Bridges and Skyscrapers

By Emily Morgan and Karen Ansberry

Bridges and skyscrapers are among the most impressive engineering achievements in human history. It is astonishing that these structures of steel and concrete continue to span longer distances and soar to greater heights. In this month's lessons, students learn some of the secrets behind these engineering marvels and discover that the materials you choose to build something are just as important as how you build it.

This Month's Trade Books

Iggy Peck, Architect
By Andrea Beaty
Illustrated by David Roberts
Abrams. 2007.
ISBN 9780810911062
Grades K–2

Synopsis

Iggy Peck spends every waking hour building things, until second grade when his teacher forbids it. He finally wins her over by using his skills to save the day on his class field trip.

Sky Boys: How They Built the Empire State Building
By Deborah Hopkinson
Illustrated by James E. Ransome
Schwartz & Wade Books. 2006.
ISBN 0375936106
Grades 3–5

Synopsis

In 1931, a boy and his father watch the Empire State Building being constructed near their New York City home, providing them hope during difficult times.

Curricular Connections

A key shift in *A Framework for K–12 Science Education* is that there is a much greater emphasis on engineering (NRC 2012). This month's lessons feature two engineering achievements–bridges and skyscrapers. In the K–2 lesson, students are engaged by a fictional story about a second grader who loves to build and uses his building expertise to engineer a bridge that saves the day on a class field trip. Students are then challenged to build a bridge, but only after testing to see which materials would be the best for building. This lesson incorporates core ideas in both engineering and science as suggested by the *Framework*. The core idea addressed for K–2 physical science is that materials have different properties and are therefore suited for different purposes (PS1-A, p. 108). The core idea for K–2 engineering is that there are multiple ways to solve a problem and it is important to test different solutions (ETS1.C, p. 209).

In the lesson for grades 3–5, students are challenged to build a structure that will hold the weight of a textbook. Then, through a story about the construction of the Empire State Building, they learn about the skeleton frame and how it was an engineering breakthrough that led to taller and taller skyscrapers. Students apply this knowledge about the skeleton frame to build the tallest toothpick and gumdrop structure possible that can hold the weight of a textbook. The core engineering idea from the *Framework* addressed by the 3–5 lesson is that the success of a designed solution has to do with how well it meets the criteria (ETS1.C, p. 209) In this case, the criteria include using only the provided materials to support the weight of a book as high off the ground as possible. The 3–5 physical science core idea addressed is the understanding that forces on an object have both size and direction and that balanced forces provide an object with stability.

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

References

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

Grades K–2: Building Bridges

Purpose: Through testing various building materials, students learn that what you build a structure out of is just as important as how you build it.

Materials

Per class:
- Roll of masking tape
- 7 straight straws
- 100 cm string
- Small paper or plastic cup
- 3 paper clips
- 50 pennies

Per pair (for bridge building):
- 10 craft sticks
- 50 cm of masking tape

Per student (for materials test):
- Craft stick
- Piece of uncooked spaghetti
- Piece of string
- Strip of paper
- Straight straw

Per class (for second bridge building activity):
- Bag of 100 craft sticks
- Box of spaghetti
- Paper
- Pack of 100 straws
- Roll of string

Engage

Show students the cover of *Iggy Peck, Architect* and introduce the author and illustrator. Ask them to look at the cover and infer what the book is about. Ask students if they know what an architect does. (Students may know that architects are involved in designing buildings.) Read the book aloud, then ask students what kinds of materials Iggy Peck used to build the structures in the book (chalk, pancakes, dirt, and so on).

Then ask how Iggy used his building expertise to solve a problem and win his teacher over (by building a bridge to rescue the class). (CC ELA Connection: Reading Literature Standards, Key Ideas and Details) Ask students if they like to build things like the character Iggy Peck. If so, what materials have they used to build something? (Have students share with a partner.)

Explore

Tell students that, like Iggy Peck, they are going to be presented with the challenge of building a bridge. They must build a bridge that will span a 15 cm gap between two desks and hold 50 pennies. Tell students they will be choosing one of the following materials to construct the bridge: paper, straws, craft sticks, string, OR uncooked spaghetti. They will be able to use masking tape to connect the pieces of whichever material they choose. Tell students that it is important to think hard about a material's properties, like how strong or flexible it is, before you use it to build something. Explain that in order to find out which materials are the strongest, you can run tests by pulling, pushing, bending, and twisting them. Project a blank Materials Data Table (Figure 1, p. 24) on the board and write each building material in the first column. Give each student a piece of paper, straw, craft stick, string, and piece of spaghetti. Test each material as a class by having each student pull the material from both ends, push it together with both hands, bend it, and twist it. Vote on a class rating (weak, sort of strong, or very strong) for each material for each test. Record each rating in the appropriate column.

