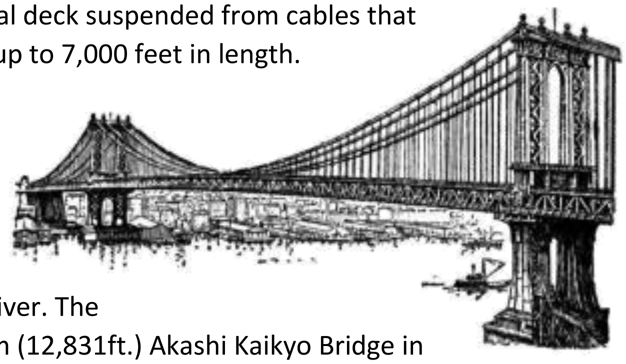
Bridging the Gap

Day 17-18: Suspenders!

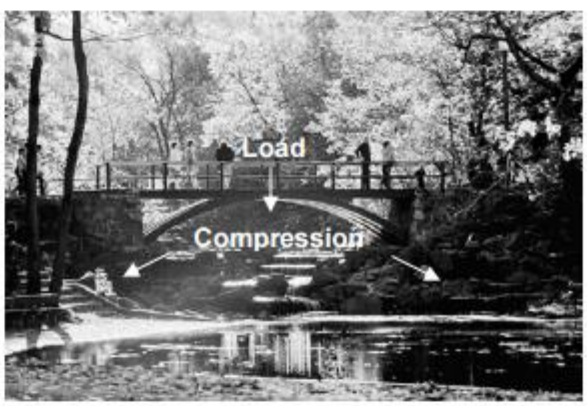
A third type of bridge is a suspension bridge (remember the Brooklyn Bridge, the Golden Gate Bridge, and those grassy bridges?). This type has a horizontal deck suspended from cables that are connected to tall piers. These bridges can span up to 7,000 feet in length.

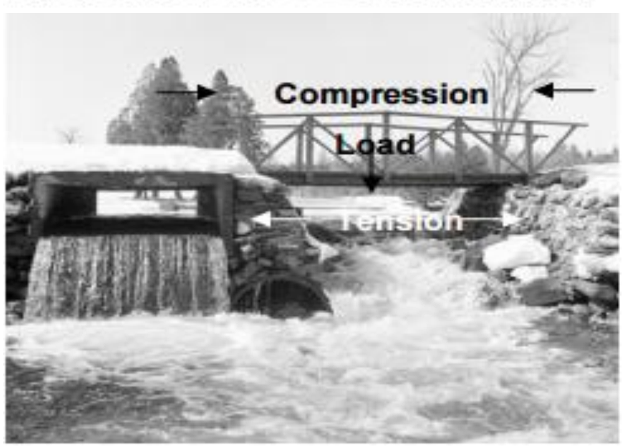


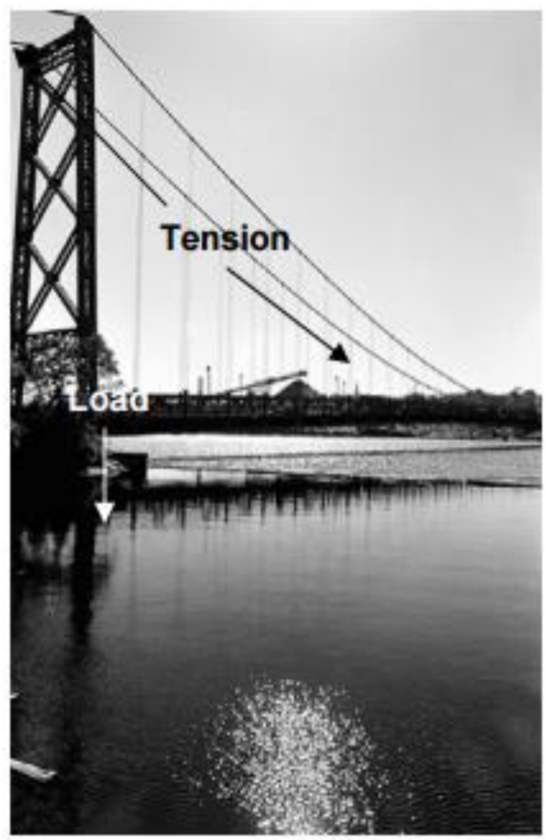
Suspension bridges are suspended from cables. The earliest suspension bridges were made of ropes or vines covered with pieces of bamboo. In modern bridges, the cables hang from towers that are attached to caissons or cofferdams which are embedded deep in the floor of a lake or river. The longest suspension bridge in the world is the 3911 m (12,831ft.) Akashi Kaikyo Bridge in Japan. The Incas created suspension bridges made with rope before European colonization occurred in the 1500s. More recent examples of suspension bridges include the Golden Gate Bridge (in San Francisco, CA), the Brooklyn Bridge (in New York, NY), and the Tacoma Narrows Bridge (in Tacoma, WA).

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.

All bridges must be very strong. First, a bridge must support its own weight, called dead weight. It must support also vehicles and people moving over it every day. This is called the load. A bridge must be able to withstand the forces of tension and compression acting on it. Forces act on big structures in many ways.







Tension is the force that pulls apart or lengthens a part of the bridge, and compression shortens or pushes on a part of a bridge.

Squeezing (Compression)
Compression is a force that squeezes a material together. When a material is in compression, it tends to become shorter.

Stretching (Tension)
Tension is a force that stretches a material apart. When a material is in tension, it tends to become longer.

Bending
When a straight material becomes curved, one side squeezes together and the other side stretches apart. This action is called bending.

Sliding (Shear)
Shear is a force that causes parts of a material to slide past one another in opposite directions. For example, during an earthquake, parts of a roadway might slide in opposite directions. This sliding action is called shear.

Twisting (Torsion)
Torsion is an action that twists a material. For example, in 1940, the Tacoma Narrows Bridge aka 'Galloping Gertie' twisted violently in strong winds and collapsed. The twisting force that tore this bridge in half is called torsion.

Finally, a bridge must handle the wind, rain, or other natural forces in the area where it is located because even steel is elastic and changes form under high stress. For example:

Tacoma Narrows Bridge
Choose another wonder

Vital Statistics:
Location: Tacoma, Washington, USA
Completion Date: 1940
Cost: $6.4 million
Length: 7,392 feet
Type: Suspension
Purpose: Roadway
Materials: Steel, concrete
Longest Single Span: 2,800 feet
Engineer(s): Leon Moisseiff

On the morning of November 7, 1940, the Tacoma Narrows Bridge twisted violently in 42-mile-per-hour winds and collapsed into the cold waters of the Puget Sound. The disaster -- which luckily took no human lives -- shook the engineering community and forever changed the way bridges were built. Engineer Leon Moisseiff had designed the ultimate in slender bridges. The roadway was a mere 39 feet -- only eight teenagers lying head to toe would fit across the bridge! Moisseiff strengthened his narrow bridge with a solid **steel** girder beneath the roadway. But soon after it opened, the Tacoma Narrows started behaving strangely. Wind caused the bridge to sway back and forth, and it also sent rippling waves along the **deck**. The Tacoma Narrows tore itself apart only four months later.

Years later, engineers found that the solid girders actually blocked the wind and caused the slender bridge to twist. The twisting bridge fanned the steady wind into a swirling motion, which caused the bridge to twist even more -- and eventually snap in two. The Tacoma Narrows Bridge was replaced in 1950 by a new bridge stiffened with a **truss**. Rather than blocking the wind, the open truss allowed the wind to blow through the new bridge.

How could the most "modern" suspension bridge, with the most advanced design, suffer catastrophic failure in a relatively light wind? While even today there is still not a unanimous agreement on why the bridge collapsed. Three key points stand out:

(1) The principal cause of the 1940 Narrows Bridge's failure was its "excessive flexibility;"

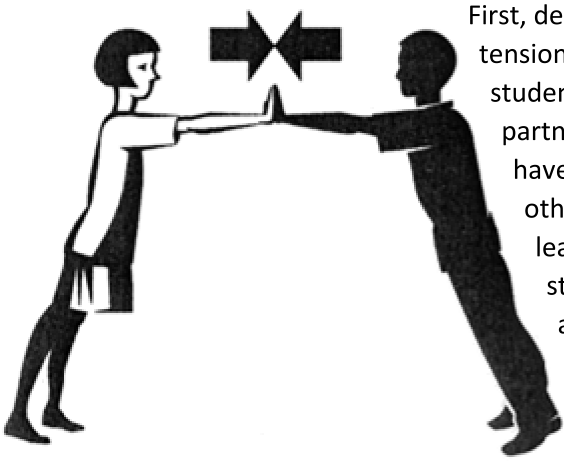
(2) The solid plate girder and deck acted like an aerofoil, creating "drag" and "lift;"

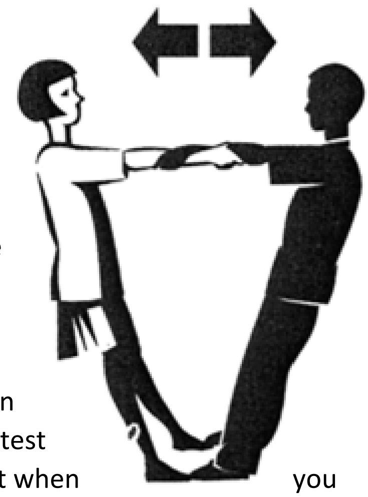
(3) Aerodynamic forces were little understood, and engineers needed to test suspension bridge designs using models in a wind tunnel. [**Now, wind tunnel testing** for aerodynamic effects on bridges is commonplace. In fact, the United States government requires that all bridges built with federal funds must first have their preliminary design subjected to wind tunnel analysis using a 3-dimensional model.]

In other words, Galloping Gertie's twisting induced more twisting, then greater and greater twisting. This increased beyond the bridge structure's strength to resist. Failure resulted.

Watch the fascinating Mysteries at the Museum: Tacoma Narrows Bridge from the Travel Channel video clip with students and quite literally see how she got the nickname 'Galloping Gertie.' What do we learn from the video that we didn't learn from what we've talked about and vice versa? Is it different to talk about the bridge twisting than watch it twist and shudder on video? Why?

Examine the diagrams pictured earlier, and observe how the tension and compression forces are different for each kind of bridge. These pictures show how tension and compression work with each of the different bridge types. In the arch bridge, (first picture, upper left) compression is pushing outward toward either side of the arch. In the truss bridge, (lower left) compression is seen across the top, and tension is felt across the bottom of the span. Tension affects the length of the cables of the suspension bridge (right).





Before the students become "engineers" in this activity, they need a short course in engineering principles and forces that help support bridges. First, demonstrate the forces of tension and compression. Ask students to stand, each having one partner. To demonstrate tension, have each team member grasp the other's forearms. Both students lean back. Their arms should stretch out between them. Go around to several pairs and lean gently on top of their arms to test their "structure". Explain that when you lean on them you are pushing down and causing their arms to stretch, or be put into tension. Have the students remain standing. To demonstrate compression, have partners press the palms of their hands together and lean toward one another. The students will be making an arch with their bodies. Go around to each pair and push on top of the arches. Explain that when you are pushing down you are causing them to push together, or to be put into compression. If time permits, ask students to look for elements under tension and compression in the classroom.

compression:The act of squeezing or pressing together.

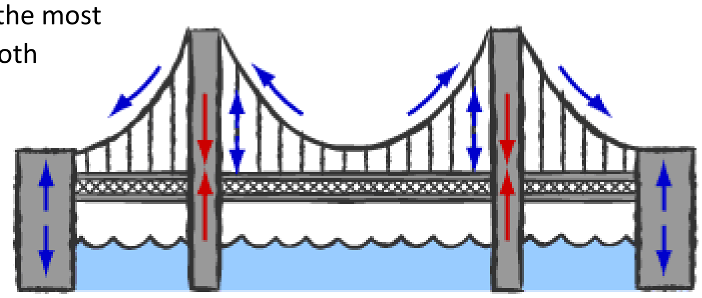
prototype: A model of something to be further developed.

tension: The force on a body that produces strain.

torsion: Strain produced by twisting.

Bridge Tower Challenge

When civil engineers design a bridge, they have to consider both the span and the amount of traffic that can be on the bridge at any one time to determine the weight load. Suspension bridges like the Golden Gate Bridge are designed to span long distances and hold the most weight due to their ability to distribute the load through both cables and towers.



One of the major challenges bridge designers face is constructing towers to support the bridge. In this activity (based on one from NOVA (all rights reserved)), students build structures that recreate problems bridge builders face.

Materials:

- Spaghetti Noodles (approximately 75-100 per group)
- clean, empty half-gallon milk carton, coffee cans, or similar containers (they must all be the same in order to ensure fair competition)
- Masking tape
- Measuring devices, ex. rulers
- standard set of weights (fishing sinkers work well)
- Printouts for recording data
- 6 strips of corrugated cardboard:
  8 cm x 30 cm (3 in. x 12 in.)
  8 cm x 50 cm (3 in. x 20 in.)
  8 cm x 80 cm (3 in. x 31 in.)
  8 cm x 100 cm (3 in. x 39 in.)
  8 cm x 120 cm (3 in. x 47 in.)
  8 cm x 150 cm (3 in. x 59 in.)

Explain to students that they will design and build a model of a bridge tower similar to the towers used in the Golden Gate Bridge. Their challenge is to construct a model tower that balances the longest road possible, supports the most weight possible, and doesn't shift or twist. In the real world, engineers do not have unlimited resources to build a bridge. This activity incorporates calculating costs for materials and staying within a budget.

Divide the students into small groups of 3 or 4. Provide each group with access to a clean, empty half-gallon milk carton or a coffee can, a package of uncooked spaghetti, masking tape, and straws. Give them a copy of the Bridge Tower Challenge handout, which is included.

Tower Criteria:

The structure must:

- Balance the longest road possible.
- Support the most weight possible.
- Prevent twists and turns.

