STEM (capitalize letter to denote focus)

Title: Wait! There's too much weight!

Grade Level: 4th

Duration: Four 45 Minute Inquiry Monday Classes

Objective: Students will design and construct a bridge that will support the weight of all three Billy Goats Gruff as they cross the bridge to return home after eating the grass and apples on the other side.	**Focus Concept/s:** Design and construct a model of a bridge to support the combined mass of the three Billy Goats Gruff with full stomachs.
Essential Question/s: How can I design and build a model of a bridge so it is strong enough to hold the combined weight of all three full Billy Goats Gruff?	**Connected Benchmark/s:** **SC.4.N.1.1** Raise questions about the natural world, use appropriate reference materials that support understanding to obtain information (identifying the source), conduct both individual and team investigations through free exploration and systematic investigations, and generate appropriate explanations based on those explorations. **SC.4.N.1.8** Recognize that science involves creativity in designing experiments.
Vocabulary: • Blueprint • Structural Engineer • Model • Prototype • Request for Proposal • Client	**Suggested Materials:** for each team: • **4 pieces of wood** to use as supports on each end of bridge (2x4 about 4" long) These can be found in the old Harcourt Kits ***Or*** 4 cans of the same size ***Or*** books of the same height • **1 stick of clay** • **20 popsicle sticks** • **3 index cards** • **60 cm of masking tape** • **Reader's Theater** The Three Billy Goats Gruff • **Engineering Planning Sheet** • **Masses** which equal a total of 170 grams • **Background Knowledge sheet**

Problem/Challenge (Engage): Read the story of the Three Billy Goats Gruff. This may be acted out as well! (See Reader's Theater attached) Reflect on the issue - the Billy Goats Gruff have crossed the bridge one at a time and eaten their fill of fresh grasses and apples for a week! They now want to go home, crossing the bridge together for safety, but know the bridge is rickety. Too much weight on the bridge beam will cause it to collapse into the river and the Troll might eat the Billy Goats Gruff! The Billy Goats Gruff are counting on you to design and construct a bridge that will allow them all to cross at the same time and keep them safe from the Troll.

Groups students into teams. Distribute Background knowledge sheet that lists three types of structures. As teams, have groups skim and discuss the types of bridges. Tell them they don't have to read it all but use it as a resource to trigger ideas. Engineers often look at previous prototypes to gain inspiration or improve on previous designs.

Brainstorm/Investigate (Focus Concepts):
Students observe their available materials and individually brainstorm up to two possible ideas on their design planning sheet.
Remind the students to consider the following:

- Do all bridges look the same?
- How will you manipulate the materials?

When they finish their individual plans, have them work together to determine the strengths and weaknesses of the plans and select one.
"It's time to put your heads together and discuss how to design a bridge that will support the weight of all Three Billy Goats Gruff. Remember that other teams of scientists are in competition with you and will be trying to steal your concept, so talk quietly."

Go to MyOn and read the book - Buildings and Structures by Nicola Barber to learn about real building challenges and what went wrong.

Plan/Design (Blueprint): Remember to label your drawings! Include notes so you remember how far apart the supports are and how much weight your bridge held.

Build/Test: Construct your prototype. Place the three Billy Goats Gruff on the bridge span to see if your design is successful in supporting their weight.

Collect/Analyze Data: Carefully record your qualitative and quantitative data. Once the prototype has been constructed and tested, it's time to put those analytical skills to work! Which features worked well? Which features do you need to redesign? Feel free to modify your design but make sure you notate changes on your blueprint in colored pencil so you know what changes have been made. You want your final bridge to support the full Billy Goats Gruff and save them from the Troll! Select the best design elements and create a final design for a bridge that will support our Three Billy Goats Gruff.