Explain

Ask students which material they think is best suited for building a bridge and why. They should be able to use evidence from the data table to show that the craft stick was the only material rated "strong" for each test. Give each pair of students 10 craft sticks and 50 cm of masking tape and allow them 10–15 minutes to build a bridge spanning 15 cm. After the bridges are constructed, have students test to see if their bridge can hold 50 pennies. If not, allow them to modify their design and test it again until they are successful. If any pair of students is still not successful after the allotted time,

Figure 1.
Materials data table.

Material	Pulling	Pushing	Bending	Twisting
Paper	Sort of strong	Weak	Weak	Weak
Straw	Sort of strong	Sort of strong	Sort of strong	Weak
Craft Stick	Strong	Strong	Strong	Strong
String	Strong	Weak	Weak	Strong
Spaghetti	Sort of strong	Weak	Weak	Weak

have other students help them complete the challenge. Next, show students some photographs of real bridges and explain that most bridges are made out of concrete and metal. Tell students that these materials are used because they are strong and can withstand a lot of pulling, pushing, bending, and twisting.

Elaborate

Revisit the picture of Iggy's bridge at the end of *Iggy Peck, Architect*. Tell students that the kind of bridge Iggy built is called a suspension bridge. Show students a photo of a suspension bridge, such as Golden Gate Bridge. Explain that real bridges are made out of a combination of materials. Tell students that your class is going to build a model of a suspension bridge to show how a combination of different materials with different properties can be used to make a bridge stronger. Follow the instructions for building a bridge out of straws on the Suspension Bridge Activity page from the PBS Building Big website (see Internet Resources). Before you add the cables (strings), test to see how much weight the straw bridge can hold on its own by hanging a cup in the center of the bridge with a paper clip. Fill the cup with pennies until the straw gives. Reassemble the bridge, and then add the cables as instructed in the activity and test the strength again with the pennies and the cup. Students should see that the cables allow the bridge to bear more weight (see the PBS Building Big website for illustrations).

Explain to students the straws on the ends are being pushed when the pennies are in the cup and the strings are being pulled. So, both the straws and the strings help carry the weight, making the bridge stronger. Even though the string was rated weak for pushing and bending when they tested it earlier in the lesson, it was rated strong for pulling and twisting. These properties make the string an ideal material for making the cables in this model.

Evaluate

Challenge students to build another bridge that either spans farther than the one they built in the explain phase or holds more weight. Let them choose from the materials they tested in the explore phase. Refer back to the Materials Data Table to remind students how different materials were rated. When students have completed their new bridges, test them, allow them a few attempts to revise them if needed, and ask them why they chose the materials they used. Students should be able to explain that they chose their materials for different parts of the bridge based on their properties.

Grades 3–6: Skyscrapers!

Purpose: Students learn how a strong skeleton frame is the key to building skyscrapers, specifically the Empire State Building.

Materials

- Photo of the Empire State Building (see Internet Resources)

Per group of 4 students:

- Bag of gumdrops
- Box of round toothpicks
- Textbook

Engage

Show students a photograph of the Empire State Building. Tell them that the building is over 1,400 ft. tall, has 103 floors with 1,872 steps, contains 473 miles of electrical wiring and 70 miles of pipes, has 73 elevators, and weighs 365,000 tons—that's 730,000,000 pounds! Ask students how they think a building so tall and so heavy can be stable. What materials do they think it is made of? Students may say metal, brick, stone, and so on.

Explore

Tell students that they are going to learn more about skyscrapers, like the Empire State Building, by building some models. Give each group of four students a handful of gumdrops and some toothpicks. Challenge them to use these materials to build a structure that can support the weight of a textbook. Test students' structures by placing a textbook on top of them. Next, challenge them to see how tall they can make the structure while still supporting the weight of the book. Then ask what they think they could do to make the structure stronger. Students may suggest using different materials, adding support in the center, and so on.

