BUILDING A GEODESIC DOME

Application of Architectural Concepts

Age Level:

Third grade and up

Subjects:

Math
Science

Time:

60 to 90 minutes for Part One

2 to 3 hours for Part Two (You will need to plan to do Part Two over more than one classroom session.)

Materials:

Building the Dome Activity:

- (Optional) Copy of Build a Geodesic Dome and Steps to Build a Geodesic Dome handouts for each student
- Minimum of 11 marshmallows per student
- Minimum of 25 toothpicks per student
- 1 to 2 sheets of newspaper per student
- Hand wipes for clean up

Larger Dome Creation Activity:

- Newspaper – at least 65 sheets per group
- Masking tape, 2 to 3 rolls per group
- Two different colors of tape
- Scissors
- Meter Stick
- Tempera Paint
- Weights for dome testing, such as books, magazines, etc.

Learning Objectives:

- Identify and understand the forces of compression and tension and how these forces affect structures; observe how different shapes have different load carrying capabilities
- Identify how triangles and tetrahedrons support and distribute weight
- Work cooperatively as a team to assemble a geodesic dome
- Have an increased awareness of the geometric shapes and components that make up a geodesic dome
- Understand the basic structural engineering concepts that underlie geodesic dome construction
- Follow directions and are expected to meet a time deadline
- Observe and review their structures performance and discuss possible future revisions to their dome

Design Professional:

It would be a good idea to create a dome first, on your own, before teaching the lesson. This will allow you to anticipate possible problems your students might encounter. To assist with teaching Part One, tape together a square made out of straws ahead of time. Next, make two more squares, one with a diagonal straw through the middle so the square is divided into two triangles, the other square needs an X made in the middle, so that there are four smaller triangles. You will use these shapes in the demonstration. To assist with teaching Part Two, create a triangle out of straws and use the simple square made out of straws from Part One and to demonstrate how much stronger a triangle vs. a square is. Work with the teacher to have materials ready for each group. See resources for more information.

Teacher:

Why Study Geodesic Domes? A geodesic dome is a system of triangular forms linked together to enclose a space. Of all structures it distributes stress and weight the most economically. Geodesic domes are unusual structures that intrigue students and offer teachers an opportunity to investigate interesting concepts in engineering, math, and environmental science. Geodesic domes are used in unique spaces—stadiums, theme parks, and playgrounds. They generally don't look like the buildings that people use in their everyday lives. Through studying geodesic domes, students are exposed to an innovative solution to the ongoing challenge of creating structures—how to maximize space while creating a strong, cost effective, people friendly structure. By studying the geodesic dome and its construction, students learn about materials, structures, and forces used in all buildings. Before the lesson, provide background for your students in the area of compression and tension. Doing these activities ahead of time will give more time for the students to spend on building their dome. You might also want to review the vocabulary in the activity section.

Rationale:

Engineering design allows students to consider various ways to problem solve. In grades 3-5, students should be able to be more systematic and creative in their engineering design process. The engineering design process can be thought of in three phases: Defining a problem, developing possible solutions, and improving designs. Students are given criteria and constraints, which allow them to plan for the specific function of their design as well as the limitations of their supplies in building their specified design. They need to develop some alternative solutions and compare them to see which meets the criteria and constraints most successfully. Improving designs comes through the testing phase where students have built a model or prototype, subjected it to a test until it "fails." Then if time, students can rework their model and try again, or learn from successes of other models whose failure rates were later in the testing phase.

Background Information:

A dome is simply a curved structure that has no angles and no corners. Despite their thin and light weight structures, domes are some of the strongest and stiffest structures in existence today. They can actually enclose an enormous amount of space without the help of a single column. In the 20th-century domes advanced in their engineering. In 1926, the first geodesic dome was created by Walther Bauersfeld, a German engineer. This radical new design changed the way engineers looked at domes for the first time in 2,000 years. The geodesic dome is a partial sphere shape structured from a series of triangles, rather than a series of arches. Today, geodesic domes come in an almost endless variety of shapes and styles.

Buckminster Fuller was an American architect born in 1895. Fuller popularized the geodesic dome in the late 1940s to demonstrate some ideas about housing. He hoped it would help in making sure housing was available for everyone so that shelters using compression and tension could be made of any size with materials that often wasteful construction methods couldn't match. He wanted to use science to solve problems for people's living environments with materials that different climates would already have in abundance.

Part One

A. Define and Demonstrate Forces Activity

Explain that a force is a push or pull on an object. When an object is at rest (not moving), the forces acting on it are balanced.

Place a chair in the middle of the floor. Ask students if there are any forces acting on this chair. Even without anyone pushing on the chair, there are forces acting on it. The force of gravity is pulling down on the chair, but it does not collapse because it supports its own weight.

Have a student push the chair a short distance across the floor. Ask what force just acted on the chair. Answer: Pushing the chair unbalanced the forces on it, enabling it to move.

