

Unit 2 (Structures): Bridges on a Budget

Concept

When we use what we know, we can build strong structures. The budget for a design project influences the design we choose.

Content Objective

Students work in “construction company” teams to make a bridge that meets a cost constraint; they use equivalent scales to determine both the value of different bridge characteristics and to score their bridges’ performance.

Language Objective

Use visual and linguistic support to understand different bridge characteristics.

Express and support **opinions** using first person present tense verbs and prepositional phrases: e.g., *therefore, as a result, thus, and so*.

Write a **persuasive** letter using newly acquired prepositional phrases.

Standards

- **NGSS:**
 - **5-PS1-3:** Observe and measure to identify materials based on their properties. 5-PS1-4. Investigate whether mixing two or more substances results in new substances.
 - **3-5-ETS1-1:** Define a simple design problem, including criteria for success and constraints on materials, time, or cost.
 - **3-5-ETS1-2:** Generate and compare multiple solutions based on criteria and constraints of the problem.
 - **3-5-ETS1-3:** Plan and carry out fair tests that control for variables and identify failure points to improve a model or prototype.
- **TEKS:**
 - **2A** Students will describe, plan, and implement simple experimental investigations testing one variable.
 - **2E** Students will demonstrate that repeated investigations may increase the reliability of results.
 - **3A** Students will analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing.
 - **3D** Students will connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.

- **4A** Students will collect, record, and analyze information using tools.
- **4B** Students will use safety equipment, including safety goggles and gloves.
- **6D** Students will design an experiment that tests the effect of force on an object.
- **ELPS:**
 - **2E** Students will use visual, contextual, and linguistic support to enhance and confirm understanding of increasingly complex and elaborated spoken language.
 - **3E** Students will share information in cooperative learning interactions.
 - **5F** Students will write using a variety of grade-appropriate sentence lengths, patterns, and connecting words to combine phrases, clauses, and sentences in increasingly accurate ways.

Materials

Design Materials:

- A copy of Bridge Design Brief (**5.2.2**) on a chart or overhead transparency
- Copies of handouts **5.2.3-5.2.5** one for each team of 4, crayons or markers, three colors per team
- Blank overhead transparencies and wipe-off pens (one each per team)

Construction Materials:

- One “kit” for each team with the following associated costs: **plastic straws** (50, 3 cost units each); **craft sticks** (10, 7 cost units each); **poster board** (1 sheet, 9 cost units per half sheet) **paper** (10 sheets, 1 cost unit each); **string** (4 one meter lengths, 1/2 cost unit per length) **tape, glue** (all you want, no cost assessment)

Investigation Materials:

- the bridge “canyon” and “island” set up on a table: 26 inches (65 cm) wide canyon made between two stacks of books 8 inches (20 cm) off the table, with a 4 x 6 inch index card as an island
- Metric rulers or meter sticks
- Calculators
- Weights [at least 5 pounds (about 2.3 kg)]

Literature Connection:

- Twenty-One Elephants by Phil Bildner

BACKGROUND INFORMATION

An important advancement in bridge engineering was the pre-Columbian Inca technique for creating suspension bridges. These bridges were essential to connecting the vast network of roads throughout the Inca Empire. Some of the bridges spanned canyons over 150 feet, making them longer than any bridges in Europe at the time. When the Spanish conquistadors arrived to South America, they were unfamiliar with suspension bridge technology and they marveled at the Incas' engineering. Without these bridges, the Spanish would never have been able to traverse the numerous canyons with their horses and cannons. Ochsendorf estimates that just *one* of the cables from the larger bridges could support 50,000 pounds. As a testament to their craftsmanship, many of the Inca bridges survived through the 19th century. One bridge near Huinchiri, Peru is still in use today. As part of an annual ceremony, the local people cut down the bridge and rebuild it using grass and plant fibers from their surroundings. Contemporary stress ribbon bridges in Europe, and now in the United States (the first of which was built in Fort Worth, TX in 2012), emulate the technology of Inca suspension bridges. However, the Inca bridge-building process uses local materials and more sustainable techniques since the bridges are completely biodegradable and do not contribute to climate change.

