




BRINGING **STEM** **TO THE** **ELEMENTARY** **CLASSROOM**

Edited by
Linda Froschauer

NSTApress
National Science Teachers Association



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Arlington, Virginia

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Contents

Introduction

ix

Part 1: GRADES PREK–5

CHAPTER 1

How to Develop an Engineering Design Task 3

Create Your Own Design Activity in Seven Steps

Chelsey Dankenbring, Brenda M. Capobianco, and David Eichinger

CHAPTER 2

Minding Design Missteps 11

A Watch List of Misconceptions for Beginning Designers

David Crismond, Laura Gellert, Ryan Cain, and Shequana Wright

CHAPTER 3

Teaching Through Trade Books 19

Design Dilemmas

Christine Anne Royce

CHAPTER 4

More Teaching Through Trade Books 31

Flying Machines

Emily Morgan, Karen Ansberry, and Susan Craig

Part 2: GRADES PREK–2

CHAPTER 5

Gimme an E! 43

Seven Strategies for Supporting the E in Young Children's STEM Learning

Cynthia Hoisington and Jeff Winokur

CHAPTER 6

THE EDP-5E 53

A Rethinking of the 5E Replaces Exploration With Engineering Design

Pamela Lottero-Perdue, Sonja Bolotin, Ruth Benyameen, Erin Brock, and Ellen Metzger

CHAPTER 7

Can a Student Really Do What Engineers Do? 61

Teaching Second Graders About Properties Using Filter Design Within a 5E Learning Cycle

Sherri Brown, Channa Newman, Kelley Dearing-Smith, and Stephanie Smith

CHAPTER 8

Catch Me if You Can! 71

A STEM Activity for Kindergarteners Is Integrated Into the Curriculum

Kimberly Lott, Mark Wallin, Deborah Roghaar, and Tyson Price

Part 2: GRADES PREK–2 (CONT.)

CHAPTER 9

Inviting Engineering Into the Science Lab 79

Two Guided-Inquiry Lessons Display the Integration of NGSS Engineering Practices Into Traditional Elementary Labs

Seth Marie Westfall

CHAPTER 10

Integrating Design 87

Peggy Ashbrook and Sue Nellor

CHAPTER 11

Elephant Trunks and Dolphin Tails 91

An Elephant-Trunk Design Challenge Introduces Students to Engineering for Animals

Lukas Hefty

CHAPTER 12

Engineering Adaptations 99

Many of the Science Investigations We Use in Our Classrooms Already Can Be Adapted to Engage Students in Engineering Design

Anne Gatling and Meredith Houle Vaughn

CHAPTER 13

Sailing Into the Digital Era 107

Students Transform STEM Journals Into E-books While Integrating Science, Technology, and Literacy

Janet Bellavance and Amy Truchon

CHAPTER 14

Inventing Mystery Machines 115

Collaborating to Improve Teacher STEM Preparation

Shelly Counsell, Felicia Peat, Rachel Vaughan, and Tiffany Johnson

CHAPTER 15

Am I Really Teaching Engineering to Elementary Students? 123

Lessons From an Environmental Engineering Summer Camp for First and Second Graders

Heather McCullar

CHAPTER 16

The STEM of Inquiry 129

Peggy Ashbrook

CHAPTER 17

Printing the Playground 133

Early Childhood Students Design a Piece of Playground Equipment Using a 3-D Printer

Stephanie Wendt and Jeremy Wendt

CHAPTER 18

A House for Chase the Dog 141

Second-Grade Students Investigate Material Properties

Meghan E. Marrero, Amanda M. Gunning, and Christina Buonamano

CHAPTER 19

Measuring Success 149

Second Graders Design, Build, Test, and Improve Tools to Map a Waterway

Tori Zissman

Part 3: GRADES 3–5

CHAPTER 20

Think It, Design It, Build It, Test It, Refine It 159

A Unit on Water Quality Ends With a Water Filtration Engineering Design Activity

Barbara Ehlers and Jeannie Coughlin

CHAPTER 21

Community-Based Engineering 169

A Design Task Helps Students Identify and Find Solutions to a School-Yard Problem

Tejaswini Dalvi and Kristen Wendell

CHAPTER 22

Engineer It, Learn It 179

Science and Engineering Practices in Action

Cathy P. Lachapelle, Kristin Sargianis, and Christine M. Cunningham

CHAPTER 23

Designing a Sound-Reducing Wall 189

Students Explore Engineering With a Fun Challenge

Kendra Erk, John Lumkes, Jill Shambach, Larry Braile, Anne Brickler, and Anna Matthys

CHAPTER 24

Blade Structure and Wind Turbine Function 199

Third and Fifth Graders Co-investigate and Co-design Wind Turbine Blades and Voltage Output

Pamela Lottero-Perdue, M. Angela De Luigi, and Tracy Goetzinger

CHAPTER 25

You and Your Students as Green Engineers 211

Using Creativity and Everyday Materials to Design and Improve a Solar Oven

Tess Hegedus and Heidi Carlone

CHAPTER 26

Smashing Milk Cartons 221

Third-Grade Students Solve a Real-World Problem Using the Engineering Design Process, Collaborative Group Work, and Integrated STEM Education

Debra Monson and Deborah Besser

CHAPTER 27

Creating a Prosthetic Hand 229

3-D Printers Innovate and Inspire a Maker Movement

Kristin Leigh Cook, Sarah B. Bush, and Richard Cox

CHAPTER 28

Gliding Into Understanding 237

A Paper Airplane Investigation Highlights Scientific and Engineering Practices

Patrick Brown

CHAPTER 29

A System of Systems 245

A STEM Investigation Project for Intermediate Students Has Real-Life Connections

Barney Peterson

CHAPTER 30

Blasting Off With Engineering 255

Toy Testing Creatively Engages Fifth-Grade Students in Engineering Design

Emily A. Dare, Gregory T. Childs, E. Ashley Cannaday, and Gillian H. Roehrig

Part 3: GRADES 3–5 (CONT.)

CHAPTER 31 _____

SCAMPERing Into Engineering! 263

A “Snapshot of Science” Program Brings
Science and Engineering Into the Library

Jenny Sue Flannagan and Margaret Sawyer

CHAPTER 32 _____

Wacky Weather 273

An Integrative Science Unit Combines
Science Content on Severe Weather With the
Engineering Design Process

Amy Sabarre and Jacqueline Gulino

CHAPTER 33 _____

Straw Rockets Are Out of This World 283

STEM Activities for Upper-Elementary
Students

Joan Gillman

CHAPTER 34 _____

Nature as Inspiration 291

Learning About Plant Structures Helps
Students Design Water Collection Devices

Kristina Tank, Tamara Moore, and Meg Strnat

CHAPTER 35 _____

The Tightrope Challenge 299

When Confronted With a Robotics
Engineering Task, Fourth-Grade Students
Develop Growth Mindsets

Bill Burton

CHAPTER 36 _____

Modeling Water Filtration 307

Model-Eliciting Activities Create
Opportunities to Incorporate New Standards
and Evaluate Teacher Performance

Melissa Parks

Index 317

Introduction

There have been few opportunities to completely rethink science education in the United States. With the release of *A Framework for K–12 Science Education* (NRC 2012) and the *Next Generation Science Standards* (NGSS; NGSS Lead States 2013) we are embarking on massive change that will influence all future generations. One particularly significant result is an increased focus on engineering education. National initiatives call for an increase in both the quality and quantity of engineering content, and the infusion of engineering into the NGSS has firmly established engineering as a core component of elementary education. With the addition of engineering to science classrooms, where math and technology have traditionally been included, we now have STEM (science, technology, engineering, and mathematics). STEM marks a significant change; it's much more than an acronym. Teachers are now deeply involved in bringing about the change—but doing so has not been easy.

Evidence shows that 21st-century workers require skills that many graduates do not acquire through formal education. Students need more experiences that provide in-depth knowledge of the STEM disciplines and apply to problem

solving. Many view STEM as a way to develop the skills essential for critical thinking, problem solving, creativity, innovation, communication, and collaboration. A study published by the American Society for Engineering Education identified the following characteristics of quality STEM programs (Glancy et al. 2014):

- The context is motivating, engaging, and real world.
- Students integrate and apply meaningful and important mathematics and science content.
- Teaching methods are inquiry based and student centered.
- Students engage in solving engineering challenges using an engineering design process.
- Teamwork and communication are a major focus. Throughout the program, students have the freedom to think critically, creatively, and innovatively, and they have opportunities to fail and try again in safe environments.