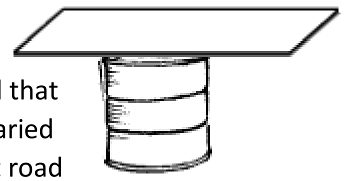
Design Guidelines

- The base of the container must be 30 cm (about 1 ft) above the floor or your desktop.
- The base of the structure should be no wider than the diameter of the can.
- The spaghetti can be cut to any length.
- The spaghetti can be taped at the top and bottom only.
- The coffee can or milk carton must be positioned with the open end facing up so you can add weights to it.

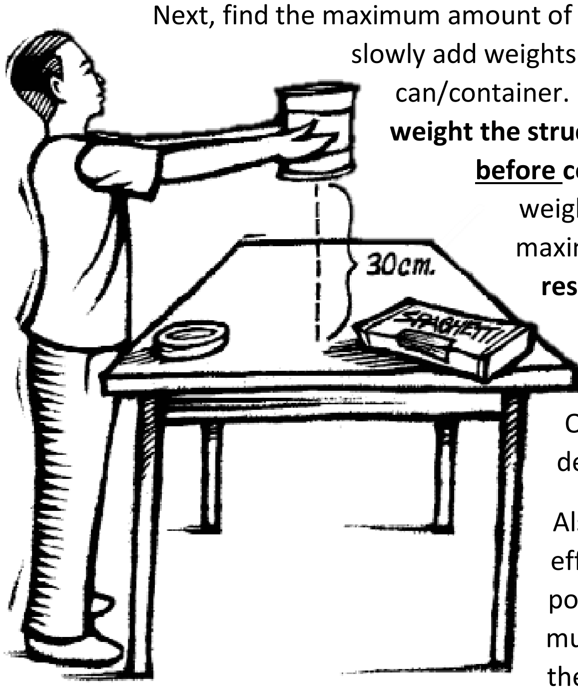
Cut the top of the carton off evenly to create a flat surface to test the span (or use the top of the can). Instruct the students to design a bridge tower that has a clearance of about 30 cm/approx. 1 foot high (younger students can be given a parameter of 9 inches of clearance) by taping the spaghetti noodles to the milk carton or can to serve as supports for the tower.

First, students should look at their materials and think about how they will design their bridge to meet the challenge. Draw their design on a separate sheet of paper.

The spaghetti can be taped to the carton or can, and the container must be positioned with the open side facing up so students can measure the amount of weight it will support. **Record the number of noodles and inches of tape used.**



After you have completed the structure, find the maximum length of cardboard road that can be balanced on top of the coffee can or milk carton. Use strips of cardboard at varied lengths from 12 inches to 36 inches long to test the design that balances the longest road on top of the tower. **Record the road length.**

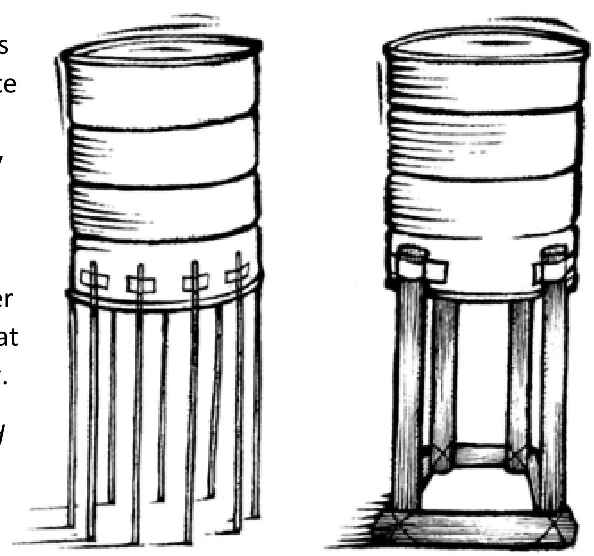


Next, find the maximum amount of weight the structure can support. Remove the road and slowly add weights inside the can/container. **Record the maximum weight the structure can support** <u>**before**</u> **collapsing.** Stop adding weights when it starts to wobble! Retest the road with the maximum amount of weight in the can and **record your results**. Does the length of road, that the bridge is able to carry, increase or decrease when there is weight in the can? Explain.

Number of noodles	Length of road	Number of weights	Length of road with weights

On a separate sheet of paper, have students sketch their design and point out its strengths and weaknesses.

Also, part of the challenge is to construct the most cost-effective bridge possible. Students must also calculate the cost of the materials they use to construct their tower, including any they wasted or broke.



Note: An important aspect of this learning experience is to allow students the opportunity to test and improve their tower designs. Be sure to provide enough time for this process so that students can collaborate and modify their designs if necessary.

Students may begin by placing individual pasta strands around the base of the can or by building a cube-like structure as shown in the images. Students will/may discover that the best way to enhance the strength of pasta and prevent *torsion is to make bundles of noodles and to use triangulation. The triangle shape, in combination with the bundles of noodles, greatly improves the tensile and compressive strengths of pasta. By adding weight to the can, students will find that the length of road the structure can support increases. The weight increases stability by compressing each leg of the triangle on its adjoining legs and preventing the materials from twisting.*

Adding weight to the coffee can stabilizes the base of the bridge tower, which in turn stabilizes the cable structure that holds up the road. The weight prevents torsion of the tower and also acts as a huge compressive force so that the entire tower stays in place.

When all of the groups have completed their towers, host a competition/compare data to see which tower supports the most weight and span at the lowest cost (they must include the cost of any supplies they wasted or broke!) Provide time for each group to present their tower, explain their rationale for the design, and demonstrate the weight and span it will support to the class. The group that constructs the strongest tower at the lowest cost will win the challenge.

After each team has completed their structure, have the class compare and analyze each team design. Which design held the most weight? How could the design that held the least weight be improved? Which design balanced the longest road? Which designs appears to twist and turn under weight? Which designs prevent twisting?

After analyzing each design, have students suggest two ways they would improve their designs.

Bridge Tower Challenge!

The Problem: In a suspension bridge, the middle supports are called towers. Long steel cables are strung over the towers and secured to anchors at both ends of the bridge. Your city has decided to construct a suspension bridge across a large lake that is almost one mile wide.

They must construct a bridge that will span the width of the lake, support the weight of the cars that will travel across the bridge, and not shift or twist.

The Challenge: Congratulations! A representative from the city has contacted you. Your team is a finalist in a bridge design competition. Your final task is to design and build a model of a bridge tower that will support the length and load of this suspension bridge.

The Materials: You will use spaghetti noodles to represent the beams that will be secured to the foundation of the bridge, a milk carton to represent the top of the tower where the cable will be attached, and masking tape. You may use no more than 100 spaghetti noodles and 2 straws. You may only use the tape to secure the spaghetti noodles to the can.

The Cost: Your bridge tower must be cost efficient to build.

You have a budget of $70,000 for each tower.

Using the cost of materials below, calculate the cost of your tower.

Beams (spaghetti noodles) = $500 each

Support beams (straws) = $1,500 each

Securing rods (masking tape) = $300/inch

Tower (milk carton) = $10,000

Brainstorm, Design and Build!

What design do you think would be the best for this challenge? Sketch your bridge design on a piece of paper and identify some ways that you might make it strong enough to support the most weight and the longest road possible within your budget. Build your model and test it to see if you will get the job!

Name___________________________

Bridge Tower Challenge

Group	Span	Weight	Cost

Which team will get the contract? Why do you think this design is the best?

Day Seventeen & Eighteen K-8 Standard Alignment

K

- 7.T/E.2 Apply engineering design and creative thinking to solve practical problems.
- 7.T/E.3 Use tools to measure materials and construct simple products.

These standards will be met and reinforced (and used as a guideline for student outputs and expectations) while students work as bridge engineers and build models of bridge towers to meet the parameters of the challenge while trying to stay within budget.

1

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3

- 7.T/E.2 Design a tool or a process that addresses an identified problem.
- 7.T/E.5 Apply a creative design strategy to solve a particular problem.

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6

- 7.T/E.1 Use appropriate tools to test for strength, hardness, and flexibility of materials.
- 7.T/E.2 Apply the engineering design process to construct a prototype that meets certain specifications.

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7

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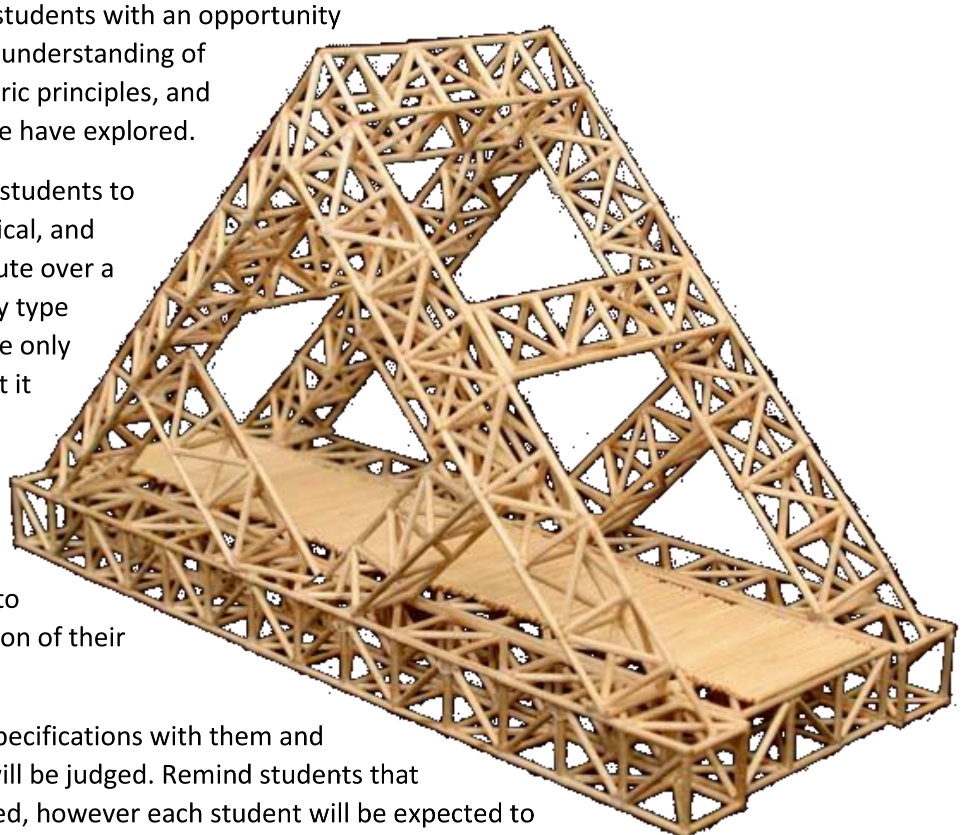
8

- 7.T/E.1 Use appropriate tools to test for strength, hardness, and flexibility of materials.
- 7.T/E.2 Apply the engineering design process to construct a prototype that meets certain specifications.
- 2.1.1 Apply a decision making process to personal or group financial choices.

These standards will be met and reinforced (and used as a guideline for student outputs and expectations) while students work as bridge engineers and build models of bridge towers to meet the parameters of the challenge while trying to stay within budget.

Days 19-22: A Test of Truss: Toothpick Bridge Challenge



This culminating activity provides students with an opportunity to demonstrate their learning and understanding of the different bridge types, geometric principles, and engineering concepts of bridges we have explored.

The goal of the competition is for students to design the most efficient, economical, and aesthetic bridge as an overland route over a waterway. Students can design any type of bridge they choose, however the only materials they can use to construct it are round toothpicks (a maximum of 1000) and Elmer's Glue-All or Craft Glue.

Provide the Toothpick Bridge Competition handout to students to guide them through the construction of their bridges.

Go over (and explain) the bridge specifications with them and the criteria by which the bridges will be judged. Remind students that parental participation is encouraged, however each student will be expected to present his/her bridge at the competition and describe the rationale for the design.

Tips: Students, especially younger students, may be more successful if they plan their bridge construction on graph paper first. Then, place a piece of waxed paper over the graph paper so that they can construct right over their blueprint plans.

There is an abundance of research that demonstrates the positive effects of parental involvement on student achievement and social and emotional growth. The most accurate predictor of a student's achievement in school is not income or social status but how the family supports learning at home. With a bit of guidance and clear expectations, you can help parents foster a home environment that encourages learning and creativity. Provide the Parent Letter for students to take home with the Toothpick Bridge Competition Guidelines (handouts). Communicate to parents what their children have learned and enable them to apply the science math, and engineering concepts even further in an at-home activity that students will present during the competition.

Toothpick Bridge Competition!

The Challenge: Your challenge is to construct a bridge that will serve as an overland route over a waterway. The goal is to design and create the most efficient, economical and aesthetic bridge possible using only toothpicks and glue.

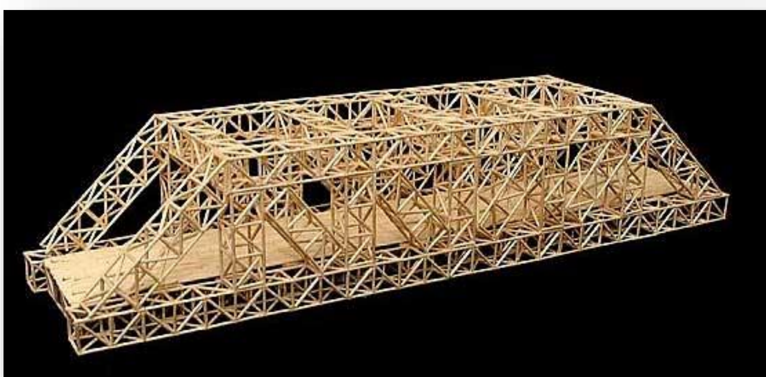
The Criteria: The structural efficiency is equal to the weight supported divided by the weight of the bridge. The aesthetics of the bridge will be determined through visual appeal, uniqueness, neatness and symmetry. The bridge will also be judged on cost effectiveness.