Sources: Ochsendorf, J. (2005, Dec 8). Engineering in the Andes Mountains: History and design of Inca suspension bridges [Video file]. Retrieved from: http://www.loc.gov/today/cyberlc/feature_wdesc.php?rec=3839

Texas Department of Transportation. (2012, Sep 17). *The TXDot update: News and information from the Texas Department of Transportation*. Retrieved from: http://www.txdot.gov/txdot_library/newsletters/txdot_update/2012/091712.html

Day 1: Engage Structures-Bridges on a Budget

Teacher Says/Does	Student Says/Does	Language requirements
<p>1. Preparation: Collect, measure, and set out the materials kits, and build the bridge “canyon’ with a stack of books. Tape a 4 x 6 inch index card to the table between the stacks of books. This makes an “island.” If you do not have sets of masses available, prepare some with zip bags of sand or rock, using a bathroom scale. The bags should fit onto the 6 inch (15 cm) wide bridge roadbeds. If possible, borrow weights from a high school science teacher or from a gym.</p> <p>2. Begin by showing images of famous or unique bridges from around the world (Inca bridge, Golden Gate Bridge, Brooklyn Bridge, a local bridge, etc.). Consult “Remarkable Bridges” (handout 5.2.1)</p> <p>3. Guide students to the conclusion that appearance, cost, and strength are important factors in building a bridge. On an anchor chart, sketch a bridge and add the words Appearance, Cost, and Strength each with a small picture clue. Refer to this chart throughout the process.</p> <p>4. Show students Design Brief (5.2.2). Tell them that they will be working as engineers to design a bridge that has quality appearance, cost, and strength.</p> <p>The bridges will be scored on:</p> <ol style="list-style-type: none"> Appearance. Each team will rate other teams’ bridges on a scale of 1 to 10. Calculate the average of these scores. Criteria for determining aesthetic quality include creativity/novelty, texture, form (symmetry, “lines”, etc.), pattern, and color. Cost. Each materials kit represents 250 cost units. Teams may return materials from their original kit if all in one piece and may return 1/2 sheets of posterboard. Teams may “purchase” additional materials, which will be charged at the rates given above. These additional materials may NOT be returned for credit, whether used 	<p>Students make observations with a partner on the different bridge designs and discuss what was involved in the building process. They share out to the class, highlighting appearance, cost, and strength as important factors in bridge building.</p>	<p>Vocabulary: appearance, cost, strength</p>

<p>or not, and they will be added to the total cost. The cost of the bridge will be figured using the equivalent scale on handout 5.2.3 "<i>Finding Your Bridge's Cost and Strength Scores.</i>" Help students practice with these scales.</p> <p>c. Strength (Load capacity). Bridges will be loaded along their lengths until failure, or until they have used up all available weights. The bridge must support the load for 5 seconds. The strength score of the bridge will be figured using the equivalent scale.</p> <p>5. A simple formula gives the bridge score, but in order to have students participate in and understand the weighted nature of the scoring, try this activity: "What's it Worth?" Circulate among the students to guide their discussions using handout 5.2.4.</p> <p>6. Help the whole group come to consensus after teams have made their decisions, then use these IMPORTANCE values in all bridge scoring calculations.</p>	<p>Students discuss and decide the "IMPORTANCE" (relative mathematical weight) of the bridges' cost, strength, and appearance. Using a scale of 100, (which results in a percentage-of-total value), students engage in dialogue.</p>	
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Day 2: Explore Structures-Bridges on a Budget

Teacher Says/Does	Student Says/Does	Language requirements
<ol style="list-style-type: none"> 1. Remind students that they will be working in teams and should the evaluation criteria from the previous lesson. Show students Design Brief. 2. While the students are working, use the collaborative dialogue template (p. 32 in Teacher Handbook) to guide conversations and take a running record of students' progress on content and language objectives. 3. Approve bridge designs as the teams finish their plans. Keep account of costs of additional materials that the teams request and credits for any they return. 	<p>Student teams should create a design plan for their bridges using a blank transparency or a piece of paper to be shown on the document camera. Their plans should include top, side, and end view drawings of the proposed bridge (to scale, if appropriate), and should be labeled to indicate materials to be used.</p> <p>Teams obtain materials kits and construct their bridges. As teams are making bridges, they should also keep an account of the material costs.</p>	<p>Vocabulary: appearance, cost, strength</p> <p>Express and support opinions using first person present tense verbs:</p> <p>I think _____</p> <p>I observe _____</p> <p>It is my opinion that _____</p>