Connecting to the NGSS

The authors of the chapters, like most teachers, are initiating STEM strategies as they work toward also meeting the requirements of the NGSS. Nationally, in some situations, teachers are not involved in the development of strategies and the use of the NGSS; in other classrooms, the curriculum is being readjusted over time to meet the needs of the NGSS. In still other cases, the NGSS is not serving as the standard for science teaching. However, this book provides classroom connections to the NGSS through explicit references to the portions of the investigations that meet the NGSS performance expectations, science and engineering practices, disciplinary core ideas, and crosscutting concepts. In many cases, seeing how lessons align with specific NGSS concepts and strategies will be helpful as you select investigations for your students and develop a continuum of learning, even if you are not focusing on the NGSS as your standard.

At the end of most chapters, you will find a table containing some of the featured components of the NGSS targeted in that chapter. The table provides some of the connections between the instruction outlined in the chapter and the NGSS. Other valid connections are likely; however, space constraints prevent us from listing all possibilities. In the first column, you will see the NGSS component. The adjacent column describes the lesson activities that specifically connect to an NGSS standard. In some cases, teachers present the lesson to a group of children off grade level with NGSS because pre-assessment indicated that students required off-grade knowledge to build the concept. In other cases, schools are readjusting their curriculum as they attempt to align with the NGSS and have not shifted the science content.

Note that the materials, lessons, and activities outlined in chapters featuring preK classrooms provide foundational experiences. Science

experiences in preK by their nature are foundational and relate to early elements in learning progressions that facilitate later learning in K–12 classrooms. Because the NGSS performance expectations are for K–12, the book does not include specific performance expectations for the preK lessons, but it does identify the disciplinary core ideas that are addressed to show the link between those foundational experiences and students' later learning.

Addressing Classroom Needs

An increasing number of publishers, equipment providers, and schools claim they have created strong programs for developing and encouraging STEM. It's critical to find a source of investigations that will provide the important elements needed for an effective STEM experience. STEM should involve problem-solving skills, serve all students equally well, encourage learning across disciplines, promote student inquiry, engage students in real-world problem solving, and expose students to STEM careers. Students should develop skills in communication, problem solving, data analysis, process following, argumentation based on evidence, solution development, and possibly product design. That is a huge list of expectations that cannot be met through a single lesson. Meeting these needs requires a continuum of learning with a focus on elements that will develop the skills and content over time and through many experiences.

The chapters in this book provide lessons that, in combination with additional learning opportunities, can support teachers in developing STEM in their classrooms. They are based on the actual classroom experiences of teachers who provided these learning opportunities for their students. Whether you are just beginning to delve into STEM experiences or you have been building STEM lessons and are now seeking new ideas, *Bringing*

STEM to the Elementary Classroom will provide you with new, interesting, and productive strategies.

The book is organized in grade-level bands. In this way, you can quickly identify strategies that were developed with a specific grade level in mind. As we all know, however, many strategies can be modified to fit the needs of learners at other grade levels. So begin by looking at the topics within grade bands and then expand the search to other grades, while recognizing that the NGSS identified for the chapter are for specific grades. The most important decision is based on what is best for your students and the experiences they need to develop conceptual understanding.

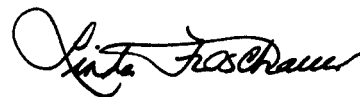
You will find a variety of strategies and topics used throughout *Bringing STEM to the Elementary Classroom*, including the following:

- 5-E Learning instructional phases
- Tested, reliable, and even some original design processes
- Pre-assessment strategies and evaluation rubrics
- Data sheets and learning tools that are readily available for immediate printing and use
- Use of technologies—from digital notebooks to three-dimensional printing
- Challenges that relate to real-world problems, such as filtering water, recycling waste, and collecting water
- Design constructions that solve problems, such as a sound proof wall, wind turbines, moving objects, solar ovens, structures to withstand harsh weather, and protection for living things

- Experiences to develop an understanding of technology

You may find the first two chapters of this book a valuable way to start your journey through the many wonderful ideas shared in *Bringing STEM to the Elementary Classroom*. They provide generic strategies that you can use at many grade levels. Chapter 1 is a good introduction to the process of designing lessons, and Chapter 2 will assist you in identifying the misconceptions of students who are new to STEM.

The goal of *Bringing STEM to the Elementary Classroom* is to help children develop an understanding of the many complex components of STEM. I hope you find these pages filled many new strategies that will support your efforts to provide valuable lessons for your students.



Linda Froschauer
Editor, *Bringing STEM to the
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NSTA President 2006–2007

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A House for Chase the Dog

Second-Grade Students Investigate Material Properties

By Meghan E. Marrero, Amanda M. Gunning, and Christina Buonamano

From a young age, children encounter different materials and learn color, hardness, texture, and shape. Focusing on observable properties is an engaging way to introduce young children to matter. In this investigation, students use observations and engineering design to decide which material would make the best roof for a doghouse. We used the 5E model (BSCS and IBM 1989) to create an engaging inquiry-based activity to meet standards and make real-life connections to physical science content. Our second-grade students enjoyed the activity and came to understand how physical properties can determine how a material is used.

Material properties are an important foundational piece of physical science content. As students advance, these early connections will be built on in chemistry, Earth science, and physics. At this age, students are learning that materials are suited for different purposes because of their properties. The children should be able to analyze data related to properties and sort materials based on this analysis. Some material properties appropriate for this age group are strength, flexibility, hardness, texture, and absorbency (NGSS

Lead States 2013). Early exploration of properties and classification helps support continued engineering work in upper elementary grades (Lachapelle et al. 2012).

Lesson Objectives

As two graduate education professors and one elementary school teacher, we have used this activity with preK and elementary students, varying the amount of support provided as was developmentally appropriate. This chapter describes how we implemented the activity with a group of primary students in one class period. Our students were introduced to the *Next Generation Science Standards* (NGSS) model of the engineering design process (EDP) and given different materials to test to determine the best solution for creating the roof of a doghouse to withstand rain. We chose to model activities with students first, giving them the opportunity to experience the appropriate science and engineering practices but still allowing us to finish the activity within one class period.

In the end, students were able to (a) draw on personal experience and prior knowledge by

explaining that roofs function to protect humans and pets from the elements, particularly precipitation; (b) compare how different materials stand up against rain; (c) use observable data to compare roof materials; and (d) decide which roof material is best on the basis of evidence from their engineering investigation.

Engage

Where do animals and people go when it rains? We used this question as a starting point for discussion leading into the activity. In our class, students said they went inside their homes, cars, and school. From there, we asked why it is important to go to those places (to stay dry) and how those places help you (or animals) stay dry in the rain. Children quickly realized the roofs of all of those places keep the rain out.

Next, we showed the class a picture of a classmate's new dog and asked whether any students have a dog at home and whether their dogs like to be outside. We explained to students that we wanted their help, and we read the following scenario:

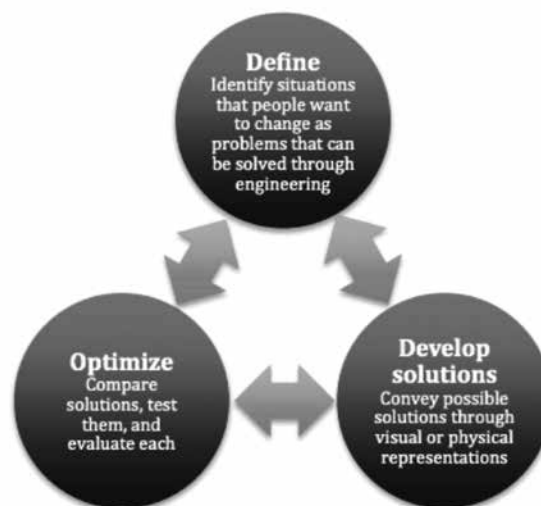
Chase the dog loves being outside. Although he has a family and a warm, dry house, he prefers to hang out in the backyard, no matter the weather. Chase has two loving kids in his house, and they are concerned for their pet. The kids have decided that the best way to keep Chase both happy and safe is to design the perfect doghouse to protect him from the elements. Your task is to begin testing roof designs and to answer the following question: What is the best material to use for the roof of Chase's doghouse to keep him dry in the rain?

We also introduced students to an example of EDP and shared the EDP graphic from the NGSS

(Figure 18.1), discussing each step of the process and explaining that engineers design, build, and test solutions to problems. We asked whether any students know an engineer and what engineers do. Discussing engineering generally helps explain the integral role engineers play in our designed world.

FIGURE 18.1

NGSS EDP for Young Learners



Explore

As with all hands-on activities with young children, this activity should be modeled before materials are distributed to students. It is important to always discuss safety with students before beginning any hands-on exploration. Be sure all milk cartons are cleaned out and prepared for student work. Start by showing the milk carton “doghouse” base and explaining it is a *model*. We introduce the idea that scientists use models all the time to learn more about what is being studied. For example, you may talk about past activities you have done with students, such as modeling friction by driving toy cars over different “roadways”

(e.g., rug vs. tile). Explain that engineers use models to test their designs. For this activity, instead of testing materials on a big doghouse in someone's backyard, we use the milk carton base. Ask students questions such as, "Why do you think it is a good idea to use a model?" Show the different roof materials to the class and discuss, "What might make a good roof material? What might we observe happen to a poor roof in the 'rain' (water spray)?" Record discussion comments on the board for visual learners.

