Lesson Title	Incredible Edible Bridges
Length of Lesson	1 day
Created By	Kylie Nash
Subject	Math
Grade Level	9^{th} -12^{th} Geometry
State Standards	Geometry:
DOK Level	DOK 2 Geometry
DOK Application	DOK 2 – Identify, Relate, Construct, Use Contest Clues, Make Observations, Predict, Show
National Standards	9^{th}- 12^{th} Geometry, Algebra
Graduate Research Element	Engineering Design Concepts- Increasing conceptual knowledge by demonstrating engineering concepts of design using shapes and relating weight properties

Student Learning Goal:

State Standards for 9^{th} – 12^{th} Geometry: Geometry

1a) Apply problem solving skills to solve and verify the solutions for unknown measures in similar polygons.

3c) Identify, classify, and apply angle relationships formed by parallel lines cut by transversals (DOK3)

National Standards for 9^{th} -12^{th} Geometry and Algebra Standard:

- Use geometric models to gain insights into, and answer questions in other areas of mathematics.
- Analyze characteristics and properties of two and three dimensional geometric shapes and develop mathematical arguments about geometric relationships
- Use visualization, spatial reasoning and geometric modeling to solve problems

Students will be able to be able to practice and use appropriate techniques to solve mathematical problems linked to real world engineering concepts. Construct 3D shapes and identify relationships and make predictions on the optimal solution for solving problems.

Materials Needed (supplies, hand-outs, resources):

Writing utensils, 1 sheet of paper, 5 paper clips and two books of equal measurement and enough pennies per group (at least 100 per group), projector for presentation; 8 marshmallows/gumdrops, 18 pieces of raw spaghetti/toothpicks, 4 pieces of raw linguine (spaghetti and linguine should be same diameter), paper and pencil to record observations, guided information about topic and guidelines in PowerPoint presentation by instructor.

Lesson Performance Task/Assessment:

Students will build two styles of bridge demonstrating their understanding of various shapes and the strengths of those various shapes. Students will be able to practice constructing 3D shapes, understand the symmetry of the design, and predict how much weight the different shapes are able to hold.

Lesson Relevance to Performance Task and Students:
Allowing students to construct bridges based on their design ideas will help build their critical thinking skills and enhance their problem solving skills for determining how to make the structure able to hold the most weight. Simulating real world applications will help strengthen math skills and engineering design concepts to students as well as how math, specifically geometry can be applied to real world applications. Increase understanding the function follows form of how different geometric shapes and designs are stronger than others. Through the use of hands on activities to synthesize and interpret concepts learned in the classroom.

Anticipatory Set/Capture Interest:
Students will be divided into groups of 3 to 4 and told that they are part of a team of civil engineers and have been selected to participate in a contest to build the cities next bridge. The team with the best design, able to hold the most weight will win the contest and their bridge will be built in the city with their names written on the bridge. Students will then be introduced to different bridge styles by showing photos of existing bridges and showing different construction types as well as what kinds of conditions need to be considered when building a bridge.

Guided Practice:
The instructor will give an introduction to types of bridges and discuss how the weight is distributed on the various types of bridges based on the particular shape of the bridge. Then the instructor will pose questions concerning engineering design considerations for various structures, symmetry, shapes and weight distribution of the different shapes. The instructor will discuss how this application can be applied to other real world applications. The instructor will also lead the discussion using the questions listed below:

1. How many of you know what a civil engineer or structural engineer does?
2. What shapes are used to build bridges?
3. Required clearances. Do boats need to go under the bridge?
4. How many lanes? What will go over the bridge?
5. What materials/technology is available?
6. Environmental and Weather related conditions and impact.

The instructor will then provide the guidelines and rules for building the bridge described below.

Guidelines:
- Bridge must span 8.5 inches.

- Nothing will go under the bridge.
- The bridge must span 2 books.
- The bridge must hold 100 pennies.

Rules:

- You may fold, wrap, crease, or roll your sheet of paper in any way (used to hold pennies only).
- All pennies must be suspended between the two books.