Points will be awarded for presentation and presentation materials. Presentations should be no longer than ten (10) minutes in length and include reasons for why your particular bridge design was chosen over another, your research into bridge designs, strength of shapes and the forces that act on structures, bridge cost information, cost effectiveness predictions, strength ratio data, graphs and pertinent career information.

The Specifications:

• Span: The bridge must have a minimum clear span of 12 inches in length, and rest on abutments on either side of the river. The abutments are to be part of the bridge.

• Vehicle Deck: The bridge deck must be at least 1.5 inches wide. This will be tested with a matchbox car. The deck must be solid so that the car can travel the length of the bridge. The loading block will also be placed on the deck.

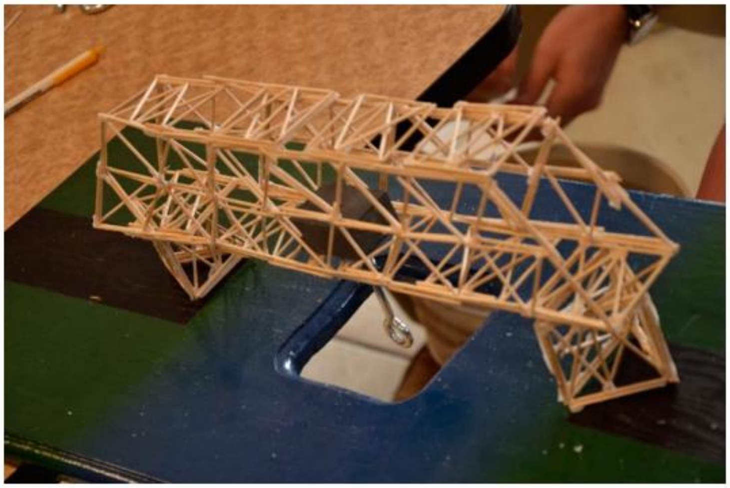


• Bridge Width: The maximum width of the bridge is 2.5 inches.

• Boat Clearance: The bridge must be more than 2 inches above the 'water'. A 2 inch high boat must pass unobstructed underneath the bridge.

• Bridge Height: The maximum height of the bridge is 8 inches from the river surface.

• Loading Connection: The bridge must be able to accommodate the loading block (1.5 inches by 2 inches) or a bar can be placed across the bridge to hold the weight for testing at the midpoint of the



deck. The loading block or support bar will be placed on the vehicle deck of the bridge (the same place the matchbox car travels). A hole in the center of the bridge MUST allow for a 1/4 inch rod to pass through the vehicle deck. (See the Loading Block Connection Photo.)

Material Specifications:

• Round uncoated toothpicks (maximum 1000 toothpicks)

• Elmer's white glue or Craft Glue (as determined by the competition). *Epoxy, wood glue, hot glue, paint and super glues are not permitted. Do NOT coat the bridge with any material (paint, stain or glue).*

• (Modification for Younger Students) Mini marshmallows (ex. 50 per student group) Note: this is approximately ½ cup per student or a 1-pound bag for every 20 students.-- *Prepare the marshmallows. Spread marshmallows on paper towels and air dry for 3–4 days. This gives the marshmallows a stiff texture that is easier to work with and easier to clean up.*

• Binder Clips: only for support! Not as part of the final design

Optional Material Additions (to be determined by the competition): *basswood strips, and balsa strips*

Any bridge not meeting the material specifications will be penalized.

Strength Ratio Predictions:

Make strength ratio predictions using the weight of your bridge and the following weights, 10lbs, 20lbs, 30lbs, 40lbs, 50lbs, 60lbs and 70lbs.

• Strength ratio is determined by dividing the weight of the bridge by weight held.

• Show your results graphically. Be prepared to share your results with the judges.

Bridge Cost: Calculate the cost of your bridge by using the following Cost Specifications:

$50 for 10 Toothpicks

$50 for 1oz of Glue

Option: You can also charge students for an 'engineering consultation.' The possibilities are endless.

Cost Effectiveness Predictions:

• Make cost effectiveness ratio predictions using the total cost of your bridge and the following weights, 10lbs, 20lbs, 30lbs, 40lbs, 50lbs, 60lbs and 70lbs.

• Cost effectiveness is determined by dividing the total cost of the bridge by weight held.

• Show your results graphically. Be prepared to share your results with the judges.

Figure 3 - Loading Block Connection

Testing Procedures:

1. All bridges will be weighed and measured for compliance with the bridge specifications. Bridges that are completed but do not meet the bridge specifications can be penalized up to **ten** points.

2. The loading block and testing apparatus will be provided and may not be altered.

3. During the testing of the bridge, the bridge will be placed in the center of the testing apparatus.

4. The load will be applied to a 1.5 inches wide by 2 inches long by 1 inch high loading block resting midway in the river. A hole in the center of the bridge must allow a 1/4 inch rod to pass through.

5. Pulling force will be applied straight down by a pulling cable until the structure exceeds the acceptable deflection (0.75 inches at the center) or until obvious structural collapse.

The total load incorporates the total mass of the loading apparatus, bucket and sand.

The Competition:

On the day of the competition your bridge will be examined for appearance, adherence to bridge specifications, and strength. Your bridge will be evaluated on each of the following categories:

1. Aesthetics (5 points)
2. Presentation (15 points)
    a. Presentation must include the total cost for your project, cost effectiveness predictions and graph, strength ratio data and strength ratio graph.
    b. Share the process used to determine the bridge design you created.
    c. Refer to the career titles explored in your research when you present your bridge.

3. Bridge Specifications (10 points)

    a. Clear Span (needs to be at least 12 inches)

    b. Vehicle Deck (needs to be at least 1.5 inches wide for matchbox car)

    c. Bridge Width (maximum width is 2.5 inches wide)

    d. Boat Clearance (at least 2 inches clear distance from table top)

    e. Bridge Height (maximum of 8 inches tall)

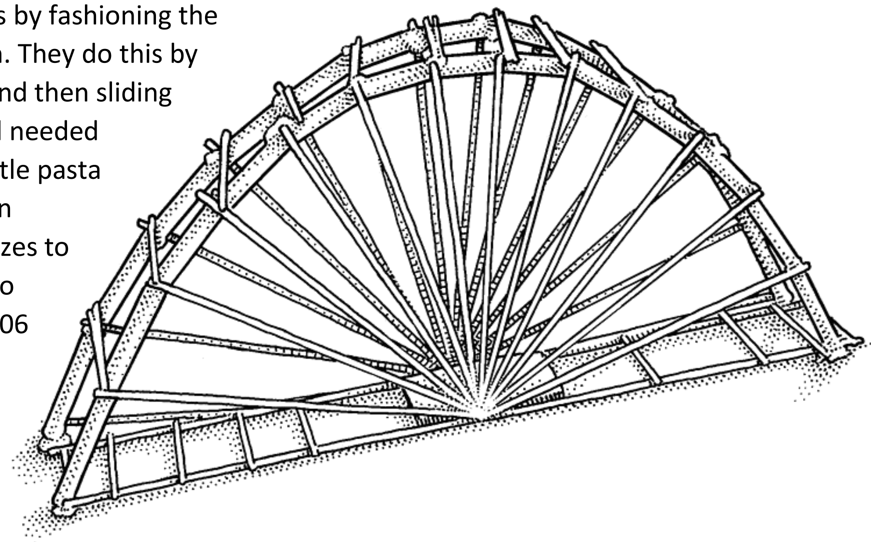
    f. Loading Connection (accommodates the loading block on top of vehicle deck)

4. Strength Points (10 points)

5. Cost Effectiveness Points (10points)

6. In the event of a tie the lightest bridge will be the winner.

Variation: Students must build the strongest span (20 inches or longer) out of a brittle substance: dry spaghetti. Students can bolster their bridges by fashioning the spaghetti into hollow tubes, such as on the arch. They do this by placing strands around a pencil, applying glue and then sliding the pencil out. In other spots, thick bundles add needed strength. It is still "mind-blowing" that thin, brittle pasta can bear so much weight: a contest at Okanagan College in British Columbia that awards cash prizes to contestants who range from middle-schoolers to graduate students' current record was set in 2006 at 978 pounds with the bridge weighing more than 2 pounds and spanning more than 39 inches.



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Provide the Toothpick Bridge Competition (handout) to students to guide them through the construction of their bridges. Explain the bridge specifications with them and the criteria by which the bridges will be judged. Remind students that you encourage parental participation, however each student will be expected to present his/her bridge at the competition and describe the rationale for the design.

Share and discuss the Toothpick Bridge Judging Rubric (handout) with the students so that the expectations are clearly communicated.

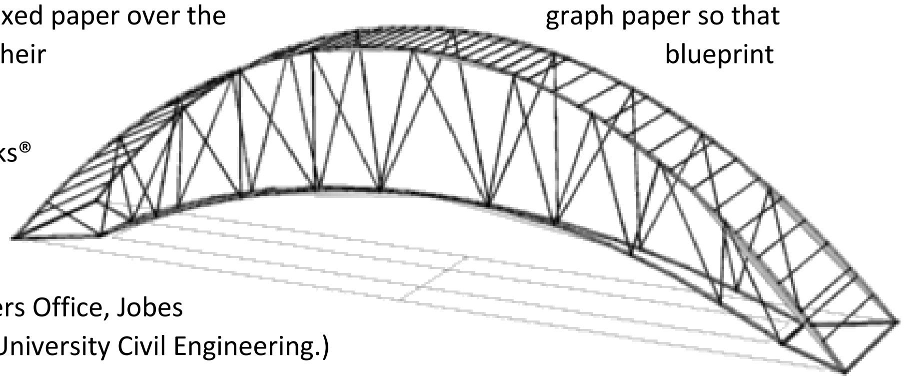
Home & School Connection

There is an abundance of research that demonstrates the positive effects of parental involvement on student achievement and social and emotional growth. The most accurate predictor of a student's achievement in school is not income or social status but how the family supports learning at home. With a bit of guidance and clear expectations, you can help parents foster a home environment that encourages learning and creativity.

Helpful hints for a successful competition:

- The bridge support platform (see Toothpick Bridge Challenge handout) can be replaced with two strong tables and a two little pieces of sandpaper.
- The loading block can easily be created or can be replaced with a small chain and carabineer clip that can be clipped through the chain and onto the bucket handle.

- You can use sand or weight in the bucket to test the load; be sure to place a tablecloth under the tables.
- Younger students may be more successful if they plan their bridge construction on graph paper first. Then, place a piece of waxed paper over the graph paper so that they can construct right over their blueprint plans.

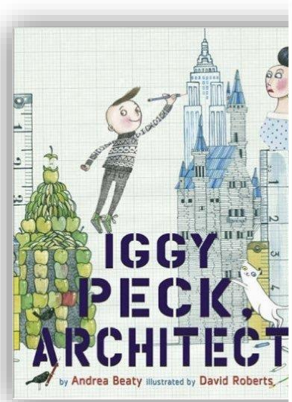


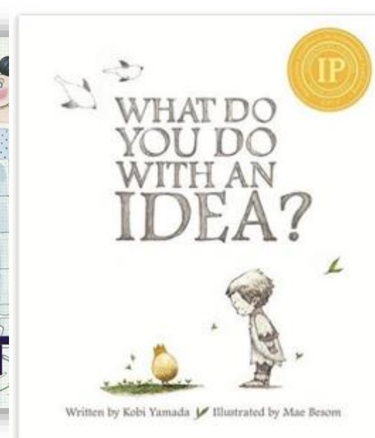
*This activity is provided by The Works® Ohio Center for History, Art & Technology. Toothpick Bridge Challenge rules and specifications sponsored by: Licking County Engineers Office, Jobes Henderson and Associates and Ohio University Civil Engineering.)

Literature Link: To help inspire students when the going gets a little tough and help them learn to persevere through challenges and challenging projects (and help counteract the idea that if they don't get something right the first time then they should just give it up and try something else) you may want to read a book, such as the charming *The Most Magnificent Thing* by Ashley Spires.

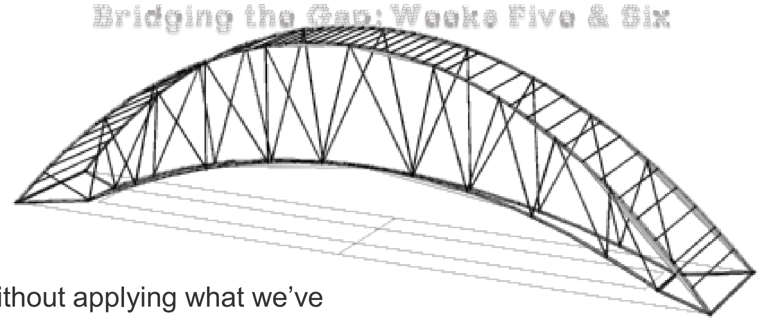
Award-winning author and illustrator Ashley Spires has created a charming picture book about an unnamed girl and her very best friend, who happens to be a dog. The girl has a wonderful idea. "She is going to make the most MAGNIFICENT thing! She knows just how it will look. She knows just how it will work. All she has to do is make it, and she makes things all the time. Easy-peasy!" But making her magnificent thing is anything but easy, and the girl tries and fails, repeatedly. Eventually, the girl gets really, really mad. She is so mad, in fact, that she quits. But after her dog convinces her to take a walk, she comes back to her project with renewed enthusiasm and manages to get it just right.

This funny book offers a perfect example of the rewards of perseverance and creativity. The clever use of verbs in groups of threes is both fun and functional, offering opportunities for wonderful vocabulary enrichment. The girl doesn't just "make" her magnificent thing -- she "tinkers and hammers and measures," she "smooths and wrenches and fiddles," she "twists and tweaks and fastens."





Also recommended are books such as *What Do You Do With an Idea?* by Kobi Yamada and *Iggy Peck, Architect* by Andrea Beaty.



Tip Sheet: How to Build a Toothpick Bridge

The process is pretty simple, but you must do it correctly! Attempting to do it with no understanding of how we need to make it or without applying what we've learned so far will result in a flimsy bridge. So, here are some basic tips.