Have two students face each other on either side of the chair and push it so that it does not move. Ask students whether there are any forces acting on the chair. If so, why doesn't it move? Although two forces are acting on the chair, they balance each other, causing it to remain in place.

B. Force Search Activity

Divide the class into two teams. Ask each team to search for building elements under compression and tension in the classroom or school. Give the class a time limit of 15 minutes to find:

• 5 elements under tension

• 10 elements under compression

Appoint one group member from each team to write down the information. When the time is up, compare the lists.

Examples of elements under compression:

• Walls

• Vertical sides of doors or window frames

• Columns

• Piers

Examples of elements under tension:

• Cables or strings hanging from the ceiling with an object attached to it, such as a map, poster, or screen

• Arches and triangular structures are in both tension and compression

C. Building the Dome Activity

Pass out newspaper to the students. Begin by having them form domes by bending a couple sheets of newspaper into a bowl shape. They will quickly note that the domes are not that structurally strong.

Next show students pictures of geodesic domes (such as Epcot Center in Orlando Florida). There are also video links in the Resources section if you want students to see domes being built.

Ask students:

> *"What shapes do you notice in these domes? Why do you think these shapes were used?"*

Demonstrate how squares are less stable structures under pressure than triangles using the pre-made straw squares

Objectives: Students will:

• Create and examine three two-dimensional shapes – a square, a triangle, and a rectangle – and determine which is the sturdiest

• Discover how changing a material's three-dimensional shape can increase its strength identify points of compression and tension within geometric shapes

Ask students to vote by a show of hands to the following question:

> *"Which shape is more stable, triangles or squares?"*

Tally their responses and write the totals on the board. Explain with visual demonstrations of that squares are less stable than triangles. It could be helpful to do the lesson "What Makes Structures Stand Up?" from Section 4 in this guide before doing this lesson.

Option 1: Hand out materials to students - minimum of 11 marshmallows, minimum of 25 toothpicks, newspaper and direction sheet. You can then have each student make their own geodesic dome using the instruction sheet. A geodesic dome is somewhat tricky to make the first time, so giving students directions will help them to be successful.

Option 2: However, if you want to make the project more challenging for your students, you can have them use the lab sheet to work through their project and go through the design process. They can use whatever geometric shape they want to build with. More toothpicks and marshmallows will be needed.

D. Activity Extension

Strength Challenge (make sure the domes have had time to "dry" before doing the following): Place a plate on top of the dome, add pennies to the plate until the dome shows signs of structural failure. Keep record of which dome had the most pennies. Have that group share how they created their dome and compare with others if they did anything differently.

Part Two

A. Larger Dome Creation Activity

Students will build a (6 foot in diameter) geodesic dome out of newspaper rolls and then test the strength of their dome (contact AFO staff if you would like dimensions to make a 3 foot in diameter dome).

Advance Preparation - 1 hour for 1 person (rolling, cutting, and labeling the newspaper rolls are best done ahead of time for the activity, especially when working with younger kids - 5th graders can do this on their own).

Divide class up into groups of 3. Stack three flat sheets of newspaper together, square newspaper is best. Have students start in one corner, roll the sheets up together tightly to form a tube. When they reach the other corner, have them tape the tube to keep it from unrolling. They must repeat this step until they have rolled 65 logs of newspapers (the group can divide up the rolling so they each are doing 21-22). Now they will need to cut the rolls on both ends to make 35 long rolls and 30 short rolls. The long rolls are 71 centimeters long, the short rolls are 66 centimeters long (half these dimensions to create a 3 foot in diameter dome). Have students use one colored tape to label the long rolls and a different color to label the short rolls.

You can have groups hang the domes in the classroom (or just sit in a secure area) and paint them bright colors. This will also make the domes stronger when they dry. (See pictures of examples on our website at www.af-oregon.org/architects-in-schools/)

Discussion Questions (before testing):

1. *Which shape is stronger, a square or triangle?*

2. *What about a circle?*

A triangle is stronger than a square. A circle has no joints and cannot disperse a force, thus it is very weak

3. *What shapes are best to build the dome out of? Why?*

Triangles are stronger then squares or circles. Triangles are best to build the dome with because they disperse weight more evenly than a square or circle

4. *What part of your structure will be the strongest?*

The base and the joints will be the strongest

Divide the students into groups of 3-6 (with younger students it is better to have larger groups). This activity can be divided into three segments, and the group can either all work together on one segment at a time, or split up and work on different segments. Each segment has its individual directions as follows. See the next page for illustrations.