Day 3: Explain Structures-Bridges on a Budget

Teacher Says/Does	Student Says/Does	Language requirements
<p>1. After the first versions of the bridges are completed, hold a “design review.” You should ask questions such as:</p> <ul style="list-style-type: none"> • Show the path the compression load force will follow when we put a lot of weight on your bridge. • Have you put the strongest members under the compression load? <p>2. As the other teams ask questions of the presenters, think about what they know and are using in their design. Facilitate a conversation among the students and give suggestions.</p> <p>3. Explain that the teams will have the remainder of class to make adjustments to their bridges based on feedback from the design review.</p>	<p>Each team presents and explains its design to the class.</p> <p>Other teams should ask questions as well.</p> <p>Teams revise their bridges as necessary after the design review.</p>	<p>I think that _____.</p> <p>I appreciate how/that/your _____.</p> <p>I am surprised that _____.</p> <p><i>therefore, as a result, thus, and so, etc.</i></p>

Day 4: Elaborate/Evaluate Structures-Bridges on a Budget

Teacher Says/Does	Student Says/Does	Language requirements
<p>1. Explain that each team will present their bridge for judging. The scores for the bridges will be determined by adding up the weighted data. Review “Scoring Your Bridge” handout 5.2.5.</p> <p>2. When the judging is completed, discuss with students the following questions:</p> <ul style="list-style-type: none"> • Were you surprised at your final bridge score? • What effects did the IMPORTANCE scores have on your final score? (Sentence stem: The IMPORTANCE values made our score...) • Tell about how you use trouble-shooting skills in your construction. • Did you stay with your plan? If not, why not? <p>3. Model the process of writing a persuasive letter. Make a word web with students’ ideas about words and phrases used to persuade an audience. Explain that students will write a persuasive letter that argues for certain weights for different categories on the rubric and explains their rationale.</p>	<p>Students vote on appearance and strength is tested.</p> <p>Student teams engage in discussion of the questions.</p> <p>Students write their persuasive letters individually or in pairs.</p>	<p>First person verbs to persuade: I feel that _____.</p> <p>I strongly believe that _____.</p> <p>We conclude that _____.</p> <p>We argue that _____.</p> <p>I propose that _____.</p> <p><i>therefore, as a result, thus, and so.</i></p>

Remarkable Bridges

Name of Bridge	Information about Design
	
	
	
	

Images retrieved from: <http://www.nps.gov/prsf/playourvisit/golden-gate-bridge.htm>;
<http://www.nmai.si.edu/inkaroad/inkaroadtoday/native-traditions.html>;
http://www.txdot.gov/txdot_library/newsletters/txdot_update/2012/091712.html; <http://www.history.com/topics/brooklyn-bridge>

Planning Map: Bridges on a Budget

Design a bridge that is strong, inexpensive, and pleasing to look at.

Specifications and constraints:

- Your bridge must cross a canyon that is 26 inches (65 cm) wide.

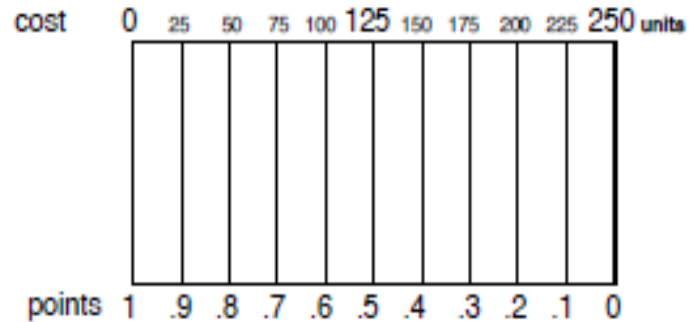


- The height at each end should be 8 inches (20 cm).
- There is a 6 in. by 4 in. (15 cm x 10 cm) “island” in the center of the “river” that you can build upon for support.
- The bridge should be 6 inches (15 cm) wide.
- The bridge should overlap the canyon edges to allow connection at each end.
- You are constrained to use materials from your kit. You can “buy” additional materials and trade in unused whole materials for credit to your company’s account.
- You must keep track of your budget.
- Your bridge will be scored on strength, appearance, and expense.

