSS and Nature of Science connections, 61–62
objectives, 60
safety notes, 63
setting the context, 63–65
engage, 63–64
guided reading, 64–65
Rowe Sanctuary website, 148, 150

S
Sagan, Carl, 296, 300, 301, 302, 306, 342
See also Gravity Versus Microgravity lesson
Sandhill Crane Migration lesson, 141–156
description and overview, 141, 145
learning outcomes, 142
making sense, 148–154, 155
evaluate, 153–154, 155
explain, 149–153, 149, 150, 151
explore, 148
extend, 153, 153
materials, 145
NGSS and Nature of Science connections, 142–144
objectives, 141
safety notes, 145
setting the context, 145–148
engage, 145–146
guided reading, 146–148
science
citizen science, 273–275
as human endeavor, xii
science process skills, x–xii
science talk, 235–236, 359
science teaching and science literature, ix–x, xv
See also Nature of Science connections; science and
engineering practices; science notebooks; science
teaching strategies; teaching how scientists and
engineers work
science and engineering practices
Airboat Race lesson, 160–161
Arbor Day and Earth Day lesson, 287–288
Building Dinosaurs lesson, 261–262
Chirping Crickets lesson, 84
Digging Up Dinosaurs lesson, 105–106
Edison's Three Questions lesson, 23
Electric Action lesson, 238
Exploring Suspension Bridges lesson, 209
Food Delivery Design Challenge, 312–314
Gravity Versus Microgravity lesson, 297–298
How Are Fruits and Vegetables Different? lesson, 36
How Do Submersibles Work? lesson, 183–184
Inventing a Solution lesson, 220–221
M is for Motion lesson, 174–175
Mysterious Sawfish lesson, 251
New Uses lesson, 277–278
Pass It Along lesson, 70
Puzzling Potatoes lesson, 94
Racing Against Friction lesson, 197
Rosie Revere, Engineer lesson, 328
Round and Round We Go! lesson, 61
Sandhill Crane Migration lesson, 142–143
Sizing Up Snowflakes lesson, 122–123
Starlight—Light From the Sun lesson, 50–51
summary table, 346–347
Thinking and Tinkering lesson, 12
Water Cycle in a Bag lesson, 132–133
What Do You Do With an Idea? lesson, 322
science notebooks
Airboat Race lesson, 159
Chirping Crickets lesson, 88, 88, 90, 91
Digging Up Dinosaurs lesson, 114
Edison's Three Questions lesson, 28, 28
Food Delivery Design Challenge, 318, 318, 320, 320
How Are Fruits and Vegetables Different? lesson, 45
Inventing a Solution lesson, 219, 223, 228–229, 229,
230–231, 231
M is for Motion lesson, 173, 179, 181
Mysterious Sawfish lesson, 250, 259
Pass It Along lesson, 72
Puzzling Potatoes lesson, 94, 100, 100
Racing Against Friction lesson, 196, 204
Rosie Revere, Engineer lesson, 332
Sizing Up Snowflakes lesson, 128, 129–130
Starlight—Light From the Sun lesson, 58, 59
Water Cycle in a Bag lesson, 138