Model for students how to lay the squares of material on top of the "house" one at a time and

use the rubber band to secure it, if needed, by stretching it around the mouth of the milk carton. Note that students may choose to design their roofs in different ways; these designs can be a basis for later discussion (e.g., some students may choose to crease the materials to make a peaked roof). Once the testing process has been modeled for students, show the predict, observe, explain (POE) chart (see NSTA Connection, p. 148). Explain that for each material they test, students will need to predict what will happen when they sprinkle water on it before they actually do so. It is a good idea to model

Materials

The following materials are required for each group of three students:

- Precut quart-sized milk carton
- Cups
- Water
- Spray bottle filled with water
- Eye droppers (1–3 per group)
- Thin, large rubber bands
- Aluminum baking trays

The following required materials should be cut to 10 in. square:

- Wax paper
- Poster paper
- Cardboard
- Aluminum foil
- Construction paper
- Cloth (e.g., old T-shirts)
- Shower curtain

Other required materials include the following:

- Sharp scissors (for adult use to cut cardboard and milk cartons)
- Children's safety scissors (to cut other materials, if desired)

Preparation

For each of the materials, cut a square for each group that is approximately 10 in. by 10 in. Students in grade 2 can measure and cut materials on their own, as an additional learning activity incorporating math. Care should be used if students are cutting materials themselves, and only adults should be cutting the thicker materials, such as cardboard or the milk cartons.

Save enough empty, quart-sized milk cartons for the class and cut each milk carton all the way around, about 3 inches from the bottom. This makes the bottom of a "house."

Create a setup for each group in the baking trays, where you place in each a cut off milk carton, eye dropper, cup (to be filled with water for the eye dropper), rubber band, and spray bottle.

what is expected and have the students reiterate the directions before they begin. We also found it useful to have students make predictions for each of their roof materials before we handed out any water. If working in groups is new to your students, be sure to model how to work collaboratively and to continue to discuss, write, or illustrate thoughts until they are told to stop.

Students should be divided into groups of three, if possible. We created our groups by considering the level of each child's cognitive stage of development. We addressed the needs of students who are at an introductory level as well as those who are ready for more in-depth, higher level thinking. This grouping allowed for varied levels of scaffolding to take place during the lesson. Tiering lessons and differentiation occurs on a daily basis, so children were unaware of the grouping methods while working together at their level of readiness. Higher performing groups were given roof materials that had similar properties, or were all generally good roofs (e.g., cardboard, shower curtain, foil). In this way, higher performing groups would have to distinguish observations and decide which material was best based on its properties. Groups of lower performing students were given roofing material with observable differences, such as construction paper, cloth, and a shower curtain. You may also choose to differentiate groups according to learning styles or any other way that you feel will benefit your students, while providing them with the same material to complete the lesson.

Once students had their materials (but not any water), they examined the possible roofs and listed each option under the first column on their group POE chart (Figure 18.2). Students then predicted what they thought would happen to each material in the rain and recorded their predictions in the second column. After much anticipation, students were given the sprayers and cups with water and droppers. Students should

be reminded not to spray one another. Also be mindful of slip hazards from wet floors. Remind students to use their eyes to see the roof and their fingers to touch the roof as part of observing. They can also look inside the house. Observations should be recorded in the third column of the POE chart. Students might also consider drawing their observations.

FIGURE 18.2

Sample POE Chart

	Prediction	Observation	Explanation
Roof Material 1: paper	get wet Dissolve it will stay flat	dripped through chase will get wet get wet	chase will get wet rain will slip through
Roof Material 2: plastic	has stayed Dry	water made a puddle stayed out and chase	The water rolled off
Roof Material 3: material cloth	it will go through	It went through chase will get wet	Chase will get wet The water drips through

Explain

After each observation is recorded, students should fill in the Explain column to decide whether a given material has properties that would make it a good roof and why. It is important for students to provide evidence for their assertions. After the experiment, teams of students brought their POE sheets to the rug and shared their findings, discussing which material they thought was the best for the doghouse roof and sharing their supporting evidence. The NGSS remind us that we must ask students to explain the solutions they have developed, "Asking students to demonstrate their own explanations ... [of] models they have developed, engages them in an essential part of the process by which conceptual change can occur" (NRC 2012, p. 68). We

TABLE 18.1

Sample Teacher Questions and Student Answers

Teacher Prompt	Sample Student Responses
Which material did the best job holding out the rain? Why?	Students discussed how the curtain was best because the water slid off of it, and the foil was good because the water didn't get in the house.
How did you know if the material would make an effective roof?	"Chase will get wet. Rain will sink through." "When the wax paper got wet my finger went through." "Paper ripped. It is not a good roof."
What happened when you used a piece of shower curtain?	"The water stayed on the roof and did not go in there." "The water rolled off."
How did the cloth perform in the experiment?	"Chase will get wet the water drips through."
How well did your predictions match up with your observations? Were you surprised by anything you found?	Students in one group discussed that they noticed the construction paper worked as long as it didn't rain hard. When it rained hard, it got soft and you could make a hole in it, which prompted us to discuss the importance of the roof being able to sustain several rainstorms.

helped students make connections between the structure and properties of the materials (e.g., the wax paper had a coating that caused water to bead up). We used questions similar to those in Table 18.1 to spark discussion. We included sample student responses taken from their POE sheets' Explain column.

Stress to students that they are using scientific observations (i.e., data) to support their ideas. Scientists and engineers must rely on data to make decisions—in this case, about which type of roof would be the best. Material properties of the roofs dictate their performance (e.g., smooth, non-porous materials, such as the shower curtain and foil, will allow water to roll off). Other materials that are porous, such as the cloth, will get wet and eventually may allow water to drip through. Direct the teams to share their findings. Because they each tested different materials, ask

them how they can make a decision about the best roof material. Explain that there is not necessarily one right answer, but that students should use evidence, which is their observational data, to support the solution they designed. This connects directly with the NGSS science and engineering practice of Constructing Explanations (for science) and Designing Solutions (for engineering).

Ask students why some materials worked better than others for this purpose. Students should be able to explain that different materials have different characteristics, or properties. Some of the materials, for example, have the property of absorbing or repelling water. We asked students, "What are some properties that are important for designing a roof? Answers included, "Being strong; Being firm; Preventing water from going through." Discuss the students' findings in light

of the concept of properties. Record the properties students share and explain properties are a way of describing a material or matter, in general. Students should come to understand that different material properties can make that material better suited for different functions, highlighting the NGSS crosscutting concept of Structure and Function.

Through questioning, help students to understand that the properties of different materials make them suitable for different purposes. Ask, “Why is cloth better than a shower curtain for a T-shirt?” (The fabric is much more “breathable” and comfortable.) If applicable, the discussion may also shift to the shapes in which students designed their roofs. Some student teams may have designed their roof to be more sloped, whereas others flattened. Use these differences as an opportunity to further discuss structure and function, asking students to share how effective the different shapes were at keeping the rain out of the house and at ensuring the roof is strong.

Elaborate

Have students describe the materials from which houses or buildings are made in your area. Ask students whether they have traveled to different places and whether the homes looked similar or different. Ask whether they think that houses are made from the same materials everywhere and why. Show students some photographs of different types of homes (e.g., a mud hut in Africa, Adobe house in the American Southwest, yurt in Mongolia). Ask students to share why they think the homes are made of different materials (i.e., ask them to consider the materials available in different areas and also different climates). Ask students the following questions: “What kinds of roofs do these houses have? Why are these features important for these roofs?”

To further explore material properties, see Internet Resource (p. 148) for a website to test metal, glass, rubber, paper, and fabric for transparency, flexibility, strength, and water resistance. The site reads the text out loud if the speaker icon is clicked, which is a great support for English language learners. It also features a quiz students may try. This application can be explored as a whole class or by individual or small groups of students, but the teacher should model it first.

Evaluate and Extensions

Opportunities for formative assessments are present throughout this activity. Begin in the whole-class portion of the lesson by drawing on students’ prior understandings of shelter and its function. While working on the activity, observe how student teams are testing the materials, and note student conversation and the observations and explanations cited on their worksheets to assess how they use engineering practices. During the class discussion, each team should share ideas and support them with evidence, allowing the teacher to assess how students are constructing their explanations and designing solutions.

As a homework assignment and extension of the activity, ask students to think about the materials they tested in class. Using those materials, students could design a coat for Chase to wear when he is in the yard, in case of rain. Students should find a design team partner at home—a parent, sibling, or other caregiver—to help with the assignment. Students should explain the roof testing that was done in school and how the different materials performed in the rain. Using this information, they should determine which material or materials would be the best to create a coat for Chase. Students should specifically include the material properties of the items used in their design and explain why they were chosen (see NSTA Connection, p. 148).