Build a Support Structure

There are many possible designs for a bridge, but, as we know, a truss bridge is one of the sturdiest. The continually subdivided reinforcement pieces divide the weight more evenly, and that allows for a more stable bridge. Also, make sure to use a group of toothpicks stuck together. If you only use a single toothpick for each support beam, it won't hold up very well. The ultimate goal is to build a bridge that is strong, but is light as possible.

Tip: Make easier building blocks by first gluing toothpick 'head to toe', as it were, and by putting the fat end and the skinny end together, we get a uniform width, flat, and stronger, building block.

Basic Tips for Construction

1. Plan before you build. Use graph paper! Don't haphazardly start throwing toothpicks together. Instead study different designs and have a diagram of how you want it to look beforehand. Ex. Draw out your truss/design of each component on graph paper, then put wax paper over the top and build it, following the lines!
2. Know your limits. You'll be given a limited number of toothpicks. You have to make sure you don't run out of them along the way. Plan out how many toothpicks will be used in each place & component.
3. Don't be afraid to be creative! SOMETHING will go wrong when you build your toothpick bridge. You'll have to improvise often if you want to succeed.
4. Wet glue is not sticky enough! Wait till the first layer of glue is dry before continuing to add on to your bridge
5. Every glue joint is important. Think of each place where building blocks are glued together as 'rivets' in your bridge. *Remember that bridges built at the last minute may not dry properly to get full strength.*
6. The spacing between the intersections of toothpicks greatly affects the strength of your toothpick bridge. Build it as uniform and thick as possible.
7. Make sure your toothpick isn't too brittle. Bent it a little to make sure it doesn't snap instantly.

8. There is an amazing ally in the fight for great glue joints. Alligator clips! Also, pins, waxed paper, and paper clips are a great help to holding things in place while the glue dries, but cannot be a part of your final bridge design.

9. Test! Test! Test! You should know when the maximum weight is reached **before** the competition. This will help you, ex. You may notice that the struts start to buckle. Your next step will be to beef up the struts! The bridge will start to bend before it breaks. When bending begins, you should avoid putting on any more weight, as that will likely cause it to snap.

Note: Most likely there will be bridges that are "overbuilt," that is they use a lot of materials but don't seem to hold many more pennies. There may also be some bridges that seem really efficient, that is they hold a lot of pennies without using many materials.

Describe it!

Have students use the questions below to guide their description of their bridge.

- Where is the bridge located?
- What obstacle does the bridge cross?
- When was the bridge built?
- What materials were used to construct the bridge? (What materials would be used in construction of the life-size bridge based on the model built?)
- Which of the basic bridge types best describes the bridge?
- What types of traffic use the bridge? (Imagine)
- What is the name of the engineer or engineering firm who designed this bridge?
- Why do you think the engineer(s) built this type of bridge for this site?
- What were the special challenges that the architects and engineers faced while designing and building this bridge?
- How did they overcome those challenges?
- Do you have any interesting stories or fun facts about this bridge?
- Do you like the way the bridge looks? Why or why not?

Criteria:					Score
Presentation (15 points)	Preparation minimal; no eye contact, disorganized (2 points)	Presentation is somewhat organized and contains few of the required elements. (6 points)	Presentation is mostly organized, and includes most of the required elements (11 points)	Enthusiastic, well – prepared, organized, all team participates, includes design process, strength graph, bridge terminology, and total cost. (15 points)	
Appearance (5 points)	Bridge is messy, not clean, with extra glue and/or toothpicks (0 points)	Bridge has some appealing qualities, but is mostly messy and very clean (1 point)	Bridge has many appealing visual qualities, but still has one or two messy areas (3 points)	Bridge is neat and clean, no extra glue, toothpicks out of place (5 points)	
Bridge criteria (10 points)					
Clear span	Does not meet criteria (0 points)			Meets criteria (1 point)	
Vehicle Deck	Does not meet criteria (0 points)			Meets criteria (1 point)	
Bridge Width	Does not meet criteria (0 points)			Meets criteria (1 point)	
Boat Clearance	Does not meet criteria (0 points)			Meets criteria (1 point)	
Bridge Height	Does not meet criteria (0 points)			Meets criteria (1 point)	
Loading connection	Does not meet criteria (0 points)			Meets criteria (5 points)	
Strength Points (10 points) Given as [(team ratio/maximum ratio) *10]					
Team ratio:		Max ratio:		Points:	
Cost Effectiveness (10 points) (cost of bridge/weight held) Given as [(team cost effectiveness/maximum cost effectiveness)*10]					

Bridge Challenge Parent Letter

Dear Parent or Guardian,

The past few weeks, we have been studying bridges and the scientific principles involved in their design and construction. We have learned about some famous bridges that have had a significant impact on the economy, transportation system, and engineering advances all around the world. We encourage you to have a conversation with your child and give him/her an opportunity to share this new learning with you.

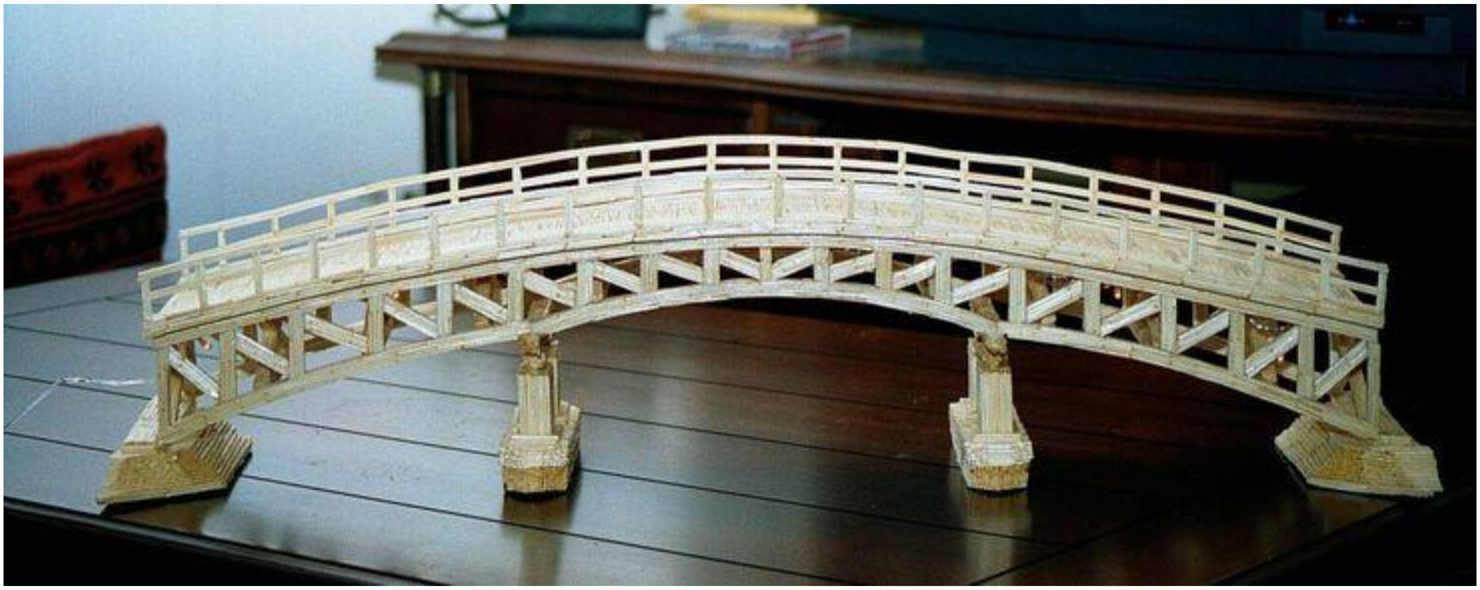
As a culminating activity for this learning experience, a Toothpick Bridge Competition is scheduled for ___________________________. This is an exciting event that will provide students with an opportunity to demonstrate their learning and understanding of different bridge types, geometric principles and engineering concepts of bridges. The goal of the competition is for students to design the most efficient, economical, and aesthetic bridge as an overland route over a waterway. Students can design any type of bridge they choose, however the only materials they can use to construct it are toothpicks and craft glue or glue-all.

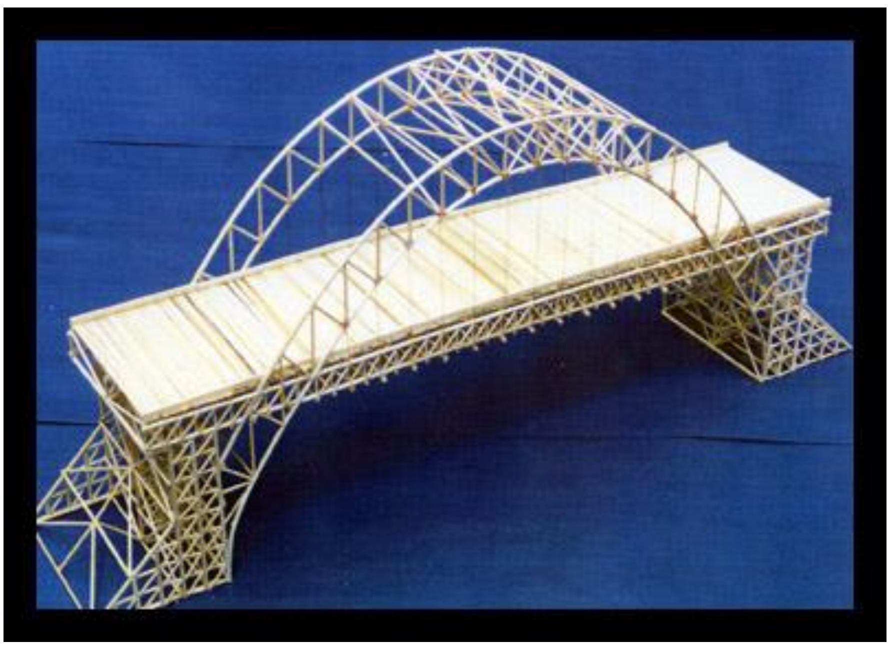
Each student will be judged on both the bridge and the presentation that includes the reasons for why the bridge design was chosen over another, important research of bridge designs, strength of shapes and the forces that act on structures, bridge cost information, cost effectiveness predictions, strength ratio data, graphs and pertinent career information.

A separate information sheet provides all of the details about the Toothpick Bridge Competition specifications, guidelines, and evaluation. Please take some time to review this information with your child so that you can plan the research and construction effectively.

There is an abundance of research that demonstrates the positive effects of parental involvement on student achievement and social and emotional growth. The most accurate predictor of a student's achievement in school is not income or social status but how the family supports learning at home. We hope you will embrace this opportunity and enjoy working with your child on this valuable learning experience. Thank you for your continued support.

Sincerely,





Variation: Popsicle Bridge Challenge

Image via: Scholastic.com. All rights reserved.

One set of materials for each group of students:

- 200 popsicle sticks
- Craft glue or glue all for younger students
- Option: Hot glue—please check before using the contest parameters. Also, hot glue must be in the control of instructors or parents, not students.
- Standard 5 and 20 pound weight (box of sugar, exercise weight, or another weight that can be standardized)
- Graph Paper
- Pencils
- Binder Clips—solely for help while building—not part of final design.

Challenge:

Your engineering team has several missions to complete. You will design and present a prototype bridge designs in order to "sell" your plans to the clients.

- very stable
- support large amounts of traffic
- elegant design
- low cost for most safety

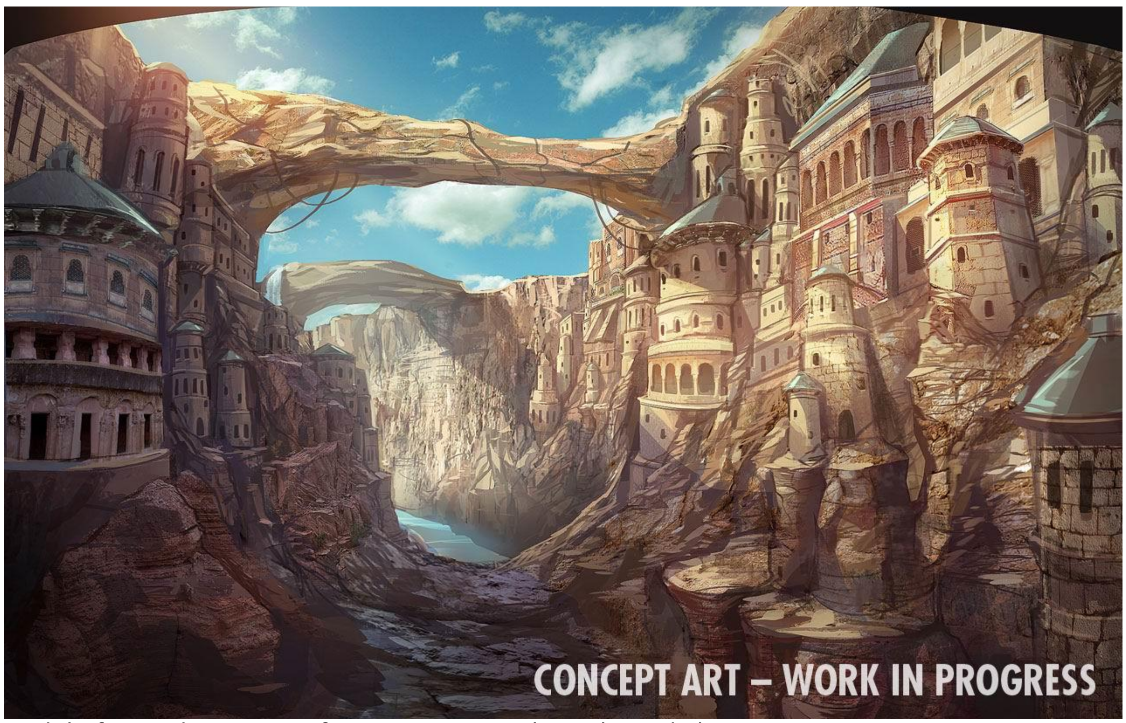
An engineer's masterful grasp of physics, the properties and availability of various building materials, and construction techniques has made it possible to build modern bridges that carry heavier loads, span greater distances, and use less material than ever before. In determining which of the three basic bridge designs to use when building a bridge, an engineer must consider, among other things, the length of the span, the surrounding terrain, the bridge's intended use, and the cost of materials and labor.

