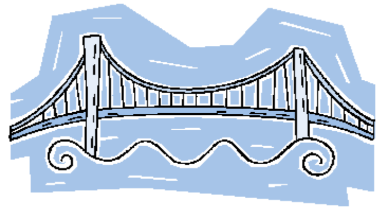
Popsicle Bridge



Provided by TryEngineering - www.tryengineering.org

Lesson Focus

Lesson focuses on how bridges are engineered to withstand weight, while being durable, and in some cases aesthetically pleasing. Students work in teams to design and build their own bridge out of up to 200 popsicle sticks and glue. Bridges must have a span of at least 14 inches and be able to hold a five pound weight (younger students) or a twenty pound weight (older students). Students are encouraged to be frugal, and use the fewest number of popsicle sticks while still achieving their goals. Students then evaluate the effectiveness of their own bridge designs and those of other teams, and present their findings to the class.

Lesson Synopsis

The "Popsicle Bridge" lesson explores how engineering has impacted the development of bridges over time, including innovative designs and the challenge of creating bridges that become landmarks for a city. Students work in teams of "engineers" to design and build their own bridge out of glue and popsicle sticks. They test their bridges using weights, evaluate their results, and present their findings to the class.

Age Levels

8-18.

Objectives

- Learn about civil engineering.
- Learn about engineering design.
- Learn about planning and construction.
- Learn about teamwork and working in groups.

Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- structural engineering and design
- problem solving
- teamwork

Lesson Activities

Students learn how bridges are designed to meet load, stress, and aesthetic challenges. Students work in teams to design and build a bridge out of up to 200 popsicle sticks and glue that can hold a standard weight based on the age of the students. Teams test their bridge, evaluate their own results and those of other students, and present their findings to the class.

Resources/Materials

- Teacher Resource Documents (attached)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

- TryEngineering (www.tryengineering.org)
- Sydney Harbor Bridge History (www.cultureandrecreation.gov.au/articles/harbourbridge)
- Building Big - Bridges (www.pbs.org/wgbh/buildingbig/bridge)
- ITEA Standards for Technological Literacy: Content for the Study of Technology (www.iteaconnect.org/TAA)
- National Science Education Standards (www.nsta.org/publications/nses.aspx)

Supplemental Reading

- Bridges of the World: Their Design and Construction (ISBN: 0486429954)
- Bridges: Amazing Structures to Design, Build & Test (ISBN: 1885593309)

Optional Writing Activity

- Write an essay or a paragraph about how new engineered materials have impacted the design of bridges over the past century.

Extension Ideas

- Challenge advanced students to design and build a bridge out of popsicle sticks and glue that can hold the weight of three students.

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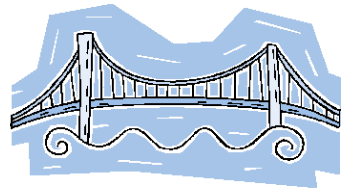


For Teachers:
Teacher Resource

◆ **Lesson Goal**

Lesson focuses on how bridges are engineered to withstand weight, while being durable, and in some cases aesthetically pleasing. Students work in teams to design and build their own bridge out of up to 200 popsicle sticks and glue. Bridges must have a span of at least 14 inches and be able to hold a five pound weight (younger students) or a twenty pound weight (older students). Students are encouraged to be frugal, and use the fewest number of popsicle sticks while still achieving their goals. Students then evaluate the effectiveness of their own bridge designs and those of other teams, and present their findings to the class.

◆ **Lesson Objectives**

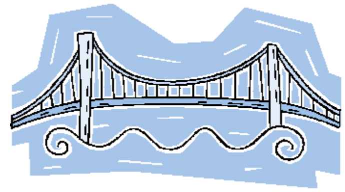
- Learn about civil engineering.
- Learn about engineering design.
- Learn about planning and construction.
- Learn about teamwork and working in groups.