Explain

Show students the cover of *Sky Boys: How They Built the Empire State Building*. Tell them that this book can help them learn more about this particular building and how skyscrapers in general are made. As you read the book aloud, ask students to use the text and illustrations to find out more about what skyscrapers are made of and how they are supported. After reading, turn back to pages 22 and 23 that show the Empire State Building in June, July, August, and November of 1930. In each of the four photos, point out the skeleton frame beneath the surface of the building. Ask students if they can recall from the reading what the frame is

made out of (steel). Reread pages 11–17, which show how the skeleton frame of the Empire State Building was constructed. (CC ELA Connection: Reading Literature Standards, Integration of Knowledge and Ideas). Explain to students that before the skeleton frame, buildings were made of stone or bricks, which limited how high the buildings could be. The higher the building, the thicker the walls would have to be at the bottom to support the weight of the building. An engineer named William Jenney came up with the idea making a frame out of steel that would hold up the entire building, including the walls and the floors—similar to the way your skeleton holds up your body. Explain that the force of gravity is pulling down on all of the parts of the Empire State Building. The parts at the bottom have to push up with the same amount of force as gravity exerts on the parts above them. When these forces are in balance, the structure is stable. Now, ask them to think about their gumdrop-toothpick structures. When the book was supported, the forces were balanced, and when the book fell, the forces were out of balance. In the case of the Empire State Building, the weight of the building (and everything in it) is held up by the skeleton frame, which spreads the weight out over many different points. To learn more about the forces acting on a skyscraper and the history of skyscraper innovation, students can go to the PBS Building Big website or the Skyscraper Museum website (see Internet Resources).

Elaborate

Tell students that they are going to be making a model of a skeleton frame with their toothpicks and gumdrops. Again, challenge students to build the tallest structure possible that will support the weight of a textbook. Because of the amount of materials needed to build the skeleton frame, you may want to combine groups for this part of the lesson. Each time a level is added to the skeleton frame, have students test to see if it can support a book. Keep adding levels until the structure is no longer able to support the weight of the book. Record the height of the tallest skeleton frame that could support the book.

Evaluate

Have students compare the height of the tallest structure that supported the book that they built in the explore phase to the tallest skeleton frame that held the book. Have students write a paragraph explaining why they were able to build a taller structure using the skeleton frame. Students should be able to explain that with the skeleton frame, the weight of the book is distributed over a larger area and more materials, making the structure stronger and more stable. (CC ELA Connection: Writing Standards, Range of Writing, starting in grade 3)

More Books to Read

Pop's Bridge
By Eve Bunting
Illustrated by C.F. Payne
ISBN: 0152047735
32 pages
Grades K–5
Synopsis: Robert and his friend Charlie watch, day after day, as their fathers help build the Golden Gate Bridge.

Skyscrapers! Super Structures to Design and Build
By Carol A. Johmann
ISBN: 1885593503
96 pages
Grades 3–5
Synopsis: This book is full of activities and explanations to help students understand how and why skyscrapers are built. A great resource for an in-depth unit on skyscrapers.

Connecting to the Common Core (CC)

This section provides information concerning the Common Core for English Language Arts (ELA) and/or mathematics to allow for cross-curricular planning and integration.

English/Language Arts

Reading Standards for Literature K–5: Key Ideas and Details

- Kindergarten standards require students to "with prompting and support, ask and answer questions about key details in a text."
- Grade 1 standards state that students are able to "ask and answer questions about key details in a text."
- Grade 2 standards require that students "ask and answer such questions as who, what, where, when, why, and how to demonstrate understanding of key details in a text."

Reading Standards for Literature 3–5: Integration of Knowledge and Ideas

- Grade 3 students are expected to "explain how specific aspects of a text's illustrations contribute to what is conveyed by the words in a story (e.g., create mood, emphasize aspects of a character or setting)."
- Grade 4 standards ask students to "make connections between the text of a story or drama and a visual or oral presentation of the text, identifying where each version reflects specific descriptions and directions in the text."
- Grade 5 standards ask students to "analyze how visual and multimedia elements contribute to the meaning, tone, or beauty of a text."
- Writing across all content areas is emphasized within the common core, as seen by standard statement 10, which begins in grade 3 and states that students should "write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.
- Furthermore the Common Core for ELA provide a standard related to the Range of Text Types for K–5 where it indicates that students in K–5 should apply the Reading standards to a wide range of texts to include fantasy stories and realistic fiction.

Common Core State Standards Initiative

www.corestandards.org/the-standards/

Internet Resources

Official Website of the Empire State Building
www.esbnyc.com

PBS Building Big Website
www.pbs.org/wgbh/buildingbig/skyscraper/index.html

Photos of the Golden Gate Bridge
http://goldengatebridge.org/photos/current.php

Skyscraper Museum
www.skyscraper.org

Suspension Bridge Activity from PBS "Building Big" Educators Guide
www.pbs.org/wgbh/buildingbig/educator/act_suspension_ho.html

Connecting to the Standards

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

Content Standards

Standard B: Physical Science

- Properties of objects and materials (K–4)
- Motions and forces (5–8)

Standard E: Science and Technology

- Abilities of technological design (K–8)
- Understandings about science and technology (K–8)

National Research Council (NRC). 1996. *National science education standards*. Washington, DC: National Academies Press.