Lesson Title	Sonobe Polyhedra Mobile
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 principles and geometric shapes

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 (DOK2)

3i) Given the pre-image or image, find figures obtained by applying reflections, translations, rotations, and dilatations; describe and justify the method used, (DOK2)

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. This activity will demonstrate a connection between the art of folding paper, mathematics and engineering design concepts.

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

Writing utensils, any type of paper (newspaper, gift wrap paper, origami paper, two sided colored paper, etc.), and an example of a pre-made Sonobe cube, scissors, and rulers. Paper should be cut into equal size 6 or 8 inch squares (6 sheets per student) and guided information about topic and guidelines in PowerPoint presentation by instructor.

Lesson Performance Task/Assessment:
Students will build Sonobe units to creating a cube first then create more advanced units to create a giant mobile. 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. Students should be able to create one Sonobe cube using six sheets of paper. Then students should be able to create more advanced polyhedral. Students should able to connect several Sonobes together to make a giant mobile 3D shape or design to display in the classroom. Each class should make their own design.

Lesson Relevance to Performance Task and Students:
Allowing students to construct Sonobe units will give students and opportunity to identify the connection between the number of Sonobe units and faces of polyhedron and how to piece together the Sonobe units to color the polyhedron in a certain way. 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. Students of all mathematical abilities will be able to recognize and understand these basic three-dimensional. Through the use of hands on activities to synthesize and interpret concepts learned in the classroom.

Anticipatory Set/Capture Interest:
Students will be introduced to the Sonobe units and any background if desired. The Sonobe unit is an Origami project with practical applications in industry. Example, car companies are interested in the best or optimal way to fold the airbag up into the dashboard that will provide the fastest and most efficient unfolding method upon impact. Students will be told that they are working as a design engineer for the Wal-Mart Corporation and are in charge of designing a way to pack as many boxes in the delivery truck as possible.

Guided Practice:
The instructor will discuss different polyhedra types, styles and designs as well as some basic definitions.

Definitions:

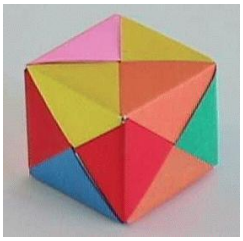
- Parallel means two or more coplanar lines that have no points in common or are identical (eg, the same line).
- Perpendicular means 2 segments, rays, or lines that form a 90 degree angle.
- Congruent means equilateral, equal, exactly the same (size, shape, etc.)
- Right angles are angles whose measure is 90 degrees.
- A triangle is a polygon with three sides.
- A square is a regular quadrilateral. This means that it has four equal sides and four equal angles (90 degree angles, or right angles).

- A rectangle is a quadrilateral whose angles are all right angles.
- A polyhedron is a three dimensional solid with straight faces and edges.
- A vertex is a corner of the polyhedron.
- An edge of a polyhedron is a line that connects two vertices.
- A face of a polyhedron is the two dimensional polygon created by the edges.
- A cube is a three dimensional solid with 6 square faces, 8 vertices and 12 edges.
- A polyhedron is n-colorable if there is a way to construct the polyhedra from n different colored Sonobe units where no Sonobe of the same color are inserted into each other.

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

Independent Practice:
Students will individually make a Snobe cube and then make more complex designs as a class.

Sonobe Instructions:
6 sheets make 1 cube



Each student should have 6 pieces of paper cut into perfect 6 or 8 inch squares.
The first step is the valley, fold the square in half.
Open and then fold each half in half.
Open the paper and now you should see four equal rectangles.
Next, fold the bottom right corner into a right triangle to the first crease.
Rotate the paper 180 degrees and once again fold the bottom right corner as before.
Now, valley fold the bottom of the sheet crisply creasing it at the first fold line.
Rotate 180 degrees and repeat.

Next, fold the lower left-hand corner all the way to the top of the paper.
Lift your new triangle and tuck it in under the top half of paper.
Rotate and repeat.
You now have a parallelogram.
One side of the parallelogram has an "X" forming pockets that each unit will fit into after all have been folded.
Flip the parallelogram over and fold each point over so that you have two new triangles and the paper is now a square.

Repeat with all sheets and then assemble.

Remediation and/or Enrichment:
Remediation:
Individual IEP, shorten activity and let students simple make the SONOBE cube structure.

Enrichment:
May be extended into a two day activity. This activity can be extended to making complex designs shown below:


Octahedron (12 units)


Icosahedron (30 units)


Spiked Pentakis Dodecahedron (60 units)


Icosahedron (30 units)

Check(s) for Understanding:
1. What kinds of polyhedron can you make?

2. Discuss the different shapes that are possible.

3. Can you predict the color variations based on the type of polyhedra?

4. How many colors are possible with a cube?

5. How many colors can you use with polyhedra?

6. What parts of the presentation and activity did you feel was the most important to helped create the Sonobe cubes and why?

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

Closure:
Discuss some real world applications (who, what, when, where and how) that would benefit from understanding concepts related to geometric shapes, polyhedra and color design. Discuss the relationship between the number of folds and the color variations associated with different types of Sonobe designs.

Possible Alternate Subject Integrations:
Chemistry
Physics
Art

Welding/Shop design

Teacher Notes:

Reference Sources:

1. http://gurmeet.net/origami/modular-origami-getting-started-with-sonobe-units/
2. http://math.sfsu.edu/cm2/papers/ashleyOrigami.pdf
3. http://www.scopeonarope.lsu.edu/classroom/lessonplans/ORIGAMI/georigami.pdf
4. http://www.origamee.net/diagrams/sonoassm.pdf
5. http://www.fortunecity.com/meltingpot/alabama/179/sonobe_unit.html