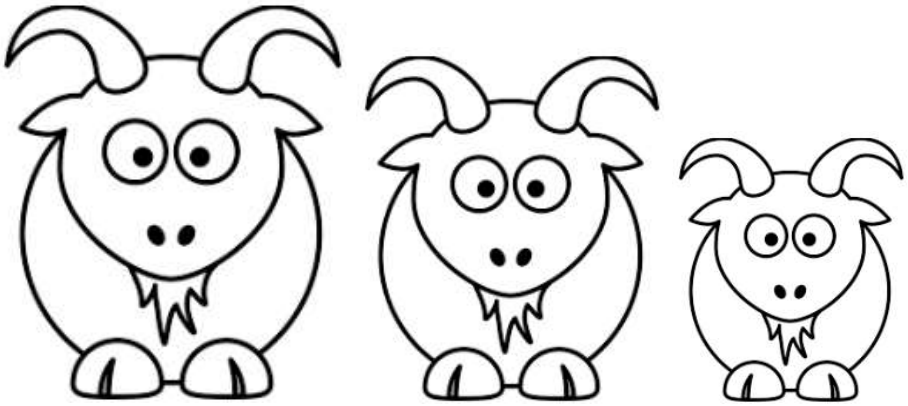
Reflect on Improvements:
Now that your final design has been tested, how did the bridge stand up to the test of the weight of the full Billy Goats Gruff?

Evaluate/Justify:
Have students view the other teams' bridges and look at their data. How did the other groups designs compare to yours? Which team in was able to construct a bridge that will allow the three Billy Goats Gruff to successfully cross the bridge at the same time and keep them safe from the Troll? How much weight was their bridge able to carry? What elements of their design do you feel were essential to their success? If you were given the opportunity to redesign your bridge one more time, what would you change and why?

Extension: If everyone was successful, what criteria could we use to determine which bridge was the best? Ex. Use of the least amount of materials (cost effectiveness), ability to hold the most weight (additional family members could join them) etc. Would the same bridge be the best under each of these circumstances?

Request for Proposal

Proposal must be submitted as a model.



Three Billy Goats Gruff have crossed the bridge one at a time and eaten their fill of fresh grasses and apples for a week! They are ready to go home. They want to cross the bridge together for safety, but they know the bridge is rickety. Too much weight on the bridge beam will cause it to collapse into the river and the Troll might eat the Billy Goats Gruff! The Billy Goats Gruff are counting on you to design and construct a bridge that will allow them all to cross at the same time and keep them safe from the Troll.

Engineers will develop a prototype of a bridge that will not break when all three goats are on it at the same time. As a structural engineer you want to think about how to build a strong structure.

Item Specifications:

- Use only the allowed materials: 1 stick of clay, 20 popsicle sticks, 3 index cards, and 60 cm of masking tape
- The bridge must support the combined weight of all three goats. The goats weigh 70 g, 60 g and 40g.
- Blueprint must be drawn with the materials labeled.
- The bridge must span at least 15 cm which is the width of the river.

Good luck!

Becoming a Structural Engineer….



Structural Engineering is the study of how to make build things so they are strong and don’t break easily. You probably don't stop to worry about whether the building you are in right now can withstand a force of nature like a hurricane or an earthquake. But if you were a structural engineer, you'd design and plan houses, schools, bridges, and skyscrapers to resist these powerful forces.

Becoming a Structural Engineer….



Structural Engineering is the study of how to make build things so they are strong and don’t break easily. You probably don't stop to worry about whether the building you are in right now can withstand a force of nature like a hurricane or an earthquake. But if you were a structural engineer, you'd design and plan houses, schools, bridges, and skyscrapers to resist these powerful forces.

Becoming a Structural Engineer….



Structural Engineering is the study of how to make build things so they are strong and don’t break easily. You probably don't stop to worry about whether the building you are in right now can withstand a force of nature like a hurricane or an earthquake. But if you were a structural engineer, you'd design and plan houses, schools, bridges, and skyscrapers to resist these powerful forces.