Science teaching strategies
about, 3–4, 351–352, 352, 353
citizen science, 273–275, 359–360
citizen science, 273–275, 359–360
concept mapping, 310, 327, 329, 331, 332, 333, 360, 361
designating makerspaces, 9–10, 352–353, 354, 355
effective questioning, 81–82, 355–356
graphic organizers as models, 47–48, 355
integration of science and mathematics, 119–120, 356–357
KLEW charts, 193–194, 199, 211, 223, 358, 358, 359
probeware and digital media, 157–158, 177–180, 357–358
science talk, 235–236
"Science Trade Book Evaluation Rubric," 335
scientists
children's views of, 6–7, 7
illustrations of, xii–xv
SCUMPS (size, color, use, material, parts, and shape), 256, 257–258
The Sea Around Us (Carson), 281
Seeds of Change (Johnson), 286, 289, 290–292, 341
self-assessment, Thinking and Tinkering lesson, 20
Seven Blind Mice (Young), 115
"Shark Tank" (television show), 199, 205
Silent Spring (Carson), xiv, 335
Sizing Up Snowflakes lesson, 121–130
description and overview, 121, 124
learning outcomes, 122
making sense, 126–130, 130
evaluate, 129–130, 130
explain, 128
explore, 126–128
extend, 129
materials, 124–125
NGSS and Nature of Science connections, 122–124
objectives, 121
safety notes, 125
setting the context, 125–126
engage, 125
guided reading, 125–126
Snowcrystals website, 125
Snowflake Bentley (Martin), 121, 124, 125–126, 336, 339
Snowflake Bentley website, 129
soda bottle bird feeder, 153, 153
stacked-paper model of the universe, 53, 53
star classification, 55–56
Starlight—Light From the Sun lesson, 49–59
description and overview, 49, 52
learning outcomes, 50
making sense, 56–59
evaluate, 58, 59
explain, 57
explore, 56–57
extend, 57–58, 58
materials, 52
NGSS and Nature of Science connections, 50–52
objectives, 49
safety notes, 52
setting the context, 53–56
engage, 53, 53
guided reading, 54–56
Starry Messenger (Sis), 173, 176, 177, 180, 340
Star Stuff (Sisson), 296, 300, 302, 341
STEAM education model, and maker thinking, 10
Steven Caney's Invention Book (Caney), 18
The Story of Snow (Cassino and Nelson), 129
Student created cloud formations, 139, 349
student evaluation. See content
student inventions, 18–19, 19
sunlight, 56–57
Survivor Tree, 294
suspension bridges. See Exploring Suspension Bridges lesson
symmetry. See Sizing Up Snowflakes lesson

T

teaching how scientists and engineers work
about, 309–310
concept mapping, 310, 327, 329, 331, 332, 333, 360, 361
See also Food Delivery Design Challenge; Rosie Revere,
Engineer lesson; What Do You Do With an Idea? lesson
See also Electric Action lesson
thinker (character trait), 11, 13, 19–20
Thinking and Tinkering lesson, 11–21
description and overview, 11, 13
learning outcomes, 11
making sense, 17–21
assessment rubric, 21
evaluate, 19–20, 19
explain, 18
explore, 17–18, 17
extend, 18–19
self-assessment, 20
INDEX

materials, 13–14
NGSS and Nature of Science connections, 12–13
objectives, 11
safety notes, 14
setting the context, 14–17
engage, 14–15
guided reading, 15–17
Trout in the Classroom program, 273–274

U
Under the Sea-Wind (Carson), 281
using mathematics and computational thinking
about, 157
probeware and digital media, 157–158, 177–180, 179,
180, 182, 188–190, 189, 357–358
See also Airboat Race lesson; How Do Submersibles
Work? lesson; M is for Motion lesson

V
Venn diagrams, 244, 244, 286, 289, 292, 293, 294, 295
visionary (character trait), 60, 63, 67

W
The Watcher (Winter), 83, 86–88, 336, 339
Water Cycle in a Bag lesson, 131–140
description and overview, 131, 135
learning outcomes, 132
making sense, 136–140, 140
evaluate, 139–140, 140
explain, 138
explore, 136–138, 138
extend, 138–139, 139
materials, 135
NGSS and Nature of Science connections, 132–134
objectives, 131
safety notes, 135
setting the context, 135–136
engage, 135
guided reading, 135–136
weather. See Water Cycle in a Bag lesson
What Do You Do With an Idea? lesson, 321–326
description and overview, 321, 323
learning outcomes, 321
making sense, 324–326
evaluate, 325–326, 326
explain, 325, 325
explore, 324–325, 324
extend, 325
materials, 323
NGSS and Nature of Science connections, 321–322
objectives, 321
setting the context, 323–324
engage, 323
guided reading, 323–324
What Do You Do With an Idea? (Yamada), 309, 321, 323–324,
341
Williams, Sunita, 302
windmills. See Inventing a Solution lesson
World’s Fair in Chicago, 63–64

Y
Young Birder’s Guide to Birds of North America (Thompson),
152
Young Thomas Edison (Dooling), 22, 25, 27–28, 339
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