Connecting to the Next Generation Science Standards

The materials, lessons, and activities outlined in this chapter are just one step toward reaching the performance expectations listed below. Additional supporting materials, lessons, and activities will be required.

2-PS1-2 Matter and Its Interactions www.nextgenscience.org/2-ps1-2-matter-and-its-interactions K-2-ETS1-3 Engineering Design www.nextgenscience.org/k-2-ets1-3-engineering-design	Connections to Classroom Activity
Performance Expectations	
2-PS1-2: Analyze data obtained from testing different materials to determine which materials are best suited for an intended purpose	Tested various materials and used observations to decide which materials were best suited as a roof to withstand rainfall
K-2-ETS1-3: Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs	Compared different roof materials in terms of how they perform under model rainfall and analyzed the strengths and weaknesses of each
Science and Engineering Practices	
Analyzing and Interpreting Data	Collected qualitative data in a chart while testing different materials under spray bottle “rainfall” Discussed observations with group members Interpreted data to determine whether each roof material was effective Explored an online application that tests different materials and properties
Constructing Explanations and Designing Solutions	Explained why roofs are important and what features are needed to make a good roof Designed solutions to the problem of building the best roof for a doghouse to withstand rainfall
Disciplinary Core Ideas	
PS1.A: Structure and Properties of Matter • Different properties are suited to different purposes.	Tested materials’ suitability for use as roofing material Discussed properties of materials observed in the activity Observed various home designs and discussed properties of different materials used to build them Discussed which properties were better suited for a shower curtain or T-shirt

2-PS1-2 Matter and Its Interactions www.nextgenscience.org/2-ps1-2-matter-and-its-interactions K-2-ETS1-3 Engineering Design www.nextgenscience.org/k-2-ets1-3-engineering-design	Connections to Classroom Activity
Disciplinary Core Ideas	
ETS1.C: Optimizing the Design Solution <ul style="list-style-type: none"> Because there is always more than one possible solution to a problem, it is useful to compare and test designs 	Tested different materials and compared how they stood up to a model of rainfall Discussed the different roofs that were tested and identified the best-performing roofs and the properties they had in common
Crosscutting Concept	
Structure and Function	Examined how the properties of different materials affect how they function, while testing properties under rainfall Discussed why a rigid roof is important to hold up against rainfall (can be extended to snowfall) Compared materials and explained what made them suited or not suited for use as a roof material

Source: NGSS Lead States 2013.

Acknowledgment

An earlier version of this activity was developed, in part, for the Smithsonian Science Education Center's STC kindergarten curriculum.

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concepts, and core ideas. Washington, DC: National Academies Press.

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states*. Washington, DC: National Academies Press. www.nextgenscience.org/next-generation-science-standards.

Internet Resource

Characteristics of Materials
www.bbc.co.uk/schools/scienceclips/ages/7_8/characteristics_materials_fs.shtml

NSTA Connection

For a homework rubric and worksheet, as well as blank POE worksheet, visit www.nsta.org/SC1601.

Index

Page numbers in **boldface** type refer to figures or tables.

A

A Framework for K–12 Science Education, ix, 43, 61, 71, 179, 283
 definition of engineering in, 3
 goals of science and engineering in, 180
 science and engineering practices in, 11, **12**, 116
A Long Way Down: Designing Parachutes curriculum, **13**
 Adapting science lessons to include engineering, 99–105
 moving pigs, 99–101
 connecting to NGSS, 104
 point pollution in a watershed, 101–103
 connecting to NGSS, 105
 strategies for, 103
 Air and Weather curriculum, **13**
 American Association for the Advancement of Science, 99
 American Society for Engineering Education, ix
 Animals, engineering for
 elephant-trunk design challenge, 91–97
 investigation of doghouse roof material properties, 141–148
 prosthetic tail for Winter the dolphin, 92
 Argument from evidence, engaging in, x, **12**, 16, **62**, 87, 307
 for parachute design unit, 182–183
 Assessment(s). *See also* Rubrics; *specific design activities*
 from Engineering is Elementary curriculum, 126
 formative, for Wheels in Motion unit, **120**
 Plus/Delta/Question feedback technique, 171
 of preK children’s building explorations, 49
 of SCAMPERing Into Engineering lesson, 269–270
 of sound-reducing wall design, 194–195
 of students’ engagement in design, 7
 of system models of school building, 240–251
 of tightrope robotics challenge, 303–304
 of toy rocket testing unit, 258–259
 of water filter model-eliciting activity, 311–312

of wind turbine blade design challenge, 207–208

B

Bernasconi, Pablo, 31
 Big ideas, 44, 56, 169, 204
 Biometry, 292, **292**
 Blokify app for 3-D printing, 136
 Boat design challenge, 23–25
 connecting to CCSS, 25–26
 connecting to NGSS, 27–28
 elaborate phase of, 25
 engage phase of, 23
 evaluate phase of, 25
 explain phase of, 24–25
 explore phase of, 23–24
 materials for, 23
 purpose of, 23
 STEM’s own amazing race, 24
 Boat sail design
 creating e-books on, 107–113
 connecting to NGSS, 113
 engineering design process for, **107**, 107–111
 rubric for, **112**
 environmental engineering summer camp unit on, 125
 Bodzin, A., 123
The Boy Who Harnessed the Wind: Young Readers Edition, 74
 Brainstorming ideas, 5
 about fortifying structures to withstand severe weather, 274, 276–277
 about green engineering, 213
 about how engineers help animals, 91
 about how rockets work, 284
 about recycling and composting, 222, 223
 for crab house design, 55, 57
 in engineering design process, 4, 14, 15–16.54
 for hovercraft design, 37
 for parachute design, 182
 SCAMPER tool for, 266, **267**, 271
 for shovel design, 21
 for solar oven design, 215, 216
 for sound-reducing wall design, **191**, 193, 195
 for 3-D printing project
 to create a prosthetic hand, 230
 to design playground equipment, 134, 136
 for tools to map a waterway, 151

for water collection device design, 293, 294
 for water filter design, 161, 164, 311
 for watering a school-yard garden, 170, 171, 172
 Breen, Steve, 31
 Building explorations for preschoolers, 43–51
 collecting assessment data for, 49
 connecting to NGSS, 51
 core building concepts and structures concepts for, **45**
 Engage-Explore-Reflect cycle for, **47**, **47**, **48**, 49
 integrating language, literacy, and mathematics in, 47–49
 making time for teachers’ own science and engineering investigations, 45
 organizing and facilitating of, 47
 preparing environment for, 44–45
 reflections, documentation, and using data from, 49–50
 sequence-build explorations intentionally, 46–47

C

Captain Arsenio: Inventions and (Mis) adventures, 31
 Car design and air resistance lesson, 264–271. *See also* SCAMPERing Into Engineering lesson
 Careers in STEM fields, x, 138, 179, 234, 246, 249
 City Technology curriculum, **13**
 Classroom needs, x–xi
 Cobb, Vicki, 49
 Collaboration of teachers, 49–50, 96, 151, 221
 with businesses, universities, or museums, 62, 66, 115–120, 134, 138, 246–247, 249
 to create model I-STEM education program, 273, 279
 with local schools, 169, 170
 Collaboration skills, ix, 45, 61, 79, 91, 94, 95, 108, 110, 144, 149, 173, 175, 184, 201, 216, 217, 224, 225, 230, 266, 304, 308, 313. *See also* Teamwork skills
Common Core State Standards (CCSS)
 connections, 307, 308, 313
English Language Arts (ELA), 21–26, 33, 35, 37–38, 47, 64, 91, 95, 117, 159–160, 173, 237, 239, 240, 241, 242, 245, 274, 311, 313

