BRINGING STEM TO THE ELEMENTARY CLASSROOM

Edited by
Linda Froschauer

NSTA press
National Science Teachers Association

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The *Next Generation Science Standards* (*"NGSS"*) were developed by twenty six states, in collaboration with the National Research Council, the National Science Teachers Association and the American Association for the Advancement of Science in a process managed by Achieve, Inc. For more information go to *www.nextgenscience.org*.

Contents

Part 2: GRADES PREK–2 (CONT.)

Part 3: GRADES 3–5

Part 3: GRADES 3–5 (CONT.)

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 Elementary Classroom*
NSTA President 2006–2007

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PreK K 1 2

18

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.

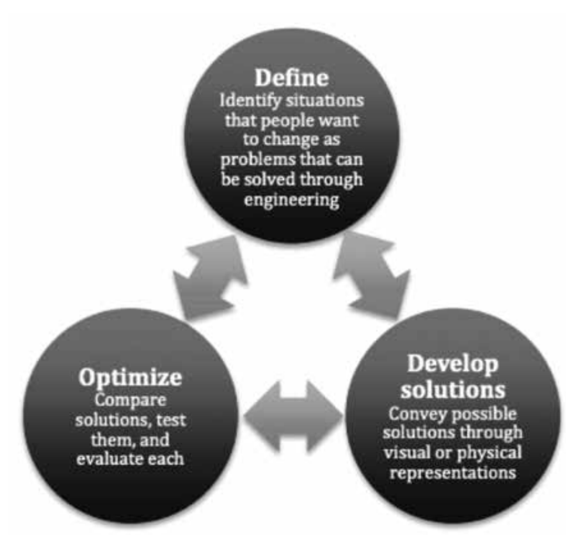
Next, we showed the class a picture of a classmate's new dog and asked whether any students have a dog at home and whether their dogs like to be outside. We explained to students that we wanted their help, and we read the following scenario:

> 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.

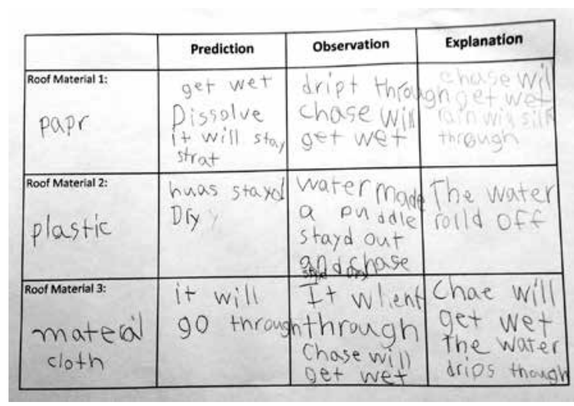
what is expected and have the students reiterate the directions before they begin. We also found it useful to have students make predictions for each of their roof materials before we handed out any water. If working in groups is new to your students, be sure to model how to work collaboratively and 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: papr	get wet Dissolve it will stay strat	dript through chase will get wet	chase will get wet rain will still through
Roof Material 2: plastic	huas stayd Dry	water made a puddle stayd out and chase	The water rolld off
Roof Material 3: materal cloth	it will go through	It wlent through Chase will get wet	Chae will get wet The water drips though

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 • 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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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.

Z

Strategies That Support the *Next Generation Science Standards*

BRINGING STEM TO THE ELEMENTARY CLASSROOM

This book is a must for your library if you're looking for creative experiences to engage your youngest students in science, technology, engineering, and math. *Bringing STEM to the Elementary Classroom* includes some of the best STEM investigations from *Science and Children*, NSTA's award-winning journal for elementary teachers.

Classroom tested to meet the needs of both preK–5 students and busy teachers, the 36 lessons are

- conveniently organized into grade-level bands;
- grounded in science education research;
- designed to encourage learning across disciplines, promote real-world problem-solving skills, expose children to STEM careers, and serve all students equally well; and
- connected to all elements of the *Next Generation Science Standards*.

Many resources help you encourage children to learn about STEM, but only this book was curated by Linda Froschauer, a veteran educator with more than 37 years of teaching experience who also serves as editor of *Science and Children*. This collection provides you with a rich variety of quality STEM experiences, whether you're a classroom teacher, homeschooler, or informal educator.

Grades PreK–5

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