Beam bridges, the simplest and most cost-effective kind of span, consist of beams made of wood, iron, or steel--the stiffer, the better--laid horizontally atop evenly spaced supports called piers. Although single-beam bridges rarely span longer than 200 feet, bridges made by joining several beams can run almost endlessly. Stiffening trusses may be added to help the bridge support heavier loads.

Arch bridges, typically steel or stone structures, are easily identified by their graceful, curved shape. Capable of spanning longer distances--200 to 800 feet--without the use of intermediate support piers, these compressive structures can be built high over deep rivers or gorges. Fixed supports, called abutments, at each end of an arch prevent it from spreading apart at its base.

A suspension bridge's signature features--its long steel cables and rising towers--support the weight of a suspended deck and the traffic it's designed to carry. The cables are anchored at each end of the bridge into solid concrete blocks, which pull on the suspension cables and keep them taut. Capable of spanning more than a mile, suspension bridges are often used over large bodies of water, like harbor entrances. Because suspension bridges typically have only two foundational piers, on top of which the towers stand, obstacles to shipping activity passing below the deck are minimized.

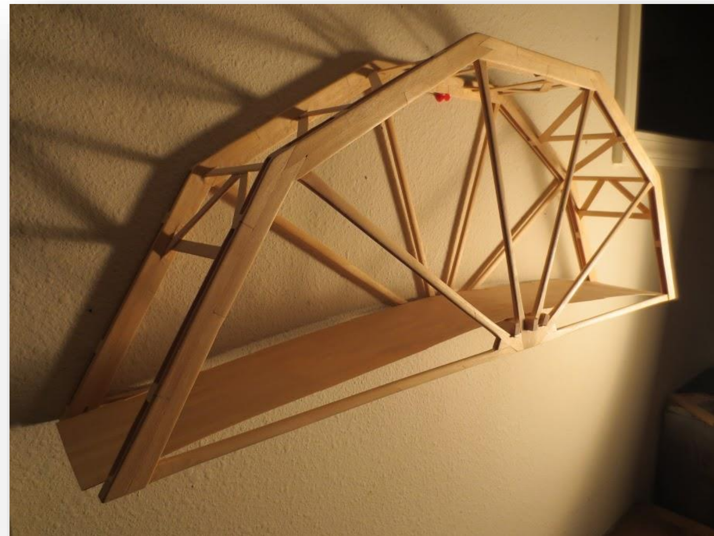
Welcome to the Great Divide!



You got here just in time. This growing community needs four new bridges, and they're very picky about what they want! You are part of a team of engineers who have been given the challenge to design a bridge. But first you're going to build a model of your design out of up to 200 Popsicle sticks and glue.

Problem Definition: Design a Bridge to span a given distance while supporting a maximum load u sing a minimum of materials.

Bridges must be able to hold a specific weight (your teacher will decide what the weight goal will be for your class based on the parameters for the large competition). 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.



This example is 30 inches long, 11 inches tall, 5 inches wide, weighs just under 347 grams (0.77 pounds), is made out of only white birch Popsicle Sticks and Elmer's White Glue, and it held 993 pounds before breaking (1300 times its own weight)

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.
4. 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.
5. 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 and stay within budget.
6. Students meet and develop a plan for their bridge. They draw their plan, and then present their plan to the class.
7. Student groups next execute their plans. They may need to rethink their design, or even start over.
8. 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.
9. 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.

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.
- If students finish early, they can write a hypothesis of how much weight they think their bridge can support and their rationale.
- Students can also use pushpins and paper to label the various parts of their bridge.

Structural Test

Have each group present their bridge and test it using increasingly heavy weights. As each group presents their bridge, students discuss which elements of bridge construction they incorporated and why.

As students test their bridges, record the data on your whiteboard, ex. using the Engineering a Bridge Sheet. Record the type of bridge, elements of the bridge (arch, beam, deck, column, fixed arch, footing, portal, strut), number of popsicles, maximum weight that each bridge held, weaknesses, and strengths of the bridge. Then create multiple ways to show the same information. Discuss why you might want to use each representation.

Engineering a Bridge

Test your model bridge and record the type of bridge, maximum weight that each bridge held, and other details about your model. Then create multiple ways to show the same information.

Team	Type of Bridge	Elements of the Bridge	Number of Popsicle Sticks	Maximum Weight	Weaknesses	Strengths
1						
2						
3						
4						
5						
6						
7						

Days 19-22 K-8 Standard Alignment

K

- 7.T/E.2 Apply engineering design and creative thinking to solve practical problems.
- 7.T/E.3 Use tools to measure materials and construct simple products.

These standards will be met and reinforced (and used as a guideline for student outputs and expectations) while students work as bridge engineers (using the engineering design process) and build models of bridges with toothpicks/popsicle sticks and glue to meet the parameters of the challenge.

1

- 7.T/E.2 Apply engineering design and creative thinking to solve practical problems.
- 7.T/E.3 Use tools to measure materials and construct simple products.
- 7.1.3 Make diagrams to record and communicate observations.

These standards will be met and reinforced (and used as a guideline for student outputs and expectations) while students work as bridge engineers (using the engineering design process) and build models of bridges with toothpicks/popsicle sticks and glue to meet the parameters of the challenge.

2

- 7.T/E.2 Apply engineering design and creative thinking to solve practical problems.
- 7.T/E.3 Use tools to measure materials and construct simple products.
- 7.12.2 Describe what happens when an object is dropped and record the observations, e.g. in a science notebook.

These standards will be met and reinforced (and used as a guideline for student outputs and expectations) while students work as bridge engineers (using the engineering design process) and build models of bridges with toothpicks/popsicle sticks and glue to meet the parameters of the challenge.

3

- 7.T/E.2 Design a tool or a process that addresses an identified problem.
- 7.T/E.5 Apply a creative design strategy to solve a particular problem.
- 7.T/E.3 Determine (and use) criteria to evaluate the effectiveness of a solution to a specified problem.
- 7.T/E.4 Evaluate an invention (including their own) that solves a problem and determine ways to improve the design.

These standards will be met and reinforced (and used as a guideline for student outputs and expectations) while students work as bridge engineers (using the engineering design process) and build models of bridges with toothpicks/popsicle sticks and glue to meet the parameters of the challenge.

4

- 7.T/E.2 Design a tool or a process that addresses an identified problem.
- 7.T/E.5 Apply a creative design strategy to solve a particular problem.

- 7.T/E.3 Determine (and use) criteria to evaluate the effectiveness of a solution to a specified problem.
- 7.T/E.4 Evaluate an invention (including their own) that solves a problem and determine ways to improve the design.

These standards will be met and reinforced (and used as a guideline for student outputs and expectations) while students work as bridge engineers (using the engineering design process) and build models of bridges with toothpicks/popsicle sticks and glue to meet the parameters of the challenge.

5

- 7.T/E.2 Design a tool or a process that addresses an identified problem.
- 7.T/E.5 Apply a creative design strategy to solve a particular problem.
- 7.T/E.3 Determine (and use) criteria to evaluate the effectiveness of a solution to a specified problem.
- 7.T/E.4 Evaluate an invention (including their own) that solves a problem and determine ways to improve the design.
- 7.12.2 Identify the force that causes objects to fall to the earth.

These standards will be met and reinforced (and used as a guideline for student outputs and expectations) while students work as bridge engineers (using the engineering design process) and build models of bridges with toothpicks/popsicle sticks and glue to meet the parameters of the challenge.

6

- 7.T/E.1 Use appropriate tools to test for strength, hardness, and flexibility of materials.
- 7.T/E.2a Know that the engineering design process involves an ongoing series of events that incorporate design constraints, model building, testing, evaluating, modifying, and retesting.
- 7.T/E.2b Apply the engineering design process to construct a prototype that meets certain specifications.

These standards will be met and reinforced (and used as a guideline for student outputs and expectations) while students work as bridge engineers (using the engineering design process) and build models of bridges with toothpicks/popsicle sticks and glue to meet the parameters of the challenge.

7

- 7.T/E.1 Use appropriate tools to test for strength, hardness, and flexibility of materials.
- 7.T/E.2a Know that the engineering design process involves an ongoing series of events that incorporate design constraints, model building, testing, evaluating, modifying, and retesting.
- 7.T/E.2b Apply the engineering design process to construct a prototype that meets certain specifications.

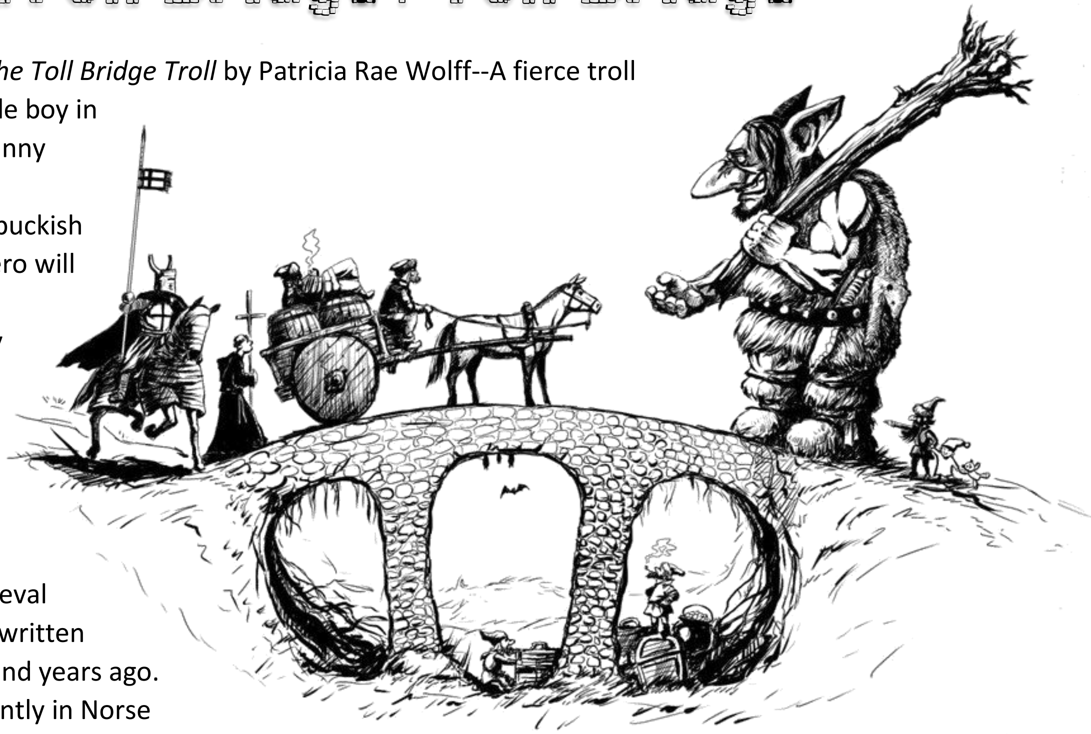
These standards will be met and reinforced (and used as a guideline for student outputs and expectations) while students work as bridge engineers (using the engineering design process) and build models of bridges with toothpicks/popsicle sticks and glue to meet the parameters of the challenge.

8

- 7.T/E.1 Use appropriate tools to test for strength, hardness, and flexibility of materials.
- 7.T/E.2a Know that the engineering design process involves an ongoing series of events that incorporate design constraints, model building, testing, evaluating, modifying, and retesting.
- 7.T/E.2b Apply the engineering design process to construct a prototype that meets certain specifications.
- 1.Inq.7 Record observations and/or data using correct scientific units and significant figures.

These standards will be met and reinforced (and used as a guideline for student outputs and expectations) while students work as bridge engineers (using the engineering design process) and build models of bridges with toothpicks/popsicle sticks and glue to meet the parameters of the challenge.

Day 23: Troll Bridge? Toll Bridge



Fun Literature Link: *The Toll Bridge Troll* by Patricia Rae Wolff--A fierce troll challenges a smart little boy in this book filled with funny riddles and rebus-like drawings. "The swift, puckish story and its plucky hero will appeal tremendously, especially to the many children inspired to play toll-bridge by *The Three Billy Goats Gruff*."

What is a troll? Trolls come to us from medieval Scandinavian legends written more than one thousand years ago. They appeared frequently in Norse mythology. According to the legends trolls were often extremely old, had great strength, and were master builders and skilled craftsmen. Some trolls lived under bridges. They didn't like light—sometimes turning into stone when exposed to sunlight. Trolls that lived under bridges usually lived alone. They were not considered very smart and they could be hard to get along with. Trolls were sometimes mischievous—playing tricks on people they met.

Teaching the Bridge Troll to read. Art by Marco Bucci

Travelers who wanted to cross their bridges were sometimes required to the troll a 'toll,' (note: there is no etymological connection between toll (of Greek origins) and troll (of Scandinavian origins)—they're just fun to put together) in other words, pay money or perform tasks as "payment" for crossing the bridge.

How did the Oakland Bay Bridge get a troll? On October 17, 1989, the Loma Prieta earthquake knocked a 50-foot piece of the east span off its supports and onto the deck below. While the bridge was being repaired, after the earthquake, a group of ironworkers created the Bay Bridge Troll. The troll holds a long wrench and was attached to the side of the bridge (without permission) near the part that collapsed to bring good luck. The Troll arrived in secret on the bridge, without authorization from Caltrans officials, and remained relatively low-key until the *San Francisco Chronicle* brought him to public attention in 1990. (While no causal relationship can be established between the presence of the Bay Bridge troll and the absence of any earthquake-related interruptions to the Bay Bridge's service during the past 24 years, the correlation cannot be denied.) Watch a video about it here.