Index

- Mathematics*, 38, 91, 95, 116, 117, 135, 163, 164, 173, 237, 240, 274
Social Studies, 95
- Communication skills, ix, x, **12**, 15, 47, **62**, 91, 95, 183–184, 224, 249–250, 251, 255, 274, 279, 307
- Community-based engineering (CBE) unit, 169–176
 connecting to CCSS, 173
 connecting to NGSS, 170, 176
 definition of, 169
 learning goals for, 170
 module overview for, 169–170
 session structure for, 170
 water transport system for school-yard garden, 170–174
 evidence of multifaceted learning from, 174–175
 session 1: teacher preparation and warm-up challenge, 170–171
 session 2: unpacking community problem with students, 171–173
 session 3: executing plans, 174
 session 4: discussing and revising models, 174
- Competitive STEM activities, 71
- Compost bin activity, 3–9
 connecting to NGSS, 5, 8–9
 steps in development of, 4–7
- Composting/crushing milk cartons activity, 221–227
 connecting to NGSS, 226–227
 connections for, 224–225
 creating, testing, and improving prototypes for, 224
 defining the problem for, 221–223, **223**
 engineering design process for, **221**, **222**
 final product created for, 224, **224**
 generating alternatives and developing and analyzing solutions for, 223
 implementing your own challenge, **225**
- Computational thinking, **12**, **62**, 72, 76, 87, 184, 186, 271, 307. *See also* Mathematics
- Crab tower design, 54–59
 connecting to NGSS, 59–60
 engagement phase of, 54–55, 58
 engineering design process (exploration) phase of, **55**, 55–56, **56**, 58
 evaluation phase of, **57**, 57–58, **58**
 explanation phase of, 56, 58
 extension phase of, 56–57, 58
- Creativity, ix, 16, 22, 54, 61, 91, 94–95, 111, 116, 134, 151, 171, 184, 195, 208, 211, 216, **217**, 221, 224, 255, 258, 259, 279, 280
- Crismond, D., 160
- Critical thinking, ix, 61, 79, 81, 83, 91, 116, 138, 184, 224, 242
- Crosscutting concepts, x, 44, 199. *See also* specific tasks
- Cultivating Young Scientists (CYS) program, 44–49
- D**
- Data, analyzing and interpreting, x, **12**, 16–17, **62**, 87, 307
 for parachute design unit, 182
- Data sheets, xi
 for magnificent things solve problems task, 21, 22
 for parachute design, **181**, **184**
 for STEM’s own amazing race, 23, 24, 25
 for straw rocket design, 285, 286
 for water filter design, 64, **64**
 for wind turbine blade design, 202
- Design brief, 3, 4, 6–7, 9, 14
 for sound-reducing wall activity, **191**, 191–192, 194–196
 for Wacky Weather unit, 274
 for wind turbine blade design, 205, **205**
- Design notebook, 4, 7. *See also* Engineering notebook; Science notebook
 for designing a sound-reducing wall, 192, 193–195
 for designing a water collection device, 295, **295**
 for wacky weather unit, 274, 277, 279
- Design teams, 4, 7, 54, 146, 205, 230. *See also* Teamwork skills
- Disciplinary core ideas, x, 5, 14, 15, 44, 129. *See also* specific tasks
- Diving into Science curriculum, **13**
- Doghouse roof material properties investigation, 141–148
 connecting to NGSS, 147–148
 elaborate phase of, 146
 engage phase of, 142
 evaluate and extension phases of, 146
 explain phase of, 144–146, **145**
 explore phase of, 142–144
 lesson objectives for, 141–142
 materials for, 143
 POE chart for, 143, 144, **144**, 145
- Dolphin Tale*, 92
- Dr. Zoon Presents Straw Rockets* video, 285
- Dweck, Carol, 299
- E**
- E-books created from STEM journals, 107–113
 connecting to NGSS, 113
 engineering design process for, 107, **107**
 ask, 107–108
 create, 109–111, **110**, **111**
 imagine, 108
 improve, 111
 plan, 108–109, **109**
 rubric for, **112**
- Edison, Thomas, 299
- Education Development Center curriculum, **13**, 15
- Elephant-trunk design challenge, 91–97
 assessment of, 95
 connecting to NGSS, 96–97
 definition and lessons for, 92–94
 engineering design process for, 91, **91**
 how engineers help animals, 91–92
 science and engineering skills for, 94–96
 steps for teaching, 96
- Energy
 potential and kinetic, 264, 265
 savings in school building, 246–247
 solar oven design, 211–218
 sound-reducing wall design, 189–196
 wind turbine blade design challenge, 199–210
- Engage-Explore-Reflect (EER) cycle, 47, **47**, **48**, **49**
- Engineering
 activities and curricula for, 11, **13**, 71
 definition of, 3
 green, 211–218
 value beyond science, 184
- Engineering design process (EDP), ix, 3–4
 adapting science lessons to include, 99–105
 for composting/crushing milk cartons activity, 221, **222**
 vs. construction activities, 13–14
 definition of, 4, 99
 for elephant-trunk design challenge, 91, **91**
 in Engineering is Elementary curriculum, 107, **107**, 149, **150**, 205, **206**
 habits of beginning designers, 14–17
 importance of failure points in, ix, 12, 28, 40, 56, 89, 92, 95, 96, 185, 195, 209, 216, 217, 225, 256, 259, 260, 271, 283, 289, 304, 305
 integrating into curriculum, 87–88, 129
 moving water activity, 89–90
 vs. inventing, 15
 missteps/misconceptions in, 11–17, 87, 160

- in NGSS, 31–32, 91, 141, **142**
- vs. scientific inquiry, 4
- teaching through trade books
 - engineering dilemmas, 19–28
 - flying machines, 31–40
- for tightrope robotics challenge, 300
- for Wheels in Motion activities, 116
- for wind turbine blade design challenge, 205–207, **206**
- Engineering design process 5E, **53**, 53–60, **57**, 57–58, **58**
 - connecting to NGSS, 59–60
 - engagement phase of, 54–55, **58**
 - engineering design process (exploration) phase of, **55**, 55–56, **56**, **58**
 - in Engineering is Elementary curriculum, 54
 - evaluation phase of, **57**, 57–58, **58**
 - explanation phase of, **56**, **58**
 - extension phase of, 56–57, **58**
 - inclusion of relevant science concepts, **58**
- Engineering design task development, 3–9
 - connecting to NGSS, 5, 8–9
 - steps for, 4–7
 - 1: identify a standard, 5
 - 2: brainstorm ideas for activities, 5
 - 3: contextualize a problem statement, 5–6
 - 4: identify necessary materials, resources, and tools, 6
 - 5: develop design brief, 6–7
 - 6: implement task, 7
 - 7: assess students' engagement in design, 7
- Engineering education, ix, 3, 11, 71
- NGSS support for, 61, 179, 255
- Engineering is Elementary (EiE) curriculum, **13**, 53–54, 129, 231
 - assessments from, 126
 - for creation of e-books, 107–109
 - for designing tools to map a waterway, 149
 - engineering design process in, 107, **107**, 149, **150**, 205, **206**
 - environmental engineering summer camp lessons adapted from, 123, 125, 126
 - solar oven unit of, 211–217
 - unit structure of, 212, **212**
- Engineering notebook. *See also* Design notebook; Science notebook
 - for environmental engineering summer camp, 126
 - for water collection device design, 295, **295**
- Engineering the ABC's: How Engineers Shape Our World*, 74
- Engineers
 - definition of, 124
 - eliciting children's ideas about, 123–124
- Engineers Without Borders, 291
- English Language Arts (ELA)*, connections to CCSS for, 21–26, 33, 35, 37–38, 47, 64, 91, 95, 117, 159–160, 173, 237, 239, 240, 241, 242, 245, 274, 311, 313. *See also* Reading standards; Speaking and listening standards; Writing standards
- Environmental engineering summer camp activities, 123–127
 - adapted from Engineering is Elementary curriculum, 123, 125, 126
 - connecting to NGSS, 127
 - engage phase of, 123–124
 - evaluate phase of, 126
 - explain phase of, 125–126
 - explore phase of, 124–125
 - extend phase of, 126
- Explanations, constructing, **12**, 17, **62**, 307
 - for parachute design unit, 183, **183**
- Exploring Trees and Ponds curriculum, **13**, 15
- F**
- Failure points, importance of, ix, 12, 28, 40, 56, 89, 92, 95, 96, 185, 195, 209, 216, 217, 225, 256, 259, 260, 271, 283, 289, 304, 305
- Fantastic Elastic and Ener Jeep curriculum, **13**
- 5E learning cycle, xi, 53
 - engineering design process 5E, **53**, 53–60
 - for environmental engineering summer camp activities, 123–127
 - for investigation of doghouse roof material properties, 142–146
 - for paper airplane investigation, 237
 - for SCAMPERing Into Engineering lesson, 264–269
 - for teaching through trade books design dilemmas, 21–25
 - flying machines, 33–37
 - for 3-D printer design of playground equipment, 134–138
 - for water filter unit, 61–68
- Fixed mindset, 299, 302, 304
- Fleming, Candace, 19
- Flight/flying machines
 - paper airplane investigation, 237–243
 - connecting to NGSS, 243–244
 - parachute design unit, 179–184
 - connecting to NGSS, 185–187
 - straw rocket investigation, 283–288
 - connecting to NGSS, 288–290
 - toy rocket testing, 255–259
 - connecting to NGSS, 259–260
 - trade books for teaching about, 31–40
 - connecting to NGSS, 39–40
- Floating and Sinking curriculum: Teacher's Guide, **13**
- Force and motion activities
 - boat design challenge, 23–25
 - connecting to NGSS, 27–28
 - gingerbread man trap design, 72
 - connecting to NGSS, 76–77
 - heavy lifting lesson, 131
 - moving pigs lesson, 99–101
 - connecting to NGSS, 104
 - paper airplane investigation, 237–243
 - connecting to NGSS, 243–244
 - SCAMPERing Into Engineering lesson, 263–270
 - connecting to NGSS, 271
 - straw rocket lesson, 283–288
 - connecting to NGSS, 288–290
 - toy rocket testing, 259
 - connecting to NGSS, 259–260
 - trade books for teaching about flying machines, 31–37
 - connecting to NGSS, 39–40
 - Wheels in Motion unit, 115–120
 - connecting to NGSS, 121–122
 - wind turbine lesson, 199–208
 - connecting to NGSS, 209–210
- Full Option Science System curriculum, **13**
- G**
- Gehringer, M., 123
- Gibbons, Gail, 49
- The Gingerbread Man*, 72
- Gingerbread man trap design, 71–77
 - completion of, 75
 - connecting to NGSS, 72, 76–77
 - designing solutions for, 72–73
 - engineering and math components of, 74–75
 - science component of, 72
 - technology and engineering components of, **73**, 73–74, **74**
 - trap design instructions for, **73**
- Green engineering
 - definition of, 211
 - introduction to, 213
 - solar oven design, 211–218
- Growth mindset, 299, 302, 304
- H**
- Habits of beginning designers, 14–17
- Habits of mind, 43, 91, 94
- Heavy lifting task, 131
- Hopkins, Lee Bennett, 74

