Can you build a bridge?

Using soda straws, string, and tape

 Bridges are important. They allow people and traffic to cross rivers, canyons, other roads, etc. efficiently and easily. We learned how different types of bridges work, now it is time for you to be an engineer and design and build a bridge. But it’s not just about making the bridge work, you also have to make it efficient (or lowest cost). Try to make a bridge out of soda straws, string, and tape and see if you can most efficiently use the materials you have available – just like a real engineer!

Project Goals

* Bridge must be able to cross a river (10 inch gap) without touching the ground except at supports.
* Bridge must be functional, support a toy car and allow the car to pass through/over it.
* Bridge will be tested to determine which bridge carries the most amount of weight using the least amount of materials (efficiency).

What you need

* Soda straws (about 30) – these members can carry tension or compression.
* String or yarn – these are tension only members.
* Scissors to cut straws to desired lengths.
* Tape (cellophane or masking) to join straws.
* Piece of cardboard to serve as bridge deck for toy car to drive on.
* Weights for testing and scale to measure total carried.
* Supports (wood blocks, books, desks etc. that can be placed 10 in. apart)



What type of bridge will you use?

Beam bridges are one of the most common types of bridges today because they can be built quickly with only a few connections to make. The material in a beam bridge is in both tension (at the bottom) and compression (at the top), but there is a lot of material (in the middle of the cross-section) that is not being stressed. Think about your soda straws, is a beam bridge the most efficient way to use the material?

Arch bridges are designed so that all the material is mostly in compression. This is great for material like masonry that is strong in compression but weak in tension. Think about your material (soda straws) how strong is it? Would the arch shape take advantage of the strength?

Truss bridges are kinda like a beam bridge, but the top and bottom chords are further apart which increases the overall shape stiffness of the bridge without needing extra material. The straws can handle tension or compression. However, truss bridges can be weak at the connections (make sure you use your tape wisely), and long thin pieces can be prone to buckling. Is a truss shape going to work best for your bridge?

Cable-stayed and suspension bridges use tendons or tension chords to help support the bridge. The string only carries tension. Could you use the string as a tendon? How do you anchor the tendon so that the bridge is stable?



Which bridge is most efficient?

To win the challenge you need to build the strongest bridge with the least amount of materials.

* Find the weight the bridge supported
* Count the number of soda straws you used (if you cut a straw and there is a bit left over that you did not use it still counts as a whole straw – count the number of whole straws used (hint – be efficient with your cuts so you have the least amount of waste).
* Count the number of pieces of string you used.
* Divide the weight supported by the number of straws and string used to determine who has the most efficient bridge.

Added challenge –Time is money. Include a bonus for a bridge design that is quicker to construct.

Redesign?

Your first design may not be the best one. Engineers usually go through many designs before determining which one meets their goals the best. Can you redesign your bridge and make it better?

Some questions to consider

* What type of bridge would be best at supporting the weight but also be easy to build?
* Think about the lengths of the straws. If you don’t have to make a cut then don’t do it.
* Think about where to place the weights. Do you want it all in the middle or spread out?



Do you want to be an engineer?

Do you like to solve problems, figure out how things work, or make them better? Then engineering might be for you! There is a wide variety of engineers out there and they need lots of different skills. What engineering skills do you have?

* Likes to solve problems
* Good at math and science
* Good at creative thinking (coming up with new ideas)
* Great at communication (writing and talking)
* Ability to organize and make connections
* Can get along well with others
* Determined to get things done and do a good job
* Leadership

The fine print…

* You cannot tape the bridge to the supports.
* You need to provide some way to add weight to the bridge (place to put or hang a cup).
* You can modify the straws in any way you want (cut, bend, split, twist).
* You can use as much tape as you want.
* Use the string wisely – only for tension members.
* Plan ahead – use the graph paper to help you come up with a plan before you start cutting. Remember it’s the total number of straws you are using – if you make a wrong cut, you still use up a straw.
* You can use anything you want for the supports – wood blocks, textbooks, desks, etc. Just make sure they are the same height on each side and that you have enough space underneath the bridge. 