Who made the troll? Bill Roan, a local blacksmith, designed the troll and sculpted it along with several of his co-workers. After the bridge collapsed he suggested that the repaired bridge needed a protector, like a gargoyle (an imaginary creature believed to scare evil spirits away), that he could make out of steel. He reportedly modeled the troll after the troll who lived beneath the bridge in the Norwegian fairy tale, Three Billy Goats Gruff, a story where three goats outwit a troll in order to cross a bridge.

Other famous infrastructure projects also have guardian trolls. For instance, Seattle's George Washington Memorial Bridge (also known as the Aurora Bridge) has the famous Fremont Troll, which patrols the underpass on North 36th Street. Sculpted from steel and concrete, and designed to look like a "grumpy old man," the Fremont Troll (named for the Seattle neighborhood in which it is located) is large enough to climb on, and too big to have snuck onto the scene. Rather, the nonprofit Fremont Arts Council commissioned the statue in 1990, in an effort to revitalize the blighted underpass. Today, the troll provides a place for children and adults to scramble and sit. This violates the traditional notion of trolls as solitary creatures, but has doubtless contributed to the statue's popularity. Norway's most famous highway also boasts its resident trolls. The Trollstiegen road runs up a steep mountain and crosses the Stigofssen

falls more than 1,000 feet in the air. Completed in 1936, it is still lauded as an impressive feat of engineering. Moreover, it is the only road in Norway to be outfitted with an official "Troll Crossing" sign.

Trolls Rock!

Basics…Get inspired! Rocks are works of art waiting to be discovered—whether made into a bridge or simply covered in paint!

Painting or drawing on a 3-dimensional surface is a fun challenge The colors of the paint/paint markers are vivid and opaque (i.e. pretty), and very easy to use.

Materials:

Selection of smooth(ish) rocks

Paint markers, ex. Elmer's Painters Pens, or acrylic paints. Tip: If using new paint markers, you'll want to shake them a bit and depress the tips until the paint starts to flow. Just follow the directions of your paint.

Covered table (the markers/any kind of paint leaves a mess on the work area that you'll be happy that you prepared for it). Butcher paper works great for this!

Sample Method:

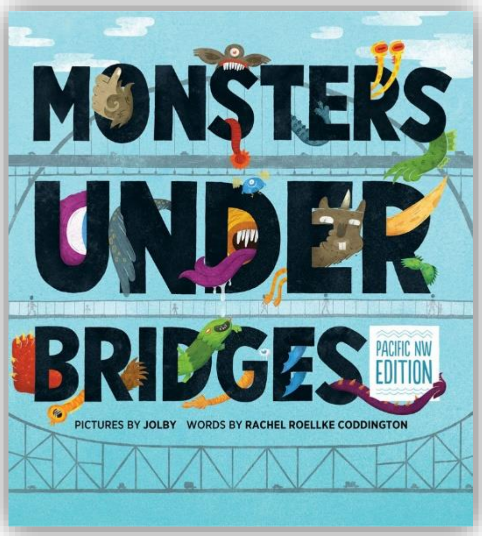
Body: Paint 1 color, let it dry (maybe an hour) and then paint a second color should you wish

Eyes: Use a black sharpie for the eyes or googly eyes.

Mouth: Black Paint

Teeth: Once the mouth has dried, use white paint for the teeth.

Variation: Spray paint them a solid color first and then use acrylic paints to decorate them. Finish them off with a spray varnish and let them dry for a few days before setting them out



Literature Link: To help inspire students' imaginations and explore more about amazing bridges around the country read *Monsters Under Bridges* by Rachel Roellke Coddington. From Portland, Oregon to Seattle, Washington to Vancouver, BC, this playful picture book introduces misunderstood monsters and the Pacific Northwest bridges they call home. Meet Irving the Noble Vegetarian who lives under the Astoria-Megler Bridge and smells like vegetables and hair gel. Or the Flixies, a group of winged pixie creatures who live under the Fremont Bridge in Portland. Each monster takes on the history and environment of their home, with tidbits about their habits as well as the geographic area or bridge and its design, making *Monsters Under Bridges* engaging as well as educational.

Extension: Students can then come up with the story behind their own 'monstrous' creation when their Rock Troll is complete! Where does it live? What does it do? What does it eat?

See the next page for even more inspiration!

Then...Rock ON!

Day Twenty-three K-8 Standard Alignment

K

- 3.1.3 Select and apply subject matter, symbols, and ideas in the student's own art.
- 1.1.3 Demonstrate precision in the use of teacher selected tools and media in a safe manner.
- 4.1.1 Recognize that art comes from different cultures, times, and places.
- 2.3.1 Recognize that art has a purpose.
- 2.4.2 Understand that art has a context.

These standards will be met and reinforced as we learn about bridge monsters & trolls and then make our bridge monsters. We will determine that art can come in many forms, including the functional (aka the protective bridge troll), and how different resources and cultures (context) shape its form and purpose.

Students will then practice painting and design techniques and then implement them in order to make their own troll art incorporating the symbolism of the protective troll and bridge monsters as modeled by the teacher.

1

- 1.1.3 Demonstrate a precision in and explore the use of teacher selected tools and media in a safe manner.
- 3.1.3 Select and apply subject matter, symbols, and ideas in the student's own art.
- 4.1.1 Understand that art comes from different cultures, times, and places.
- 4.2.1 Understand that culture and history influence art.
- 2.3.1 Understand that art has a purpose.
- 2.4.1 Understand that art has a context.

These standards will be met and reinforced as we learn about bridge monsters & trolls and then make our bridge monsters. We will determine that art can come in many forms, including the functional (aka the protective bridge troll), and how different resources and cultures (context) shape its form and purpose.

Students will then practice painting and design techniques and then implement them in order to make their own troll art incorporating the symbolism of the protective troll and bridge monsters as modeled by the teacher.

2

- 3.1.3 Implement chosen subject matter, symbols, and ideas in the student's own art.
- 1.1.2 Demonstrate a precision in and explore the use of teacher selected tools and media in a safe manner.
- 4.1.1 Understand that art comes from different cultures, times, and places.
- 4.2.1 Understand that culture, history, and art influence one another.
- 2.3.1 Understand and apply purpose in art.

- 2.4.1 Understand and apply context in art.

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3

- 3.1.3 Produce subject matter, symbols, and ideas in one's own artwork as guided by the teacher.
- 1.2.1 Demonstrate media in the intended manner as modeled by the teacher.
- 4.1.1 Understand and demonstrate that art comes from different cultures, times, and places.
- 4.2.1 Understand and demonstrate how culture, history, and art influence each other.
- 2.5.1 Understand purpose in art.
- 2.7.1 Understand context in art.

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Students will then practice painting and design techniques and then implement them in order to make their own troll art incorporating the symbolism of the protective troll and bridge monsters as modeled by the teacher.

4

- 3.1.3 Produce subject matter, symbols, and ideas in one's own artwork as modeled by the teacher.
- 1.2.1 Execute a variety of media in the intended manner as modeled by the teacher.
- 4.1 Explore the relationship of art from different cultures, times, and places.
- 4.2 Examine and demonstrate how culture, history, and art influence one another.
- 2.5.1 Understand purpose in art.
- 2.7.1 Understand context in art.

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Students will then practice painting and design techniques and then implement them in order to make their own troll art incorporating the symbolism of the protective troll and bridge monsters as modeled by the teacher.

5

- 3.1.3 Produce subject matter, symbols, and ideas in one's own artwork as coached by the teacher.
- 1.2.1 Execute a variety of media in the intended manner as coached by the teacher.
- 4.1.1 Explore the relationship of art from different cultures, time, and places.
- 4.2.1 Examine and demonstrate how culture, history, and art influence each other.
- 2.5.1 Evaluate purpose in art.
- 2.7.1 Evaluate context in art.

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6

- 3.1.3 Apply subjects, themes, and symbols in works of art in an effective manner.
- 1.1.2 Develop and demonstrate control of different types of media, techniques, and processes.
- 4.1.1 Demonstrate an understanding of the historical and cultural contexts of artwork.
- 4.2.1 Demonstrate an understanding of the role of artists throughout history and cultures.
- 4.5.1 Reflect on how historical and cultural factors influence contemporary artwork and visual culture.

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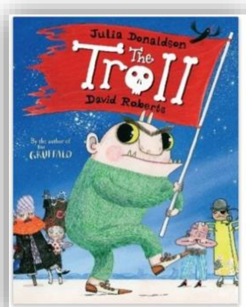
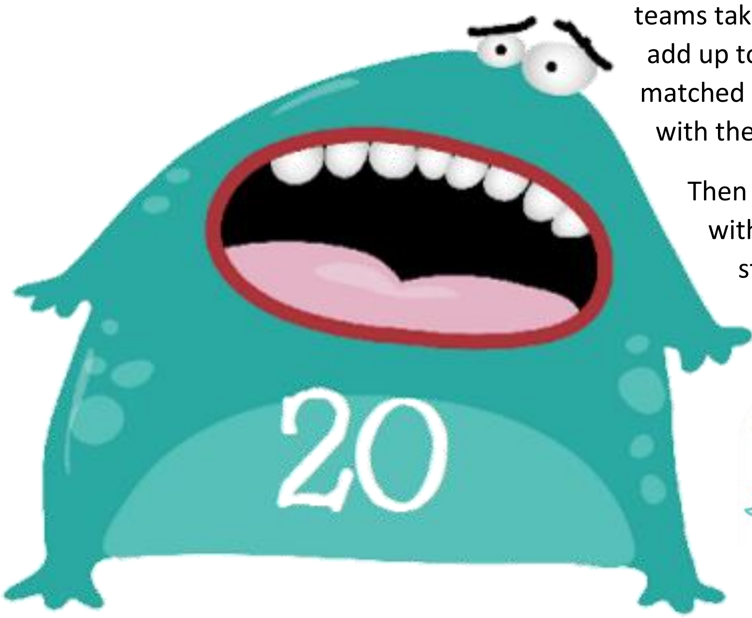
Day 24: Troll Math!



For a fun literature link start the conversation about trolls with the book *The Troll* by Julia Donaldson- - Watch the fun unfold as two very different worlds collide in a gloriously comic story from the creators of the highly acclaimed *The Gruffalo* & *Tyrannosaurus Drip*

The following game is played like a game of Memory. Students place the monster cards face down or they're taped/attached backwards to the board. Students are divided into teams and teams take turns turning over two monster cards. If the two cards add up to 10, they get to keep them. When all cards have been matched the game ends. The team/individual (if playing in pairs) with the most cards wins.



Then play the the making 20 version. It is the same game with a different set of numbers and monsters. Once your students have mastered making ten, you can take them to the next level! Print on cardstock, cut, and (optionally) laminate.

Troll Army! Variation

Arrange the trolls/Bridge Monsters up on the board in rows—using the same numbers for each team. Any set of numbers reachable by adding, subtracting, dividing, or multiplying 1-6 can be used, traditionally the following are used.

1 2 3 4 5 6
7 8 9 10 11 12
1 2 3 4 5 6

7 8 9 10 11 12

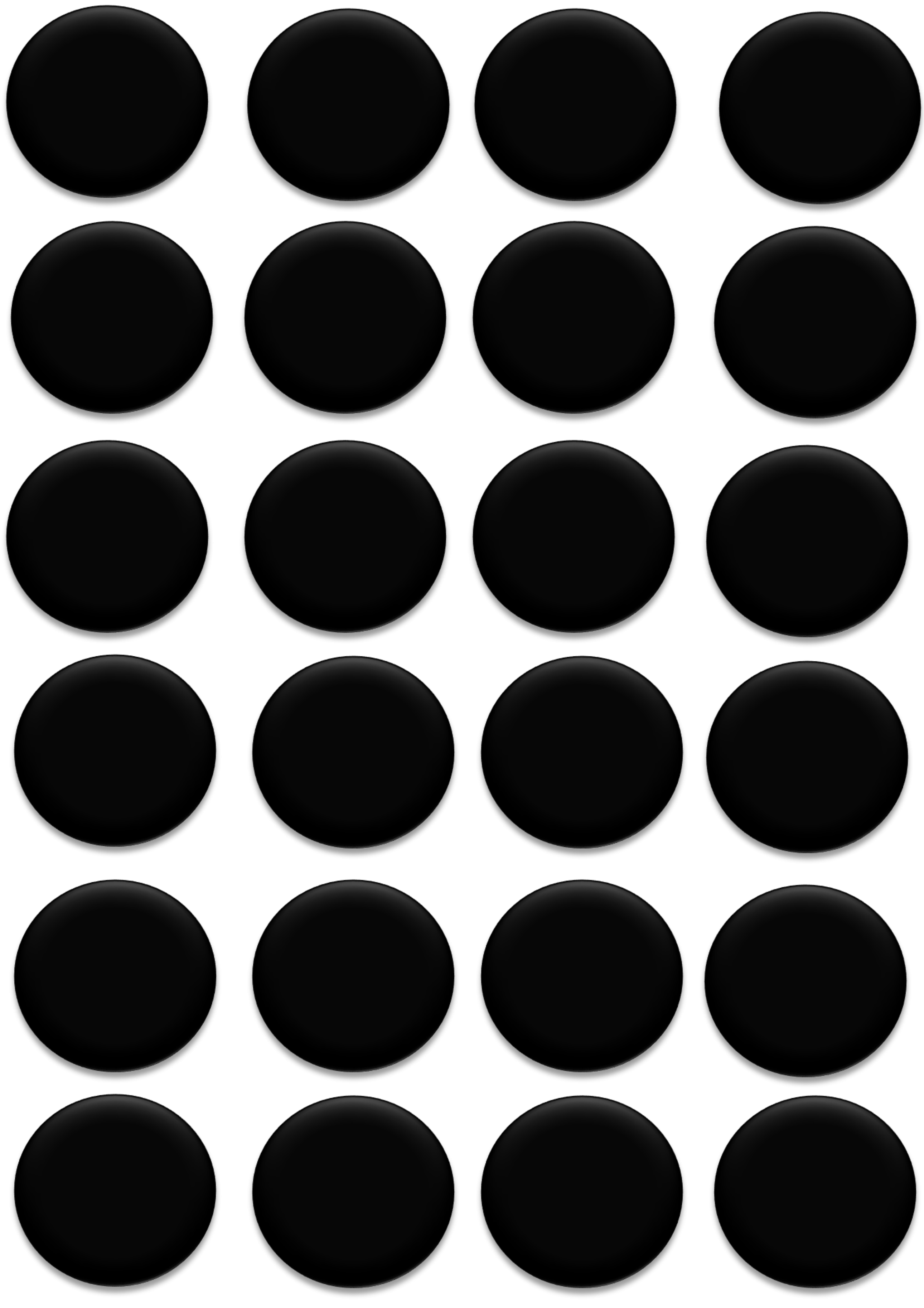
But other combinations of numbers can work as well.