Index

- Hovercraft design task, 35–37
How a House Is Built, 49
 How Could a Carrier Make the Job Easier? curriculum, 13
- I**
I Fall Down, 49
 Implementation of design task, 7
Incredible Inventions, 74
 Information, obtaining, evaluating, and communicating, 12, 15, 62, 307
 for parachute design unit, 183–184
 Innovation process, ix, 91, 136, 229, 233, 299, 300, 304. *See also* Inventing/inventions
 Inquiry, scientific, ix, x, 11, 71
 compared with engineering design, 4
 directed, 4
 guided, 4, 79
 open-ended, 4
 STEM of, 129–130
 designing a tool for heavy lifting, 131
 structured, 79
 Interdisciplinary projects
 composting/crushing milk cartons, 221–227
 3-D printing design of playground equipment, 133–140
 3-D printing of prosthetic hand, 229–236
 Inventing/inventions. *See also* Innovation process
 vs. engineering design process, 15
 inventing mystery machines, 115–122
 technology and, 74
 Investigations, planning and carrying out, 12, 62, 307
 for parachute design unit, 181, 181–182, 182
 iPads, 179
 creating E-books on, 107–113
 design apps that will print to a 3-D printer, 136
 developing video presentations on, 245, 246
 professional development for classroom use of, 107–108
 weather research on, 275
- K**
 Kamkwamba, William, 74
 Keeley, Page, 135, 136
 KWL charts, 119, 160, 163, 164, 225
- L**
 Lab activities integrating engineering practices, 79–85
 engineering sound, 81–82, 82
 connecting to NGSS, 85
 observations of, 82–83
 solids, liquids, and gases, 80–81, 81
 connecting to NGSS, 83–84
 3-D printing of prosthetic hand, 229–234
 connecting to NGSS, 234, 235–236
 Lego products, 138
 alternatives to, 303
 for tightrope robotics challenge, 300, 300, 301, 303
Lerato Cooks Up a Plan: A Green Engineering Story, 212
Lief Catches the Wind, 125
 Literacy, connections to *CCCS for English Language Arts*, 21–26, 33, 35, 37–38, 47, 64, 91, 95, 117, 159–160, 173, 237, 239, 240, 241, 242, 245, 274, 311, 313.
See also Reading standards; Speaking and listening standards; Writing standards
- M**
 Magnificent thing design task, 21–23
 connecting to CCSS, 25–26
 connecting to NGSS, 26–27
 elaborate phase of, 22
 engage phase of, 21
 evaluate phase of, 22
 explain phase of, 22
 explore phase of, 21–22
 materials for, 21
 purpose of, 21
 Makerspaces, 229. *See also* Three-dimensional printing
 Mapping a waterway, designing tools for, 149–155
 connecting to NGSS, 155
 elaborate and evaluate phases of, 153–154, 154
 engage phase of, 150–151
 engineering design process for, 149, 150
 explore phase of, 151–152, 152
 investigate and explain phases of, 152–153
 purpose of, 154
 reflections on, 154
 setting the stage for, 150
 use of writing prompts or science notebooks, 154
 Marzano Art and Science of Teaching Framework, 307
 Marzollo, Jean, 92
 Mathematics, using, 12, 49, 62, 87, 129, 307
 connecting to CCSS for *Mathematics*, 38, 91, 95, 116, 117, 135, 163, 164, 173, 237, 240, 274
 for gingerbread man trap design, 74–75
 for paper airplane investigation, 237, 240
 for parachute design unit, 184, 184
 for testing toy rockets, 255
 for 3-D printing task, 135
 for Wacky Weather unit, 274
 for watering a school-yard garden, 173, 175
 for Wheels in Motion activities, 116–117
 Mealer, Bryan, 74
 Mendelovici, R., 79
 Meteorology. *See* Wacky Weather integrative STEM unit
Mindset, 299
 Model-eliciting activities (MEAs)
 connecting to CCSS, 307
 connecting to NGSS, 307–308
 definition of, 307
 for water filter design, 307–314
 Models, developing and using, 12, 62, 87, 307
 for parachute design unit, 180–181
 for 3-D printer design of playground equipment, 133–140
The Most Magnificent Thing, 19, 21–22
 Motion. *See* Force and motion activities
 Moving pigs adapted lesson, 99–101
 defining problem for, 100–101
 developing and optimizing solutions for, 101
 Moving water activity, 89–90
 materials for, 90
 objective of, 89
Muncha! Muncha! Muncha!, 171
- N**
 National Aeronautics and Space Administration (NASA), 33, 40, 256, 285
 National Research Council (NRC), 179
Next Generation Science Standards (NGSS), ix–xi, 71, 79, 99, 123, 133, 179, 211, 229, 255, 291, 307
 engineering design process in, 31–32, 91, 141, 142
 inclusion of engineering in, ix, 11, 53, 79
 lesson connections to, x
 for 5E learning cycle water filter unit, 67–68
 for compost bin activity, 5, 8–9
 for composting/crushing milk cartons activity, 226–227
 for creation of e-books, 113
 for designing a tool to map a waterway, 155
 for elephant-trunk design challenge, 96–97

