Lesson Title	Strongest Polygon
Length of Lesson	2 days
Created By	Kylie Nash
Subject	Math
Grade Level	10^{th} – 12^{th} (Geometry)
State Standards	9^{th} -12^{th} Geometry 3c.
DOK Level	DOK 2
DOK Application	Construct, Identify Patterns, Collect, Compare, Calculate, Make Predictions, Recognize
National Standards	9^{th}- 12^{th} Geometry
Graduate Research Element	Engineering Design

Student Learning Goal:

State Standards for 9^{th} – 12^{th} : Geometry 3c.
(c) Identify, classify and apply angle relationships formed by parallel lines cut by transversals.

National Standards for 9^{th} -12^{th} Geometry : Use visualization, spatial reasoning, and geometric modeling to solve problems

- Use geometric models to gain insights into, and answer questions in, other areas of mathematics; draw and construct representations of two- and three-dimensional geometric objects using a variety of tools

Construct 3D polygon structures in the form of structures using appropriate techniques and materials. Calculate the exterior angles of polygons including the interior and exterior of polygons. Collect measurements on the height and amount of weight their polygon structures can hold. Identify patterns and shapes that support different weight loads. Compare their structures to others groups based on geometric types, number of polygons and combination of shapes used to make the structures. Make any predictions concerning the strengths and weakness of their structures in terms of geometric shapes. Recognize the strongest geometric shape.

Students will be able to practice and use appropriate techniques to collect, calculate and analyze data for measurement and critical analysis between relationships among geometric shapes.

Materials Needed (supplies, hand-outs, resources):
Notepaper, protractors (1 per team), writing utensils, tape measure (1 for teacher), 25 small marshmallows (per group), 20 pieces of uncooked spaghetti (per team), weights (textbooks, sheet paper, etc.), informative information about topic in PowerPoint file GeometricShapes.ppt.

Lesson Performance Task/Assessment:
Students will be able to construct a 3D model of a structure using spaghetti and marshmallows in an effort to build the tallest and/or strongest structure. They will use existing knowledge of polygons, and then identify shapes used in the model. Students will be able to identify different shapes and measure interior and exterior angles of the polygon shapes as well as identify the strongest geometric shape. Each team will need to build one structure, measure interior and exterior angles, record the weight of the structure, height of structure and amount of weight capacity each model can hold. Students will be asked to discuss their structures in terms for height and weight and which shapes are the strongest found from the activity.

Lesson Relevance to Performance Task and Students:
Allowing students to build structures of their own imagination and design choice will help introduce basic engineering design concepts to students as well as how math, specifically geometry can be applied to real world applications. It will provide a physical component to the concepts related to building various structures such as stadiums, bridges, towers, skyscrapers, and etc. Students will learn concepts related to interior and exterior angles specifically related to triangles, which should lead them to realizing the strongest shape. Students will be able to measure a physical object that they created and calculate measurement and make predictions based on their own product design. These lessons and performance tasks will strengthen the students, interest, knowledge and understanding of mathematical concepts of angle measurement and polygon shape design through the use of hands on activities to synthesize and interpret concepts learned in the classroom.

Anticipatory Set/Capture Interest:
Students will be told that they are engineers for a local well known company and they have been chosen to design a mini-model of new structure for the city. The only requirements are to use the provided materials, make it strong and able to hold weight. Discussing with the students about costs, available resources, polygons and designs will help students think about patterns and shape relationships to build their structures. Students should be told to think of building the structures in terms of shapes instead of free style designing. This discussion activity will serve as the first section of one day's activity and lead into the second section of the first day's activity; it is to occur in no more than 10 to 12 minutes. Each small group will be given a limited set of marshmallows and spaghetti and told that they have total freedom to make a structure designed to hold weight, that will be measured on height and weight load. A hint of thinking about no more than three shapes such as circles, triangles and squares may be given.

Guided Practice:

Day One:

The instructor will give a quick introduction to various building types and structures. Then the instructor will pose questions concerning engineering design considerations for various structures (bridges, skyscrapers, stadiums, schools, etc.) and what factors affect the shape and stability of the structures (wind, earthquakes, water, people, vehicles, etc.).

The instructor will introduce concepts related to polygon shapes (sides, angles measurements, etc.). The instructor will ask students to form small groups and pick one spokesperson. Remind the students that their structure should be designed to hold some type of weight (mini-cars, textbooks, shoebox, etc). Students will have 35 to 40 minutes to finish their structures.

Each group will be given marshmallows and spaghetti. They should be told that all of the materials do not have to be used. The teams will have total control over what structure they design. Then students should be told that there is no one correct way to construct their structure, as long as they use at least three geometric shapes (polygons). Instructor will take up measurement worksheets (shapes_structures.docx).