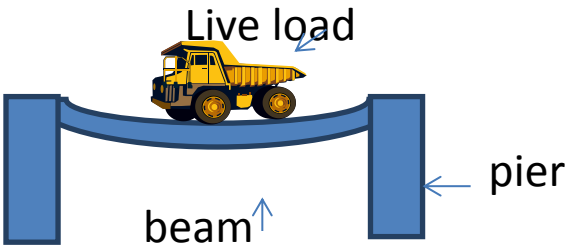
Background Knowledge

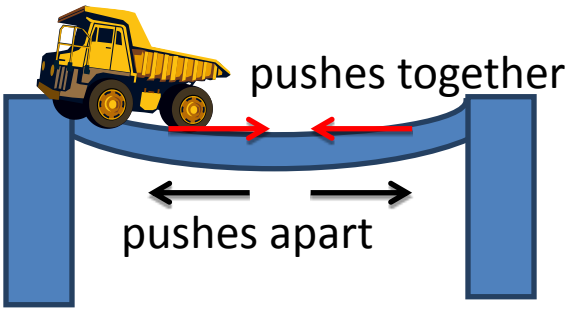
People everywhere have always needed bridges to cross obstacles in their paths such as bodies of water and valleys between mountain ridges. Have you ever wondered how bridges support all of the weight that they carry? Or why most bridges are built differently? Some bridges have arches while others are straight.

Bridge engineers must consider many things when deciding what type of bridge is perfect for a location including the materials available, the load the bridge will carry, the distance to be spanned and the type of ground the bridge will be built upon. These criteria help engineers determine the size, shape, and design of a bridge. Since the beginning days of bridge building, engineers have designed three basic types of bridges: beam, truss and arch.

The beam bridge has a horizontal **beam** supported at each end and sometimes in the middle, by **piers**. The weight of the beam pushes straight down on the piers. When a live load pushes down on the beam, the beam bends. The top edge is pushed together while the bottom edge is pulled apart.


Beam bridge

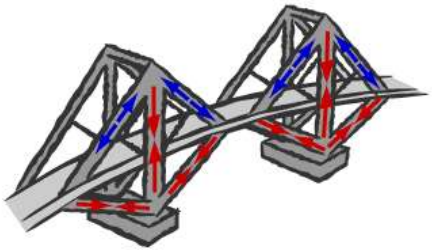




The farther apart the bridge piers are located, the weaker the beam becomes! Beam bridges are rarely built to span more than 250 feet.

The truss bridge is a series of triangles assembled together to form a truss, which is the load bearing structure. Truss bridges are one of the oldest types of modern bridges. They have simple designs which could be easily analyzed by early engineers. (Remember, they didn't have computers to help them.) A

truss bridge is economical to construct because it uses few materials, it can be assembled off site and erected quickly, in a single piece, on site.

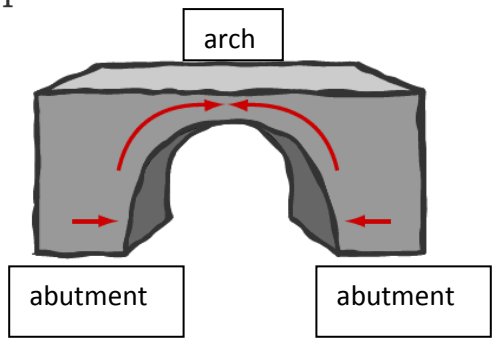


Every bar in a truss bridge experiences either a pushing or pulling **force**. The bars rarely bend. This is why truss bridges can span farther than beam bridges. You can see the forces a live load creates as it travels across a truss bridge by looking at the arrows in the diagram. Notice how the shape of the triangle distributes the force of the live load across all of the triangular sections of the truss bridge.

The arch bridge has great natural strength, but building one isn't easy! The structure is unstable until the two spans meet in the middle! A long time ago, engineers used a wooden form to support the two sides until they locked together. Now engineers use cables attached to the ground on either side of the bridge to support the spans. Thousands of years ago, Romans built arches out of stone. Today, most arch bridges are made of **steel** or **concrete**, and can **span** up to 800 feet.