Have students form two teams, each team having a pair of dice. The teams must race to defeat their troll army first by rolling the dice and using the total amount to take a troll, or combination of trolls, off the board.

Ex: the team rolls a 6. They can take off just troll 6, OR remove a combination of trolls, ex. a 5 & a 1; or a 4 and a 2; OR a 1, a 3, and a 2. Anything that adds up (or multiplies or divides if using larger numbers in the army) to the number rolled.

Note: A worksheet & set of printable markers are also included for pair/small group play.

Can You Defeat the Troll Army?

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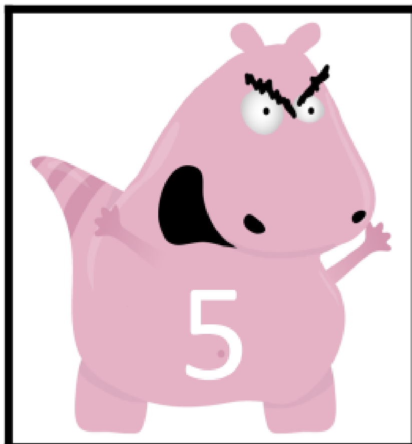
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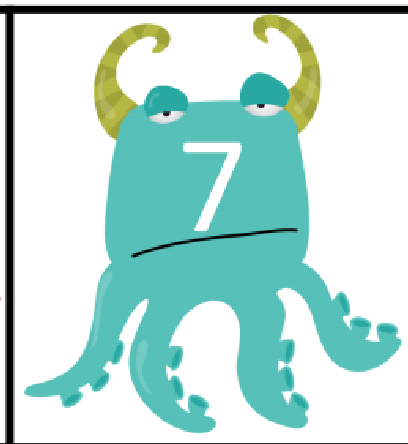
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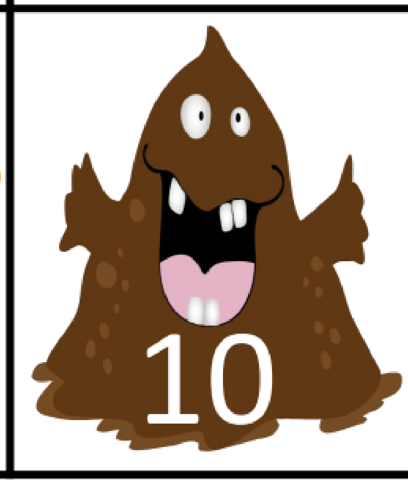
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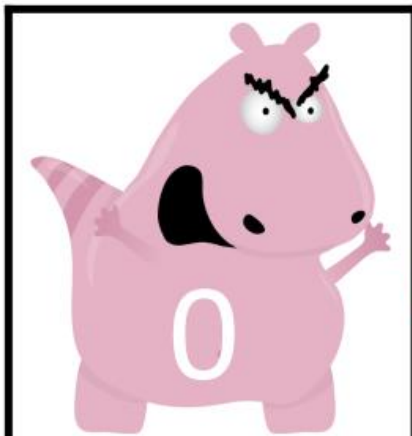
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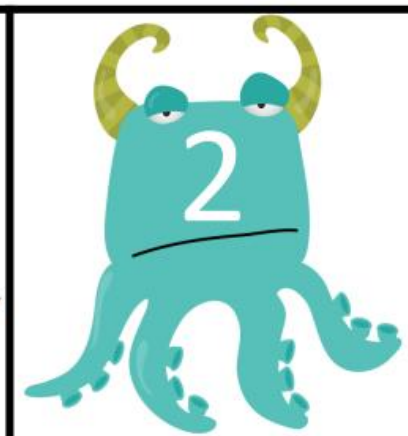
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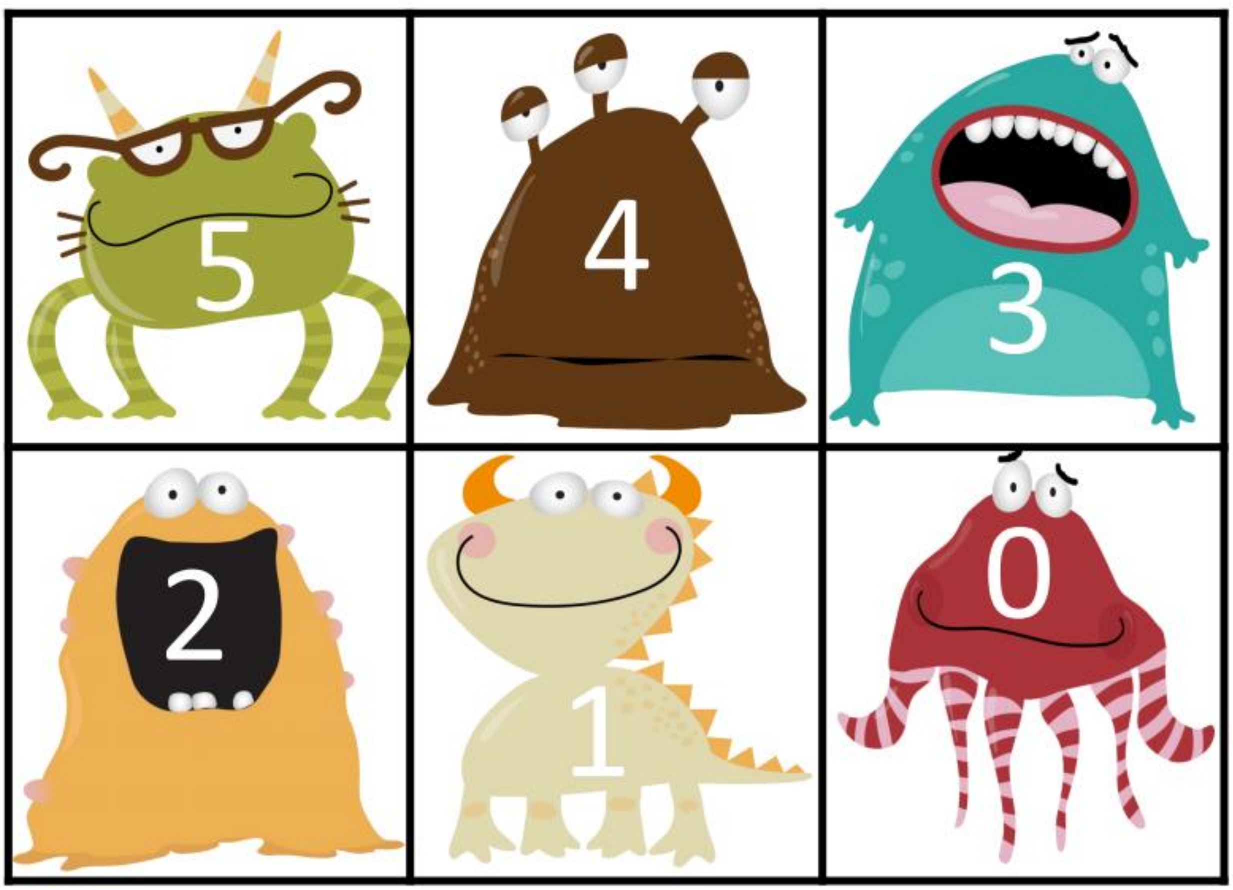
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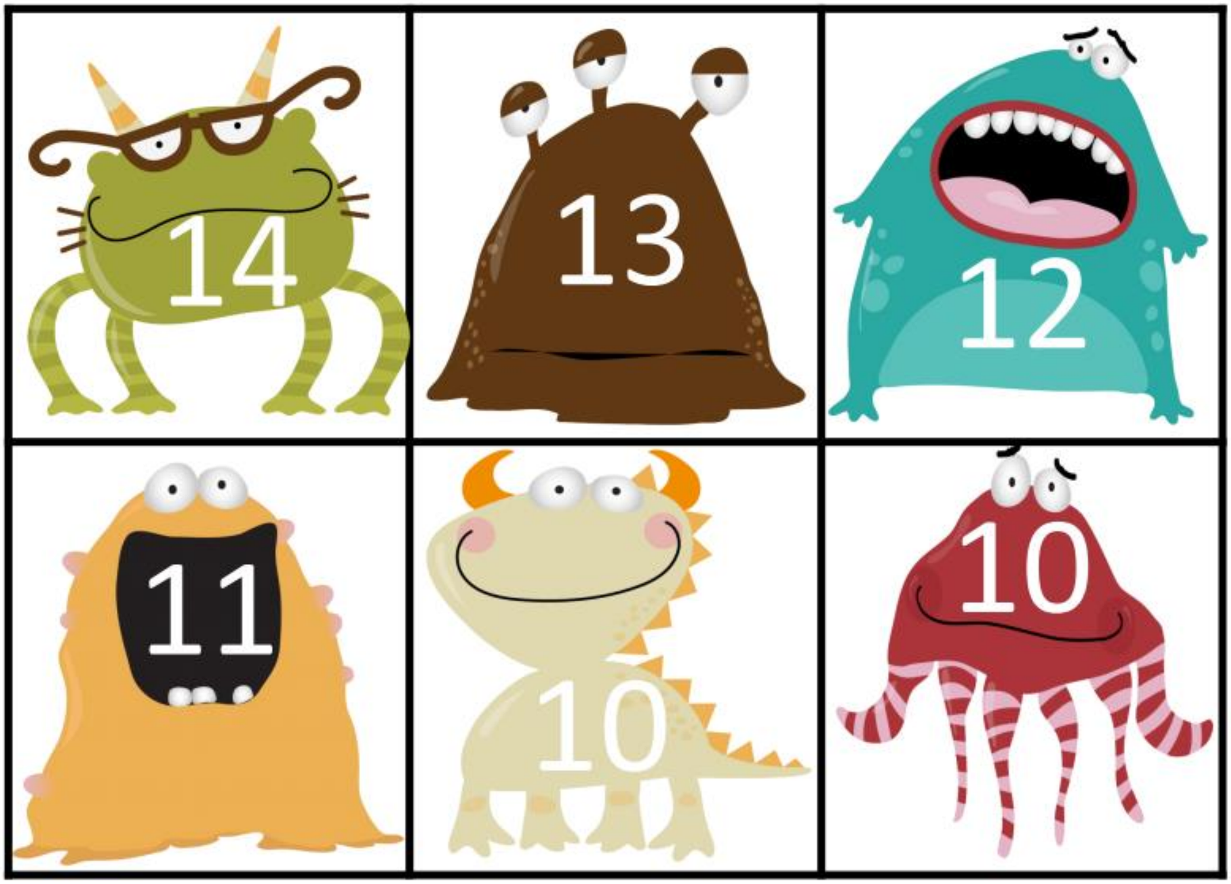
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Day Twenty-four K-8 Math Skills

The following are selected from the comprehensive list of the math skills students learn in each grade. Remember, these skills build on each other. They are assuming that students have mastered all the ones in the previous grades.

The skills are organized into categories: As you read (and complete) the activities in the plan, keep in mind the specifics skills your students need to practice and master in the different grade levels you work with. Use their needs to guide your approach in how you'll modify and present the activities and what specific tasks you will have the students do.