◆ **Materials**

- Student Resource Sheet
- Student Worksheets
- One set of materials for each group of students:
  - 200 popsicle sticks, hot glue gun (or craft glue for younger students)
  - Standard 5 and 20 pound weight (box of sugar, exercise weight, or another weight that can be standardized)

◆ **Procedure**

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.
2. Divide students into groups of 2-3 students, providing a set of materials per group.
3. Explain that students must develop their own bridge from up to 200 popsicle sticks and glue. Bridges must be able to hold a five pound weight for younger students and a twenty pound weight for older students. The bridge must span at least 14 inches (so it must be longer than 14 inches). When the bridge has been constructed, it will be placed at least one foot above the floor (place it between two chairs, as an example) and tested with a weight bearing test. In addition to meeting the structural and weight bearing requirements, the bridge will also be judged on its aesthetics, so students should be encouraged to be creative. Students will be encouraged to use the fewest number of popsicles possible to achieve their goal.
4. Students meet and develop a plan for their bridge. They draw their plan, and then present their plan to the class.
5. Student groups next execute their plans. They may need to rethink their design, or even start over.
6. Next….teams will test their bridge's weight capacity by placing it at least one foot above the floor (try using blocks or a chair supporting each end of the bridge). The bridge must be able to bear the assigned weight (depending upon student age) for a full minute.



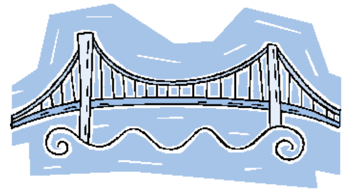
7. Each bridge should be judged by the class in terms of its aesthetic value on a scale of 1-5 (1: not at all appealing; 2: not appealing; 3: neutral/average; 4: somewhat appealing; 5: very appealing). This is of course subjective.
8. Teams then complete an evaluation/reflection worksheet, and present their findings to the class.

◆ Time Needed

Two to three 45 minute sessions

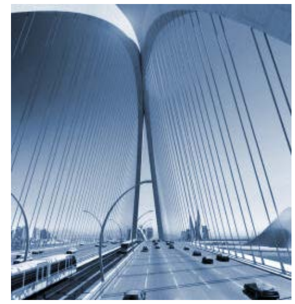
◆ Tips

- For older students, increase the load the bridge must bear….bridges of this type made with hot glue can bear the weight of several students if well executed.
- A glue gun works best for this project, but for safety reasons, we suggest you use craft glue for younger students.



Student Resource: Types of Bridges

There are six main types of bridges: arch, beam, cable-stayed, cantilever, suspension, and truss.



◆Arch

Arch bridges are arch-shaped and have abutments at each end. The earliest known arch bridges were built by the Greeks and include the Arkadiko Bridge. The weight of the bridge is thrusted into the abutments at either side. The largest arch bridge in the world, scheduled for completion in 2012, is planned for the Sixth Crossing at Dubai Creek in Dubai, United Arab Emirates.

◆Beam

Beam bridges are horizontal beams supported at each end by piers. The earliest beam bridges were simple logs that sat across streams and similar simple structures. In modern times, beam bridges are large box steel girder bridges. Weight on top of the beam pushes straight down on the piers at either end of the bridge.

◆Cable-stayed

Like suspension bridges, cable-stayed bridges are held up by cables. However, in a cable-stayed bridge, less cable is required and the towers holding the cables are proportionately shorter.. The longest cable-stayed bridge is the Tatara Bridge in the Seto Inland Sea, Japan.

◆Cantilever

Cantilever bridges are built using cantilevers — horizontal beams that are supported on only one end. Most cantilever bridges use two cantilever arms extending from opposite sides of the obstacle to be crossed, meeting at the center. The largest cantilever bridge is the 549 m (1800 ft.) Quebec Bridge in Quebec, Canada.

◆Suspension

Suspension bridges are suspended from cables. The earliest suspension bridges were made of ropes or vines covered with pieces of bamboo. In modern bridges, the cables hang from towers that are attached to caissons or cofferdams which are embedded deep in the floor of a lake or river. The longest suspension bridge in the world is the 3911 m (12,831ft.) Akashi Kaikyo Bridge in Japan.