Ancient Roman aqueduct

When the live load exerts downward pressure as it travels across the arch bridge, the arch is squeezed together. This squeezing **force** is carried outward along the curve to the supports at each end. The supports, called abutments, push back on the arch and prevent the ends of the arch from spreading apart!



New River Gorge, W.irginia

Now that you've mastered the bridge basics, test your bridge-building skills in the **Bridge Challenge!**

Three Billy Goats Gruff
Reader's Theater

Narrator: Once there were three goats that lived on a hillside. They had eaten all the grass on their side of the hill. They were sad and very, very, very hungry.

All Three Goats: We are sooooo sad and sooooo hungry!

Narrator: But on the other side of the hill, across the bridge, there was lots, and lots, and lots of grass to eat.

All Three Goats: We should go over there; Over to the other side of the hill.

Big Goat: We should, but what about that big, nasty troll that lives under the bridge? He has a big appetite and he really loves juicy goat meat!

Middle Goat: Maybe the troll is gone. Maybe he is visiting his relatives.

Little Goat: Yeah! He is probably visiting his relatives. Let's go across the bridge.

Big Goat: Tell you what Little Goat; you go across the bridge first.

Little Goat: Me? Why me?

Big Goat: Well, you are soooo skinny and soooo weak. Just look at you, Little Goat, we can hardly even see you! If you don't get to the other side of the hill first, you might just disappear!

Little Goat: You're right Big Goat. I will go first, and while I'm eating all that tall, green, swaying grass, I'll be thinking of both of you. Goodbye!
(Little Goat starts crossing the bridge.)

Troll: WHO GOES ACROSS MY BRIDGE?

Little Goat: (Trembling, in a scared little voice) It is I, the Littlest Goat.

Troll: I SHALL EAT YOU! (Slowly move towards the Little Goat)

Little Goat: No! No! Don't eat me! I am skinny and scrawny and really do not taste good at all. Please, wait for the bigger goats. They are bigger, tastier, and juicier. They will be coming in just a minute. Please wait for them!

Troll: Hmmmm…You're right! You are hardly a little snack. I would much rather have bigger, tastier, and juicier goats. You may pass across the bridge.

Little Goat: Thank you! Thank you! (Runs across the bridge and exits)

Middle Goat: Hmmm…It must be alright to cross the bridge. Look over there, Little Goat is eating all that delicious grass. I better get over there before Little Goat eats it all.
(Middle Goat starts crossing the bridge)

Troll: WHO DARES TO CROSS OVER MY BRIDGE?

Middle Goat: (Shaking and scared) It is I, the Middle Goat.

Troll: I HAVE BEEN WAITING FOR YOU! I AM GOING TO EAT YOU IN ONE BITE!!!

Middle Goat: No! Don't eat me! I am just the Middle Goat. Wait for Big Goat. He is so much bigger than I am. Think about it; do you want to settle for second best? Of course not! Wait for the big, huge, tender Big Goat. Pleeeeeeeese!!!

Troll: He's bigger than you? (Middle Goat nods his head) Hmmmmm. Then I shall wait for Big Goat. You're right; I deserve the very best meal. You may cross the bridge.

Big Goat: Well, look at that! Both Little Goat and Middle Goat are enjoying the luscious field of green grass. The silly Troll must be visiting his relatives after all. I think I will trot along and join them on the other side.
(Big Goat starts crossing the bridge)

Troll: WHO GOES ON MY BRIDGE!?

Big Goat: (In a very loud voice) It is I, the Big Billy Goat.

Troll: I HAVE BEEN WAITING FOR YOU! I SHALL EAT YOU FOR MY SUPPER!!!

Big Goat: Oh, I don't think so! (Lowers his head) One! Two! Three! (Big Goat charges and hits the Troll in the stomach and knocks the Troll on the ground.)

Troll: Uggghhhhhh!!!!!

Big Goat: Now it is time for me to join my family and have some supper.

(Big Goat crosses the bridge and joins his family)