The students will be instructed to build their bridges based on the above guidelines and rules. Each team will add pennies to their bridge one at a time until the bridge collapses. Record the number of pennies the bridge held until it collapsed. After the students shave built their bridges then the instructor can lead the discussion on why their bridges collapsed as well as how many pennies each held before it collapsed. The instructor or student can report each team's number of pennies on the board, to keep the completion going.

Many students should not be able to hold 100 pennies. The instructor should introduce the idea of the accordion style models and cross or lattice styles (triangle patterns) of bridge building to better hold the pennies for the bridge. The instructor should reinforce the idea of how triangles are the strongest shapes and how several together are even stronger. Then the instructor should instruct them to build a new bridge based on the different styles and see what happens. The goal is to hold more than 100 pennies. The students can also try other styles such as lattice cross sections (triangle patterns) and count the number of cross section needed to reinforce the bridge. If students try the accordion style then count the number of folds and number of pennies ratio to see a pattern.

**Students can be given several sheets of paper to keep trying their designs, but check to make sure only one sheet is being used at a given time for both parts of the activity.

** Students should record weights, number of pennies or number of paper folds and design styles to share with their classmates and the best design should win a prize for the group.

Independent Practice:

A. Students will divide into groups and first build bridges based on any style and shape they choose, using one of the initial 4 shapes described by teacher. Each team will add pennies to their bridge one at a time until the bridge collapses. Record the number of pennies the bridge held until it collapsed. Students will discuss why their bridges collapsed with the number of pennies it held. They should recognize that their bridge

structures don't have an even distribution of support. The winner can be determined by calculating the number of pennies and team with the highest number wins.

B. Once the students have been introduced to the accordion style/cross lattice bridge style, then they will build new bridges based on these criteria to determine the max number of folds in the paper holds the most pennies or max number of cross sections. The teams for the groups can be kept the same as the first part of the activity and they compete to win for the highest number of folds and pennies and or cross sections and pennies. The teams may also be grouped into specific teams shown below depending on time not to determine a winner or get a prize. Either team will add pennies to their bridge until the bridge collapses and report the number of pennies and number of folds the structure held before it collapsed.

Remediation and/or Enrichment:

Remediation:

Individual IEP, shorten activity and let students build bridges using only either only the 4 types of bridge designs or the accordion style and discuss the reasons for success or failure, individual assistance. They will add pennies to their bridge until the bridge collapses and report the number of pennies or number of folds the structure held before it collapsed.

Enrichment:

This activity can be extended to algebra concepts such as regression

Check(s) for Understanding:

1. Discuss the connections between styles of bridges and weight.

2. Discuss the relationship between the style of bridge and numbers of pennies the object can hold. Did the pennies work better in the center or evenly?

3. Discuss the differences between the 4 traditional style bridge types and the accordion style cross/lattice style designs

4. What shape is the strongest?

5. How do you think the results will change if you use linguine for the bridge instead?

6. Test your hypothesis by repeating the experiment with the linguine as the bridge.

7. Was the round (spaghetti) or flat (linguine) shape stronger?

8. What parts of the presentation and activity did you feel was the most important to helped create the 3D model of the bridges and why?

9. What parts of the presentation and activity did you feel was the least important to helped create the 3D model of the bridges and why?

Closure:
Discuss some real world applications (who, what, when, where and how) that would benefit from understanding concepts related to geometric shapes and strength of bridges design. Discuss the relationship between the number of folds and the amount of weight compared to other bridge shape designs.

Possible Alternate Subject Integrations:
Physics- Look at what role such as tension and forces play on the strength of different polygons shapes and designs. Explore the impact of gravity on the bridge structure.

Teacher Notes:

Reference Sources:

1. http://www.learnnc.org/lp/pages/3050
2. http://www.pbs.org/wgbh/buildingbig/educator/act_paper_ei.html
3. http://www.sciencebuddies.org/science-fair-projects/project_ideas/CE_p018.shtml
4. http://www.apegm.mb.ca/PEGW/2010/S-BDemonstrationHandout.pdf
5. http://www.tryscience.org/teachers/files/handout_spaghetti.pdf