◆ Truss

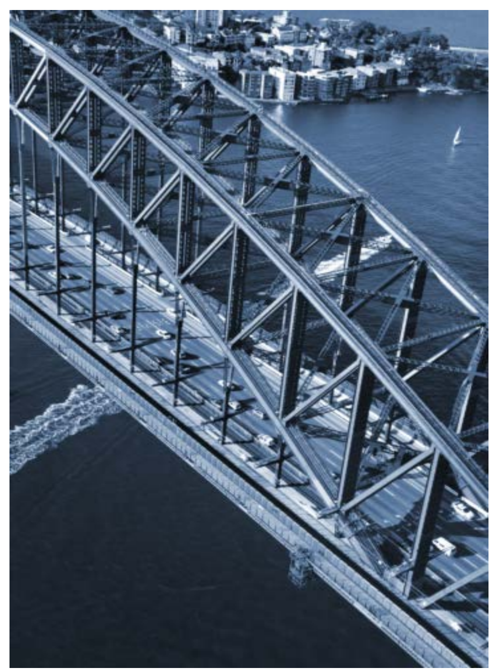
Truss bridges are composed of connected elements. They have a solid deck and a lattice of pin-jointed girders for the sides. Early truss bridges were made of wood, but modern truss bridges are made of metals such as wrought iron and steel. The Quebec Bridge, mentioned above as a cantilever bridge, is also the world's longest truss bridge.

Student Resource: Famous Bridges

◆Firth of Forth Bridge, Scotland

The Forth Bridge is a cantilever, railway bridge over the Firth of Forth in the east of Scotland. The bridge is, even today, regarded as an engineering marvel. It is 2.5 km (1.5 miles) in length, and the double track is elevated 46 m (approx. 150 ft) above high tide. It consists of two main spans of 1,710 ft (520 m), two side spans of 675 ft, 15 approach spans of 168 ft (51 m), and five of 25 ft (7.6 m). Each main span comprises two 680 ft (210 m) cantilever arms supporting a central 350 ft (110 m) span girder bridge. The three great four-tower cantilever structures are 340 ft (104 m) tall, each 70 ft (21 m) diameter foot resting on a separate foundation. The southern group of foundations had to be constructed as caissons under compressed air, to a depth of 90 ft (27 m). At its peak, approximately 4,600 workers were employed in its construction.

◆ Sydney Harbour Bridge, Australia



The Sydney Harbour Bridge is a steel arch bridge across Sydney Harbour that carries trains, vehicles, and pedestrian traffic between the Sydney central business district and the North Shore area. The dramatic view of the bridge, the harbour, and the nearby Sydney Opera House is an iconic image of both Sydney and Australia. The bridge was designed and built by Dorman Long and Co Ltd, from Middlesbrough, Teesside, U.K., and was the city's tallest structure until 1967. According to Guinness World Records, it is the world's widest long-span bridge and its tallest steel arch bridge, measuring 134 metres (429.6 ft) from top to water level. It is also the fourth-longest spanning-arch bridge in the world. The arch is composed of two 28-panel arch trusses. Their heights vary from 18 m (55.8 ft) at the center of the arch to 57 m (176.7 ft) (beside the pylons).

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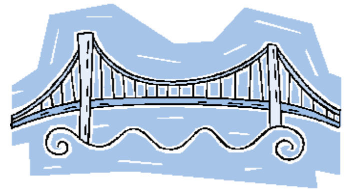


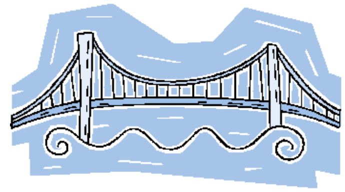
Student Worksheet:
Design Your Own Bridge

You are part of a team of engineers who have been given the challenge to design a bridge out of up to 200 popsicle sticks and glue. Bridges must be able to hold a specific weight (your teacher will decide what the weight goal will be for your class). The bridge must span at least 14 inches in length. But, it must be longer than 14 inches because when it has been constructed, it will be placed between two chairs so it is at least one foot above the floor for a weight bearing test. In addition to meeting the structural and weight bearing requirements, the bridge will be judged on its aesthetics as well, so be creative! And, you are encouraged to use the fewest number of popsicles possible to achieve your goal.