K

Adding

- I.1 Addition with pictures - sums up to 5
- I.2 Add two numbers - sums up to 5
- I.3 Addition sentences - sums up to 5
- I.4 Ways to make a number - sums up to 5
- I.6 Addition with pictures - sums up to 10
- I.7 Add two numbers - sums up to 10
- I.8 Addition sentences - sums up to 10
- I.9 Ways to make a number - sums up to 10
- I.10 Addition word problems - sums up to 10

Positions

- K.1 Inside and outside
- K.2 Left, middle, and right
- K.3 Top, middle, and bottom
- K.4 Above and below

Numbers and counting up to 20

- D.1 Count to 20
- D.2 Count dots - 0 to 20
- D.3 Represent numbers - up to 20
- D.5 Count up - up to 20
- D.6 Count up and down - up to 20
- D.7 Tally marks - up to 20
- D.9 Before, after, and between - up to 20
- D.10 Count forward - up to 20
- D.11 Count forward and backward - up to 20
- D.12 Names of numbers - up to 20

1

Addition

- B.1 Addition with pictures - sums to 10
- B.5 Ways to make a number using addition
- B.6 Ways to make a number - addition sentences
- B.7 Adding zero
- B.8 Adding doubles
- B.9 Addition facts - sums to 10

- B.10 Addition facts - sums to 18
- B.11 Addition word problems - sums to 18
- B.12 Complete the addition sentence
- B.13 Adding three numbers
- B.16 Addition facts - sums to 20
- B.17 Add tens
- B.19 Add a one-digit number to a two-digit number - without regrouping
- B.20 Regrouping tens and ones
- B.22 Add a one-digit number to a two-digit number - with regrouping

Counting and number patterns

- A.15 Skip-counting patterns - with tables
- A.16 Sequences - count up and down by 1, 2, 3, 5, and 10

2

Addition - one digit

- E.1 Review - add one-digit numbers - sums to 10
- E.2 Review - ways to make a number - sums to 10
- E.3 Review - writing addition sentences - sums to 10
- E.4 Add one-digit numbers
- E.5 Addition with pictures - sums to 20
- E.6 Write addition sentences to describe pictures - sums to 20
- E.7 Addition input/output tables - sums to 20
- E.8 Add zero
- E.9 Addition word problems - one digit
- E.10 Complete the addition sentence - one digit
- E.11 Write the addition sentence - one digit
- E.12 Balance addition equations - one digit
- E.13 Add three or more one-digit numbers

Multiplication

- W.1 Multiplication sentences
- W.2 Multiplication tables up to 5
- W.3 Multiplication tables up to 10

3

Addition

- C.1 Add two numbers up to three digits
- C.2 Addition input/output tables - up to three digits
- C.4 Complete the addition sentence - up to three digits
- C.5 Balance addition equations - up to three digits
- C.6 Add three or more numbers up to three digits each
- C.8 Addition patterns over increasing place values
- C.9 Add two numbers with four or more digits
- C.12 Complete the addition sentence - four or more digits
- C.13 Balance equations - four or more digits

- C.14 Add three or more numbers with four or more digits

Multiplication

- E.1 Multiplication sentences
- E.2 Multiplication - facts to 12
- E.4 Missing factors - facts to 12
- E.6 Squares up to 20
- E.7 Multiplication patterns over increasing place values
- E.8 Multiply by a multiple of ten
- E.9 Multiply numbers ending in zeroes
- E.10 Multiply a one-digit number by a larger number
- E.12 Multiply three or more numbers

4

Addition

- B.1 Add numbers up to millions
- B.3 Addition: fill in the missing digits
- B.4 Properties of addition
- B.5 Add 3 or more numbers up to millions
- B.6 Addition patterns over increasing place values
- B.7 Choose numbers with a particular sum
- B.8 Estimate sums
- B.9 Estimate sums: word problems

Multiplication

- D.1 Multiplication facts to 12
- D.2 Missing factors - facts to 12
- D.3 Choose the multiples of a given number up to 12
- D.4 Identify factors
- D.5 Multiply 1-digit numbers by larger numbers
- D.7 Properties of multiplication
- D.8 Estimate products
- D.10 Multiply a 2-digit number by a 2-digit number: complete the missing steps
- D.11 Multiply a 2-digit number by a 2-digit number
- D.13 Choose numbers with a particular product
- D.15 Multiply a 2-digit number by a larger number
- D.17 Multiply numbers ending in zeroes
- D.19 Multiply 3 numbers up to 2 digits each

5

Addition and subtraction

- D.1 Add and subtract whole numbers up to billions
- D.5 Complete addition and subtraction sentences
- D.6 Fill in the missing digits
- D.7 Choose numbers with a particular sum or difference
- D.8 Properties of addition
- D.10 Estimate sums and differences of whole numbers
- D.11 Estimate sums and differences: word problems

Multiplication

- F.1 Multiply by 1-digit numbers
- F.3 Multiplication patterns over increasing place values
- F.4 Multiply numbers ending in zeroes
- F.6 Properties of multiplication
- F.7 Choose numbers with a particular product
- F.8 Estimate products
- F.10 Multiply by 2-digit numbers: complete the missing steps
- F.11 Multiply a 2-digit number by a 2-digit number
- F.12 Multiply a 2-digit number by a larger number
- F.14 Multiply three or more numbers up to 2 digits each
- F.15 Multiply by 3-digit numbers
- F.16 Multiply three numbers up to 3 digits each

6

Add and subtract integers
- I.1 Review - add and subtract whole numbers
- I.3 Properties of addition
- I.4 Integer addition and subtraction rules
- I.7 Subtract integers - using counters
- I.8 Subtract integers

Multiplication
- K.1 Multiply whole numbers
- K.3 Multiply whole numbers with four or more digits
- K.4 Multiply numbers ending in zeroes
- K.6 Multiply three or more numbers
- K.8 Estimate products
- K.9 Properties of multiplication
- K.10 Solve for a variable using properties of multiplication
- K.11 Integer multiplication rules
- K.12 Multiply integers

7

Operations with integers
- E.1 Integer addition and subtraction rules
- E.2 Add and subtract integers using counters
- E.3 Add and subtract integers
- E.6 Integer multiplication and division rules
- E.7 Multiply and divide integers

8

Operations with integers
- C.1 Integer addition and subtraction rules
- C.2 Add and subtract integers using counters
- C.3 Add and subtract integers
- C.4 Add and subtract three or more integers
- C.6 Integer multiplication and division rules
- C.7 Multiply and divide integers

Extensions:

Mr. Troll

Use this game to have younger children learn their numbers (or other skills).

Create some kind of a bridge. You could lay down two skipping ropes, you could use rubber dots, or use painter's tape to mark a bridge on the floor. Choose one child to be the troll. The troll is on one side of the bridge and the rest of the class is on the other side.

Give all the students numbers and have a matching set in a bag for the 'Troll.'

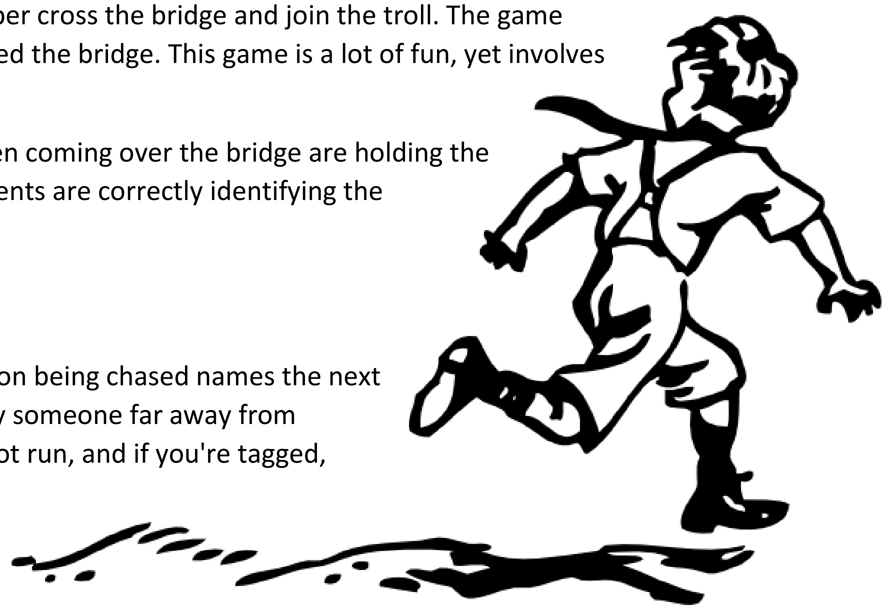
All the children sing the question: "Mr. Troll, Mr. Troll may we cross the bridge? May we cross to the other side?" The troll pulls out a number, ex. 10, and answers them "Only if you're holding [10] - if not you'd better run and hide."

The children holding the chosen number cross the bridge and join the troll. The game continues until all children have crossed the bridge. This game is a lot of fun, yet involves no real competition or chaos!

The teacher can check that the children coming over the bridge are holding the correct number and assess if her students are correctly identifying the numbers.

Troll Tag

The rules of Troll are simple: The person being chased names the next Troll *before they get caught* (hopefully someone far away from them!) You're only allowed to walk, not run, and if you're tagged, you're out!



Crossing the Lava

This is a game in which the players imagine that the floor or ground is made of lava (or any other lethal substance, such as raging rapids, acid or quicksand), and thus must avoid touching the ground lest they get burned or otherwise injured.

Create or use objects (as simple as mats, paper plates, or colorful pieces of paper taped to the floor) to use as 'bridge slats' and create trails of stepping stones which the players must use to stay off of the floor. Players may not remain still and must move from one piece of the 'bridge' or 'bridges' to the next in order to reach 'safety' on the other side.

The person who is posing as the 'troll' can be on the 'lava' with the objective of attempting to tag another player. If players fall off the 'bridge' by stepping on the ground or get tagged they are out for that round.

Option: Either the first or last person to be tagged is the next 'Troll' depending on how you want to structure the game.

Option: Create a separate criss-crossing trail on which the "Troll" player must navigate across instead of the main trail.

You can also set up obstacles to make the game more challenging, ex. a variation of an obstacle course.

K-8 Standard Alignment for Extension Activities

K-2

- 1.2.1 Demonstrate skills of chasing, fleeing and dodging to avoid or catch others.
- 4.2.5 Engage in sustained daily physical activity which causes an increased heart rate and heavy breathing
- 5.3.1 Work cooperatively with others in structured and non-structured activities

These standards will be met, reinforced, and used as guidelines for student behaviors during the physical games and activities.

3-5

- 1.2.1 Demonstrate mature motor patterns for basic locomotor, non-locomotor and selected manipulative skills in structured settings

- 1.2.2 Apply basic skills in game-like situations
- 5.3.1 Demonstrate sportsmanship in physical education, recess, and outside the school setting.
- 1.1.1 Perform developmentally appropriate teacher designed games using a variety of locomotor, non-locomotor and manipulative skills.

These standards will be met, reinforced, and used as guidelines for student behaviors during the physical games and activities.

6-8

- 1.2.1 Utilize basic locomotor, non-locomotor and manipulative skills in game situations.
- 4.2.1 Participate in moderate to vigorous physical activity in a variety of settings.
- 1.1.1 Skip, hop, jump, walk, run, gallop, slide, chase, flee, dodge, turn, twist, roll, balance, transfer weight, stretch, curl, throw, catch, kick, punt, dribble, volley, and strike with proper form.

These standards will be met, reinforced, and used as guidelines for student behaviors during the physical games and activities.

Sample Academic Vocabulary to Reinforce Weeks 5-6

K

- Job
- Addition
- Needs
- Subtraction
- Tools
- Rules
- Cooperation
- Human
- Shape
- Compare
- Difference
- Size
- Pattern
- Parts
- Location

1

- Property
- Push
- Pull
- Invent
- History
- Technology
- Culture
- Vertical
- Horizontal
- Length
- Weight
- Property

2

- Type
- Distance
- History
- Natural Resources
- Multiplication
- Similarities
- Differences
- Symbol
- Tradition
- Compare
- Contrast
- Landmark
- River

3

- Landforms
- Natural resources
- Tools
- Conclusion
- Factor
- Product
- Scarcity
- Setting
- Capacity
- Force

4

- Expansion
- Weather(ing)
- Exploration
- Friction
- Supply and demand
- Function
- Chance
- Accuracy
- Relationship
- Remainder

5

- Region
- View
- Model
- Core
- Gravity
- Integrate
- Remainder
- Solution
- Reconstruct
- Historian

6

- Technological
- Cause
- Effect
- Control
- Criteria
- Similarity

- Simulation
- Triangle
- Prototype
- Design Constraint

7

- Impact
- Topography
- Speed
- Stress
- Phenomenon
- Function
- Property
- Juncture

8

- Human impact
- Variation
- Angles
- Sequence
- Function
- Tension
- Infrastructure
- Element

Sample Supply List Bridging the Gap Weeks 5-6

Day 17-18

- Spaghetti Noodles (approximately 75-100 per group)
- clean, empty half-gallon milk carton, coffee cans, or similar containers (they must all be the same in order to ensure fair competition)
- Masking tape
- Measuring devices, ex. rulers
- standard set of weights (fishing sinkers work well)
- Printouts for recording data
- 6 strips of corrugated cardboard:
  8 cm x 30 cm (3 in. x 12 in.)
  8 cm x 50 cm (3 in. x 20 in.)
  8 cm x 80 cm (3 in. x 31 in.)
  8 cm x 100 cm (3 in. x 39 in.)
  8 cm x 120 cm (3 in. x 47 in.)
  8 cm x 150 cm (3 in. x 59 in.)

Days 19-22

- Chosen books
- Graph paper
- Pencils
- Weight testing device (ex. loading block, chain, bucket, sand, and hook, etc.)-- can easily be created or can be replaced with a small chain and carabineer clip that can be clipped through the chain and onto the bucket handle

Toothpick Bridge Variation:

- Round uncoated toothpicks (maximum 1000 toothpicks)
- Elmer's white glue or Craft Glue (as determined by the competition). *Epoxy, wood glue, hot glue, paint and super glues are not permitted*. *Do NOT coat the bridge with any material (paint, stain or glue).*
- (Modification for Younger Students) —please check the contest parameters before using. Mini marshmallows (ex. 50 per student group) Note: this is approximately ½ cup per student or a 1-pound bag for every 20 students.-- *Prepare the marshmallows. Spread marshmallows on paper towels and air dry for 3–4 days. This gives the marshmallows a stiff texture that is easier to work with and easier to clean up.*
- Optional Material Additions (to be determined by the competition): *basswood strips, and balsa strips*
- Binder Clips: only for support! Not as part of the final design

Popsicle Bridge Variation:

One set of materials for each group of students:

- 200 popsicle sticks
- Craft glue or glue all for younger students-- *Epoxy, wood glue, paint and super glues are not permitted*.
- Option: Hot glue—please check the contest parameters before using. Also, hot glue must be in the control of instructors or parents, not students.
- Standard 5 and 20 pound weight (box of sugar, exercise weight, or another weight that can be standardized)
- Graph Paper
- Pencils
- Binder Clips—solely for help & support while building—not part of final design

Day 23

- Selection of smooth(ish) rocks
- Paint markers, ex. Elmer's Painters Pens, or acrylic paints. Tip: If using new paint markers, you'll want to shake them a bit and depress the tips until the paint starts to flow. Just follow the directions of your paint.
- Covered table (the markers/any kind of paint leaves a mess on the work area that you'll be happy that you prepared for it). Butcher paper works great for this!

Day 24

- Chosen books
- White board
- Markers
- Printouts
- Scissors
- Optional: tape or sticky-back magnets—to attach the trolls to the whiteboard

SOURCES& REFERENCES

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- http://www.tunstallsteachingtidbits.com/2011/07/monster-math-tubs.html
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