Finding Your Bridge's Cost and Strength Scores

COST:

Color in the Scale to show the amount you spent on the bridge.

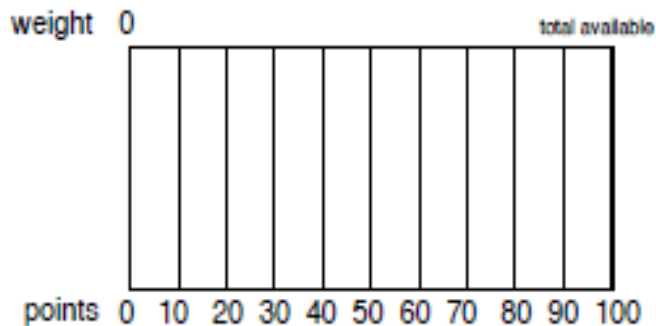


Why is a big cost worth fewer points?

STRENGTH:

Write the *most available weight* above the "100" end of the scale. Then write the weights that are in between, spreading them out evenly.

Color in the scale to show how much your bridge held before it failed.



What's It Worth?

What characteristics are important for a food like milk? What about a haircut? And what about a bridge? Would you judge them all the same way?

1. Use three colors of crayon or marker. Make a color key for low cost, good looks, and strength:

Low Cost =

Color 1

Good Looks =

Color 2

Strength =

Color 3

2. Now color on each scale how **IMPORTANT** *low cost, good looks, and strength* are for:

Milk



A Haircut



A Bridge



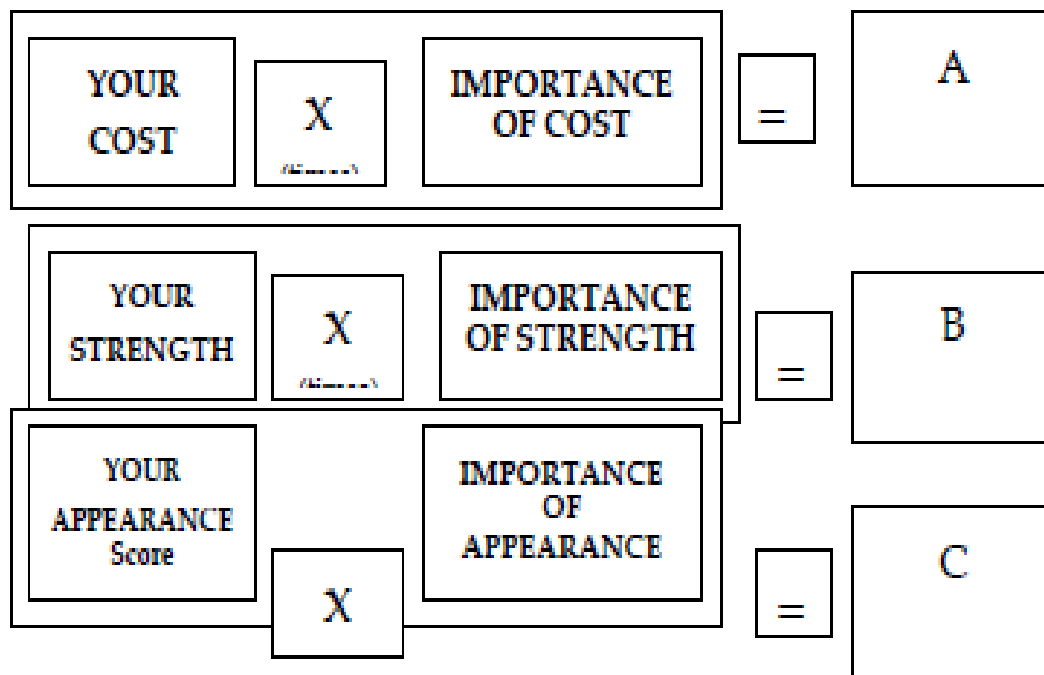
Compare your importance scores with another team, then talk about it with the class.

Scoring Your Bridge

Your bridge is being scored on cost, strength, and appearance.

1. Fill in the importance values your class decided.

- Write in your final cost, strength, and appearance scores.
- Find the values for A, B, and C, then add them up!



$$\text{TOTAL} = \frac{\quad}{A} + \frac{\quad}{B} + \frac{\quad}{C} = \frac{\quad}{\text{SCORE}}$$