- for engineering adaptations, 104–105
- for engineering design process 5E, 59–60
- for environmental engineering summer camp activities, 127
- for gingerbread man trap design, 72, 76–77
- for investigation of doghouse roof materials properties, 147–148
- for lab activities integrating engineering practices, 83–85
- for paper airplane investigation, 237, 238, 243–244
- for parachute design unit, 185–187
- for preK building explorations, 51
- for SCAMPERing Into Engineering lesson, 271
- for solar oven design unit, 216, 218
- for sound-reducing wall design activity, 195–196
- for straw rocket lesson, 283, 288–290
- for systems and system models investigation of school building, 252–253
- for teaching about design dilemmas through trade books, 20, 26–28
- for teaching about flying machines through trade books, 31–32, 39–40
- for 3-D printing for design and creation of prosthetic hand, 234, 235–236
- for 3-D printing of design for playground equipment, 139–140
- for tightrope robotics challenge, 301, 304–305
- for toy rocket testing unit, 255, 259–260
- for Wacky Weather integrative STEM unit, 274, 280–281
- for water collection device design, 296
- for water filter model-eliciting activity, 307–308, 314
- for water filtration device design, 166–167
- for Wheels in Motion unit, 121–122
- for wind turbine blade design challenge, 209–210
- performance expectations for, x, 5, 8, 11, **12**, 16, 44
- science and engineering practices, x, 11, **12**, 14–17, 44, 61–62, **62**, 116, 179–184
- Novak, Patty O'Brien, 74
- Nuffield Primary Solutions in Design and Technology curriculum, **13**, 15
- O**
- One Well, the Story of Water on Earth*, 292
- P**
- Papa's Mechanical Fish*, 19, 23–25
- Paper airplane investigation, 237–243
 - conclusions about, 242–243
 - connecting to CCSS, 237, 239, 240, 241, 242
 - connecting to NGSS, 237, 238, 243–244
 - elaborate phase of, 241–242
 - engage phase of, 238
 - evaluate phase of, 242
 - explain phase of, 239–241, **241**
 - explore phase of, **238**, 238–239, **239**
 - fair test issues and safety guidelines for, 238–239, **239**
 - science and engineering practices for, 237, 240
 - using 5E model for, 237
- Parachute design unit, 179–187
 - connecting to NGSS, 185–187
 - science and engineering practices for, 179–184
 - analyzing and interpreting data, 182
 - asking questions and developing problems, 180
 - constructing explanations and designing solutions, 183, **183**
 - developing and using models, 180–181
 - engaging in argument from evidence, 182–183
 - obtaining, evaluating, and communicating information, 183–184
 - planning and carrying out investigations, **181**, 181–182, **182**
 - using mathematics and computational thinking, 184, **184**
 - value of engineering beyond science, 184
- Performance expectations, x, 5, 8, 11, 44
 - for grades 3–5 and K–2, **12**, 16
- Picture STEM curriculum, 291
- Pierre the Penguin*, 92
- Plant packaging investigation, 58
- Playground equipment design. *See* Three-dimensional printing design of playground equipment
- Plus/Delta/Question (+/Δ/?) feedback technique, 171
- Pre-assessment strategies, x, xi
- Predict, observe, explain (POE) chart, 143, 144, **144**, 145
- PreK engineering education, x, 129
 - building explorations, 43–50
 - engineering design process 5E, 53–60
- Problem-solving skills, ix, x, 4, 20, 54, 79, 83, 130.138, 169, 174, 175, 184, 211, 221, 255, 279, 295, 299, 304, 308, 313
- Problem statement, 5–6, 14, 300
 - for tightrope challenge, 301
 - for water collection device task, 293, **293**
 - for wind turbine task, **205**
- Problems, defining, **12**, 14, 87, 129, 307
 - for composting/crushing milk cartons activity, 221–223, **223**
 - for parachute design unit, 180
- Product comparisons, 16
- Product design, x, 15
- Project-Based Inquiry Science curriculum, **13**
- Properties of materials
 - for doghouse roof, 141–148
 - for solar oven, 213–214
 - for water filter unit, 61–68, **63**, **64**
- Prosthetic hand. *See* Three-dimensional printing design and creation of prosthetic hand
- Prosthetic tail for Winter the dolphin, 92
- Prototype(s), 4, 6–7
 - for 3-D printing of prosthetic hand, **232**, 232–234, **233**
 - of solar oven, 214
 - testing of, 4, 16–17, 171
 - cars and air resistance, 266–268
 - crab house, 57, **57**
 - doghouse roof materials, 143, 146
 - straw rockets, 286
 - toy rockets, 265–260
 - water filtration device, 163–164, **164**
 - windmills, 125
- Q**
- QR tags, 250, 251, 252
- Questions, asking, **12**, 14, **62**, 307
 - for parachute design unit, 180
- R**
- Ramps and Pathways* module, 118
- Reading standards, connections to, 21, 23, 25, 26, 33, 38, 47
- Reflection prompts, 7, 47, **48**
- Research in engineering design process, 15. *See also specific tasks*
 - for 3-D printing of prosthetic hand, 230–231, **231**

Index

- for Wacky Weather unit, 274–275, **275**
- Revealing the Work of Young Engineers in Early Childhood Education*, 99
- Riparia's River*, 159
- Robotics. *See* Tightrope robotics challenge
- Rockets
 - history of, 284
 - how they work, 284–285
 - straw rocket investigation, 283–290
 - toy rocket testing, 255–260
- Rubrics, xi
 - for compost bin activity, 10
 - for composting/crushing milk cartons activity, 225, 228
 - for crab tower design, 58
 - for doghouse roof material properties investigation, 148
 - for e-books, 111, **112**, 114
 - for elephant-trunk design, 95, 97
 - for gingerbread man trap design, 74, 75
 - for modeling water filtration, 311–312, 315
 - for solids, liquids, and gases lab, 81
 - for sound engineering lab, 82, 86
 - for sound-reducing wall design, 194–195, 197
 - for straw rocket investigation, 288
 - for systems and system models investigation of school building, 250, 253
 - for 3-D printing creation of prosthetic hand, 232
 - for tightrope challenge, 303, 306
 - for toy rocket testing, 258, 261
 - for Wacky Weather investigation, 275, **276**, 279, 282
 - for water filtration device design, 167
 - for water transport system for school-yard garden, 175, 177
 - for wind turbine blade design, 208, 210
- S**
- SCAMPERing Into Engineering lesson, 263–270, 269–270
 - assessing student thinking for, 269–270
 - background of, 263–264
 - connecting to NGSS, 271
 - elaborate phase of, 266–268
 - engage and explore phases of, 264–266
 - what to know, engineer, and do for the unit, **265**
 - evaluate phase of, 268–269
 - explain phase of, 266
 - use of SCAMPER brainstorming tool for, 266, **267**, 271
- Science, technology, engineering, and mathematics (STEM) careers, x, 138, 179, 234, 246, 249
- Science, technology, engineering, and mathematics (STEM) education, ix–xi, 71, 123
 - activities for, 71
 - characteristics of quality programs for, ix
 - classroom integration of, 71
 - developing engineering design tasks for, 3–9
- Science, technology, engineering, arts, and mathematics (STEAM) lab, 229–236. *See also* Three-dimensional printing design and creation of prosthetic hand
- Science and engineering practices, x, 11, **12**, 14–17, 44, 61–62, **62**, 116, 179–184. *See also specific tasks*
 - children's everyday use of, 87
 - integrating into lab activities, 79–85
 - model-eliciting activities and, 307–308
 - for paper airplane investigation, 237, 240
 - for parachute design unit, 180–184
 - analyzing and interpreting data, 182
 - asking questions and defining problems, 180
 - constructing explanations and designing solutions, 183, **183**
 - developing and using models, 180–181
 - engaging in argument from evidence, 182–183
 - obtaining, evaluating, and communicating information, 183–184
 - planning and carrying out investigations, **181**, 181–182, **182**
 - using mathematics and computational thinking, 184, **184**
 - for 3-D printer design of playground equipment, 133–140
- Science Friday Education blog, 101
- Science NetLinks website, 99
- Science notebook. *See also* Design notebook; Engineering notebook
 - digital, xi, 108
 - for environmental engineering summer camp, 126
 - for mapping a waterway lesson, 154
 - for solids, liquids, and gases lab, 80, **81**
- for sound lesson, 82, **82**
- for water filter unit, 62–65
- Science standards, 5. *See also* Next Generation Science Standards
- SketchUp software, 133, 136, 137
- “Snapshots of Science” program, 263
- Solar oven design, 211–218
 - conclusions about, 217
 - connecting to NGSS, 216, 218
 - defining and delimiting engineering problems for, 212–213
 - introducing green engineering, 213
 - story for, 212–213
- engineering design process for, 214–216, **215**
- impact scoring sheet, 215, **216**
- recording oven temperature in sun and shade, 215–216, **216**
- Engineering is Elementary unit for, 211–212, **212**
- testing properties of materials for, 213–214
 - environmental impact analysis, 214, **215**
 - safety precautions, 214
 - what was learned, 216
 - creative thinking, 216, **217**
 - productive moments of failure, 217
- Solids, liquids, and gases lab activity, 80–81, **81**
 - connecting to NGSS, 83–84
- Solutions, designing, x, **12**, 15–16, 17, **62**, 87, 307
 - for parachute design unit, 183, **183**
- Sound engineering lab, 81–82, **82**
 - connecting to NGSS, 85
- Sound-reducing wall design, 189–196
 - assessment of, 194–195
 - connecting to NGSS, 195–196
 - engineering design challenge for, 191–194
 - design brief, **191**, 191–192
 - design sketches, **192**, 193
 - stages and timing, **191**
 - testing and reflections, **193**, 193–194
 - overview of two-room testing model for, **190**, 190–191
 - science of sound, 190
- Speaking and listening standards, connections to, 22, 24, 26, 33, 37, 38, 47, 173, 245, 304, 311, 313
- Spires, Ashley, 19
- Standards for Technology Literacy*, 229
- Straw rocket lesson, 283–290
 - building directions for, **287**
 - connecting to NGSS, 283, 288–290
 - design challenge for, 285