◆ Planning Stage

Meet as a team and discuss the problem you need to solve. Then develop and agree on a design for your bridge. You'll need to determine how many popsicle sticks you will use (up to 200) -- and the steps you will take in the manufacturing process. Think about what patterns might be the strongest….but you are also being judged on the aesthetics of your bridge! Draw your design in the box below, and be sure to indicate the number of sticks you anticipate using. Present your design to the class. You may choose to revise your teams' plan after you receive feedback from class.

Number of popsicle sticks you anticipate using:



Student Worksheet (continued):

◆ Construction Phase

Build your bridge. During construction you may decide you need additional sticks (up to 200) or that your design needs to change. This is ok -- just make a new sketch and revise your materials list.

◆ Aesthetic Vote

Each student will cast a vote about the look of each bridge. The scale is 1 - 5 -- (1: not at all appealing; 2: not appealing; 3: neutral/average; 4: somewhat appealing; 5: very appealing). This number is averaged to generate a score for each bridge. This score is not based on how well the bridge might hold weight, but on how it looks.

◆ Testing Phase

Each team will test their bridge to see if it can withstand the required weight for at least one full minute. Be sure to watch the tests of the other teams and observe how their different designs worked.

◆ Evaluation Phase

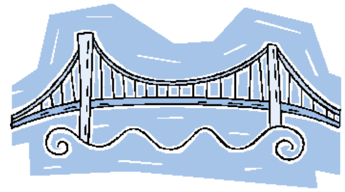
Evaluate your teams' results, complete the evaluation worksheet, and present your findings to the class.

Use this worksheet to evaluate your team's results:

1. Did you succeed in creating a bridge that held the required weight for a full minute? If not, why did it fail?

2. Did you decide to revise your original design while in the construction phase? Why?

3. How many popsicle sticks did you end up using? Did this number differ from your plan? If so, what changed?



Student Worksheet (continued):

4. What was the average aesthetic score for your bridge? How did this compare to the rest of the class? What design elements of other bridges did you like the best?

5. Do you think that engineers have to adapt their original plans during the construction of systems or products? Why might they?

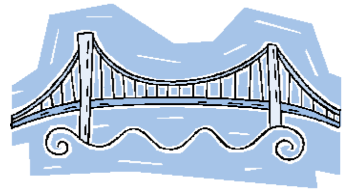
6. If you had to do it all over again, how would your planned design change? Why?

7. What designs or methods did you see other teams try that you thought worked well?

8. Do you think you would have been able to complete this project easier if you were working alone? Explain…

9. What sort of trade-offs do you think engineers make between functionality, safety, and aesthetics when building a real bridge?

Popsicle Bridge



For Teachers:
Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4 - 9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- ✦ Properties of objects and materials

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- ✦ Abilities of technological design
- ✦ Understanding about science and technology

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10 - 14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- ✦ Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- ✦ Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- ✦ Abilities of technological design
- ✦ Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- ✦ Risks and benefits
- ✦ Science and technology in society

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- ✦ History of science

For Teachers:
Alignment to Curriculum Frameworks (continued)

◆**National Science Education Standards Grades 9-12 (ages 14-18)**

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- Motions and forces

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Historical perspectives

◆**Next Generation Science Standards Grades 3-5 (Ages 8-11)**

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆**Next Generation Science Standards Grades 6-8 (Ages 11-14)**

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

For Teachers:
Alignment to Curriculum Frameworks (continued)

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 5: Students will develop an understanding of the effects of technology on the environment.
- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.

The Designed World

- Standard 20: Students will develop an understanding of and be able to select and use construction technologies.