See an excellent video from Teach Engineering (<https://www.youtube.com/watch?v=keM4UJ4eFfo>) for more information.

Use this graph paper to help design your bridge

10 inches

Teacher Notes:

Prepare ahead of time

* Make sure you have enough supplies (first page) for all students. Students can work in groups.
* Print out copies of instructions including graph paper.

Introduce the challenge (20 min video + 10 min discussion)

* Show the video on how bridges work.
* Talk with students about how bridges work. What are the different bridge types? Why are triangles used in trusses? How is a bridge designed? What would be a good bridge type for a bridge made of soda straws (they are strong in both tension and compression)?
* Go over activity instructions and goals.

Brainstorm and Design (10 min)

* Give students about 10 min to brainstorm and design their bridges. Have them check-
  + Does the bridge meet the must haves – can it span a 10-inch gap and allow truck to pass through?
  + Is the shape efficient (can you use less materials to carry more weight)?
  + Where might the bridge fail (weak point)? Can this be reinforced?

Build, Test, Evaluate, Redesign (30 min)

* Have students build bridges. Help them think through design and if it will work.
* Test the bridges. Apply weight to the bridge until it fails. Failure is when any one member breaks – joint failure, buckling of straw, etc. (bridge may not have completely collapsed). If you have weights (like pennies) of the same size you can count the weights, if not you can simply weigh the total on a scale after testing.
* If there is time let the students redesign and come up with a better bridge.
* Total the weight (or number of weights) and subtract the number of straws and strings used. Who had the most efficient bridge?

Discussion (10 min)

* Ask some of these questions to help students think about their design.
  + Look at which bridges were the most efficient. Did they share any common characteristics?
  + What type of bridge most efficiently uses the materials of straws and strings?
  + Why is it important that bridges be efficient? (more efficient bridge = less cost)
  + What did you learn about bridge design?
  + Did brainstorming and thinking about their design help them come up with a good design?
  + Why is it important to redesign? Did anyone come up with a better design the second time around?

Optional – Inquiry based learning questions.

* Your class is asked to determine the most efficient design for a bridge. To test different designs, you are tasked with building models and determining which one works best. You have the materials of soda straws (which represent steel members), string (which represents steel cables), and tape that allows you to connect (weld) the members. Investigate which bridge design will be the most efficient.
* Design your investigation.
  + Define how you determine efficiency.
  + How many bridge types and designs should you investigate? Are there any that can be ruled out before testing?
  + How should you conduct the experiment?
* Conduct experiment and record data.
  + Design and build bridges.
  + Test bridges. Record the weight carried and the number of materials used (possibly time to construct).
* Analyze and interpret results.
  + Which bridges had the most efficiency? Why?
* State conclusions
  + Which design would you recommend for the bridge?

How bridges work – Standards Alignment

**Middle School**

* [**Next Generation Science Standards**](https://www.nextgenscience.org/)
  + [MS Engineering Design](https://www.nextgenscience.org/topic-arrangement/msengineering-design)
    - [MS-ETS1-1 Engineering Design](https://www.nextgenscience.org/pe/ms-ets1-1-engineering-design)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 Engineering Design](https://www.nextgenscience.org/pe/ms-ets1-2-engineering-design)Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
    - [MS-ETS1-3 Engineering Design](https://www.nextgenscience.org/pe/ms-ets1-3-engineering-design)Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
    - [MS-ETS1-4 Engineering Design](https://www.nextgenscience.org/pe/ms-ets1-4-engineering-design)Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
* **Common Core State Standards Connections:**
  + ELA/Literacy –
    - RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-ETS1-3)
    - RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ETS1-2),(MS-ETS1-3)
    - WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (MS-ETS1-2)
    - WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. (MS-ETS1-1)
    - WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research. (MS-ETS1-2)
  + Mathematics –
    - MP.2 Reason abstractly and quantitatively. (MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3),(MS-ETS1-4)
    - 7.EE.3 Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. (MS-ETS1-1),(MS-ETS1-2),(MS-ETS1-3)