- evaluation of, 288
 - history of rockets, 284
 - how rockets work, 284–285
 - manipulating variables in, 286
 - misconceptions related to, 287
 - rocket testing for, 286
 - Student-centered education, ix, 4
 - Student mindsets, 299, 302, 304
 - Student missteps/misconceptions, xi
 - in engineering design process, 11–17, 87, 160
 - of preschoolers, 43
 - in straw rocket investigation, 287
 - Student notebooks. *See* Design notebook; Engineering notebook; Science notebook
 - Stuff That Works! Packaging curriculum, 13, 15
 - Systems and system models
 - investigation of school building, 245–253
 - calling on community resources for, 249
 - connecting to NGSS, 252–253
 - evaluation of, 250–251
 - figuring out systems for, 246
 - learning from experts, 246–247
 - learning results and future considerations for, 251–252
 - learning to use tools and create video presentations for, 245–246
 - organizing a system of systems for, 247–249, 248
 - reflections on, 251
 - sharing information about, 249–250
- T**
- Teamwork skills, ix, 95, 200, 234, 245, 249, 251, 252, 255, 299, 304. *See also* Collaboration skills
 - Technology, xi, 129. *See also* iPads; Videos
 - creating e-books, 107–113
 - creating videos of school as system of systems, 245, 247, 249, 250–252
 - definition of, 124
 - eliciting children's ideas about, 123–124
 - in gingerbread man trap task, 73, 73–74, 74
 - Standards for Technology Literacy*, 229
 - 3-D printer creation of prosthetic hand, 229–236
 - 3-D printer design of playground equipment, 133–140
 - Thermal insulators, 212, 214, 214
 - Think-Pair-Share strategy, 135, 136, 140
 - Thinking Inside the Box: Designing Plant Packages*, 58
 - Three-dimensional (3-D) printing, xi, 229
 - safety precautions for, 233, 234
 - Three-dimensional (3-D) printing design
 - and creation of prosthetic hand, 229–236
 - conclusions about, 234
 - connecting to NGSS, 234, 235–236
 - identified need and overview of, 229–230
 - safety precautions for, 233, 234
 - STEAM town hall, 234, 234
 - week 1: building empathy and defining a purpose, 230
 - week 2: conducting guided research, 230–231, 231
 - week 3: creating a blueprint on Tinkercad, 231, 231
 - week 4: building the prototype, 232, 232
 - week 5: engaging in public relations, 232–233
 - week 6: finalizing the design, 233, 233–234
 - Three-dimensional (3-D) printing design
 - of playground equipment, 133–140
 - annotated student drawing of, 134, 135
 - connecting to NGSS, 139–140
 - elaborate phase of, 136–137
 - engage phase of, 134–135
 - evaluate phase of, 137–138
 - explain phase of, 136
 - explore phase of, 135
 - how printer works, 134
 - interactive resources for, 136
 - printer access and funding for, 133–134
 - providing opportunities for, 138
 - reflections on, 138
 - Tightrope robotics challenge, 299–305
 - assessment of, 303–304
 - background for, 300
 - building process for, 302
 - completion of, 302–303
 - conclusions about, 304
 - connecting to NGSS, 301, 304–305
 - engineering process for, 300
 - planning for, 301, 301–302
 - setting up, 300, 300–301
 - use of Legos for, 300, 300, 301, 304
 - alternatives to, 303
 - Tools to solve a problem, development or improvement of, 15, 20, 129
 - community-based engineering task, 169
 - water transport system, 173
 - elephant-trunk design, 92–93
 - gingerbread man trap design, 74
 - heavy lifting, 131
 - magnificent thing design task, 21–23
 - mapping a waterway, 149–154, 152, 154
 - solids, liquids, and gases lab, 80
 - 3-D printing of prosthetic hand, 229–236
 - Toy rocket testing unit, 255–260
 - assessment of, 258–259
 - challenge for, 256–257
 - connecting to NGSS, 255, 259–260
 - development of, 256
 - suggested improvements for, 258
 - test and share stage of, 257–258
 - Trade books to teach about design dilemmas, 19–28
 - connecting to CCSS, 25–26
 - connecting to NGSS, 20, 26–28
 - curricular connections for, 20
 - magnificent things solve problems, 21–22
 - STEM's own amazing race, 23–25
 - suggested books for, 21
 - Trade books to teach about flying machines, 31–40
 - connecting to CCSS, 37–38
 - connecting to NGSS, 39–40
 - curricular connections for, 31–32
 - designing a hovercraft, 35–37
 - suggested books for, 31
 - testing flying machines, 33–34
 - 21st-century skills, ix, 184, 211
- V**
- Vehicles in Motion curriculum, 13
 - Video conferencing, 134
 - Videos, 107
 - of 3-D printing design, 134
 - about composting and recycling, 221, 222, 226, 227
 - of boat sail trials, 108, 109, 110, 112, 113
 - of cardboard boat races, 25
 - Design Squad, 174
 - Dr. Zoon Presents Straw Rockets*, 285
 - of hovercraft design, 36–37, 39, 40
 - NASA for Kids: Intro to Engineering, 33, 34
 - of prototype tests, 17
 - of school building as system of systems, 245, 247, 249, 250–252
 - for severe weather unit, 274, 277, 279, 281
 - of sound-reducing wall design, 194
 - Teachers' Domain Water Treatment Plant*, 66
 - of water collection device design, 295
 - Violet the Pilot*, 31, 33–34
 - Vocabulary development, 24, 25, 26, 47, 49, 65, 66, 94, 150, 151, 274
- W**
- Wacky Weather integrative STEM unit, 273–281

Index

- background of, 274
- check phase of, 279
- connecting to CCSS, 274
- connecting to NGSS, 274, 280–281
- create phase of, 277
- design brief for, 274
- design challenge for, 275–277
- design of, 273–274
- materials for, 276–277
- modeling what you teach, 279–280
- plan phase of, 274–275
- rubric for, 275, 276, 279
- severe weather alert chart for, 277, 278
- student research for, 274–275, 275
- Water collection device design, 291–296
 - background for: biometry, 292, 292
 - brainstorming for, 293, 294
 - conclusions about, 295
 - connecting to NGSS, 296
 - creating and testing phase of, 294
 - nature as inspiration for, 291–292
 - problem statement for, 293, 293
 - sharing and redesign phases of, 294–295, 295
 - testing criteria for, 293–294
 - understand, plan, and create phases of, 292–293
- Water filter design (grade 2), 61–68, 63, 64
 - collaborating with water company informal educator for, 61, 62, 65, 66
 - connecting to NGSS, 67–68
 - elaborate phase of, 65
 - engage phase of, 62–63, 63
 - engineering framework for, 61–62, 62
 - evaluate phase of, 65–66
 - explain phase of, 64–65
 - explore phase of, 63–64, 64
- Water filter design (grade 4), 159–167
 - background for, 159–160
 - build-it step of, 163
 - connecting to CCSS, 159–160
 - connecting to NGSS, 166–167
 - design-it step of, 162–163
 - getting started with, 160–161
 - refine-it step of, 164–165
 - reflections on, 165
 - test-it step of, 163–164, 164
 - think-it step of, 161–162
- Water filter design model-eliciting activity, 307–314
 - assessment of, 311–312
 - building, testing, and revising phases of, 311
 - connecting to CCSS, 307, 311, 313
 - connecting to NGSS, 307–308, 314
 - learning goal for, 308
 - reviewing and synthesizing phases of, 311–313, 312
 - safety precautions for, 311
 - student responses to introductory challenge letter for, 308–310, 309
 - time required for, 312–313
- Water transport system for school-yard garden, 169–176
 - connecting to CCSS, 173
 - connecting to NGSS, 170, 176
 - definition of community-based engineering, 169
 - evidence of multifaceted learning from, 174–175
 - learning goals for, 170
 - module overview for, 169–170
 - session 1: teacher preparation and warm-up challenge, 170–171
 - session 2: unpacking community problem with students, 171–173
 - session 3: executing plans, 174
 - session 4: discussing and revising models, 174
 - session structure for, 170
- Watershed point pollution adapted lesson, 101–103
 - connecting to NGSS, 105
 - defining specific criteria and constraints for, 102
 - developing solutions for, 102
 - optimizing a solution for, 102–103
- Wheels in Motion unit, 115–120
 - concept development phase of, 117–118
 - connecting to NGSS, 121–122
 - engineering design process for, 116
 - formative assessment probe for, 120
- introduction and exploration phase of, 116–117
- learning cycle pedagogy and inquiry practice for, 116
- mystery machine application phase of, 119–120
- use of productive questions in, 116, 117, 118, 119
- varying motion application phase of, 118–119
- Wind turbine blade design challenge, 199–210
 - assessing student learning in, 207–208
 - conclusions about, 208
 - connecting to NGSS, 209–210
 - context of lessons for, 199–200
 - design brief for, 205
 - engineering design process for, 205–207, 206
 - experimental investigation for, 200–204
 - construction of blades, 201–202, 202, 206
 - evaluation of power, energy, and voltage data, 202–203, 207
 - rhombus vs. square blade orientation, 201
 - safety tips, 201
 - selection of independent variables, 200–201
 - sharing results, 204, 204
 - testing blades, 202, 207
 - using digital multimeters to measure output voltage, 204
 - goals of, 205
 - introduction to wind turbine, 200
- Windmill design, environmental engineering summer camp unit on, 125–126
- Writing prompts, 154
- Writing scripts, 245, 249, 251
- Writing standards, connections to, 22, 24, 25–26, 37, 38, 47–49, 107–109, 241, 311, 313

Z

Zion, M., 79

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