Day Two:

Then a short presentation will continue from day 1 to discuss to the interior and exterior angles. The instructor will go through a few examples of measuring angles from various polygon shapes. Students will then measure both interior and exterior angles from their actual structure models from day 1.

Theorem 1. Sum of Exterior Angles of Polygon

The sum of the measures of the exterior angles of any (regular) polygon is 360.

Theorem 2. Sum of Interior Angles of Polygon

The sum of the measures of the interior angle: Sum= 180(n-2)

n= number of sides

Exterior Angle = $\frac{360}{n}$ **Interior Angle** = 180 – Exterior Angle

Then the instructor will discuss the results of the worksheet measurements and test each group's weight limitations using 3 to 4 different types of weights. Once all the structures have been tested then the instructor can lead the discussion on why some structures were stronger than the other. Next, the instructor will lead the discussion of the strength of the students' structure and which shape is the strongest and why.

A prize can be given to the group with the strongest and tallest structure or two prizes; one for tallest and one for strongest. What predictions can be made concerning the use of

various shapes in combination to create a stronger structure? The discussion would also include real-world applications, benefits and usefulness of the topics learned from this lesson or activity.

Independent Practice:

Day One:

Students will select teams and pick a manager or leader and a recorder for the engineering design teams. Students will design 3D structures using the supplies and material provided by the instructor; they may or may not use all of the materials. Once students have completed their structures they will fill out their measurement sheet (shapes_structure.docx) and turn them in to be used on day two. They will only fill out the height and weight of structure chart and submit it to the instructor.

Day Two:

The students will interactively solve example problems provided by the instructor on measuring interior and exterior angles of different polygons. Next the students will each measure a few angles and identify various shapes included in their structure and record the results on their data measurement sheet. During this time the instructor will measure the strength of the structure using the various weights and then they should calculate the load/weight ratio.

Then the groups can present their structures to the class and discuss any shapes and angles in their structures. Once all groups have presented their structures the students can discuss the various components that made each one strong or weak; leading to the discussion of the strongest angles. The students can ask questions and answer questions that help tie real world applications to mathematical problems and receive some type of incentive for best product or the team who had the highest load/weight ratio.

Remediation and/or Enrichment:

Remediation:

Shorten the length of the activity, by excluding the component concerning the strength of the structure; focus on one equation set either finding the sum of the angles or calculating the angles, partner help throughout the activity, individual assistance, individual IEP.

Enrichment/Extension:

1. Identify polygon types of 3D structure through measurement (i.e. convex vs. nonconvex).

2. Discuss and measure triangle angle relationships (acute, obtuse, right, equiangular, interior and exterior angles).

Check(s) for Understanding:

Day One:

1. How difficult was it to build a structure with limited material and time constraints? What role did the material play in the strength of the structure?

2. What geometric shape proved to be a stronger shape? Are there other polygons that were not used that may be stronger ? If so, why?

3. Did the structure with the highest or lowest height have the strongest or weakest strength? Why?

Day Two:

1. What parts of the presentation and activity did you feel was the most important to helped create the 3D structure and understand the concept of measuring polygon angles and why?

2. What parts of the presentation and activity did you feel was the least important to helped create the 3D structure and understand the concept of measuring polygon angles and why?

3. Do you have a better understanding and improved knowledge of how to measure polygon angles and manipulate associated equations?

Closure:

Day Two:

1. Do you think that with the skills and knowledge learned through this exercise that you can apply these concepts of building a structure can be applied other everyday tasks?

Discuss some real world applications (who, what, when, where and how) that would benefit from understanding and measuring angles of various structures.

Possible Alternate Subject Integrations:

Science/Chemistry - Analyze how angle measurements of different molecules, atoms can be defined by the angle measurement of their chemical makeup.

Physics- Look at what role such as tension and forces play on the strength of different polygons shapes.

Food/Nutrition- What are the structures of different foods that make them strong or weak. What characteristics of food give them thickness or dense structures.

Teacher Notes:

Reference Sources:

1.http://www.bucciteacher.com/modeling/SpaghettiTower/spaghettitower.htm

2.http://www.teteschercheuses.ca/e/students_elementary/creative_genius_program/pdf/short_challenges_04.pdf

3. http://www.yesmag.ca/projects/tower.html

4. http://www.simplot.com/education_council/spaghetti_marshmallow_tower.cfm

5. Scott, D., Farnsworth, D., Jackson, M., Clark, M., The effects of complex geometry on Tall Towers, Structural Design of Tall and Special Buildings. Vol. 16, no. 4, pp. 441-455. Dec. 2007.