Segment 1:

Use 20 long and 10 short newspaper members

- Tape ten longs together to make a circle, which will form the base of the dome
- Tape a long and a short to each joint. Arrange those so two longs are next to each other and two shorts are next to each other and so on
- Tape the tops of the two adjacent shorts together to make a triangle. Tape the next two longs together, and so on, all the way around

Segment 2:

Use 10 long and 15 short newspaper members

- Form another circle out of ten shorts to create the base for the next layer
- At every other joint, attach a short sticking straight up
- Attach two longs to each short from the joints on either side of the short, forming new triangles
- Attach the base of Segment 2 to the top of the triangles of Segment 1. Segment 1's short triangles should align with Segment 2's short vertical tubes

Segment 3:

Use 5 long and 5 short newspaper members

- Create a circle with five longs. Tape a short at each joint (should be 5 shorts) and connect the tips of all of the shorts forming a single point
- Connect this final segment to the rest of the dome

Discussion Questions (after testing):

1. *Did your structure break the way you anticipated?*
2. *Did the middle cave in, did a joint fail, or did a roll break in the middle?*
3. *What would you do different next time?*

Work together better, tape joints differently, use less/ more tape.

4. *What would you keep the same?*
5. *Did you work together well? How did you tape the joints and put the dome segments together?*

Activity Extensions:

Have students find examples of compression and tension outside of the classroom and bring ideas back to class for discussion.

Have students research Buckminster Fuller further and write a paragraph about his ideas.

Web Resources:

How to build a dome: www.youtube.com/watch?v=ecXzKtwJpMA&t=21s (This is a 14 minute video, but you can show a small portion for your students to get the idea)

This video shows a clear example of pentagon and hexagon shapes in the building: www.youtube.com/watch?v=L1DnMDzMJPU

Article on how geodesic domes work: http://science.howstuffworks.com/engineering/structural/geodesic-dome.htm

Zoom Science (PBS Kids) Geodesic Dome Activity: https://opb.pbslearningmedia.org/resource/arct14.sci.bbgeo/geodesic-dome-activity/

BUILD A GEODESIC DOME

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Building a Geodesic Dome

NAME	DATE

ASK: The question for this challenge is: How can you design and build a geodesic dome using only marshmallows and toothpicks? What geometric shape will you use?

PLAN: Use the back of the paper to sketch out your ideas for your dome. Discuss ideas with your team.

CREATE: Discuss the plans with your team. Which plan will you follow? Why?

PROBLEMS & SOLUTIONS: As you work, you may encounter some problems. What solutions did you try in order to create your dome?

REFLECTION: Sketch which geometric shape you used. What did you learn today? What might you do differently next time?

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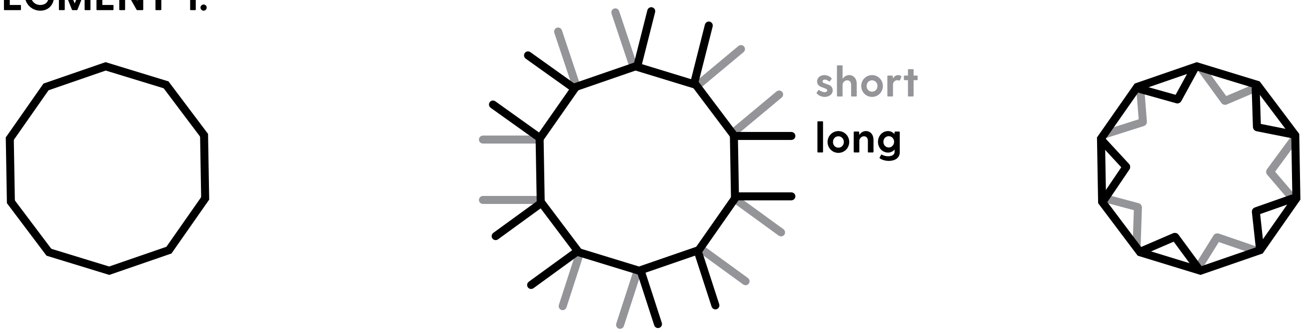
STEPS TO BUILD A GEODESIC DOME

Building A Geodesic Dome

SEGMENT 1:

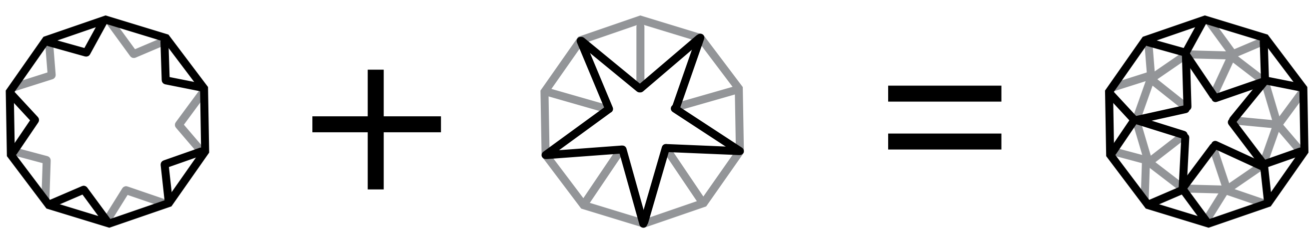


Step 1 Step 2 Step 3

SEGMENT 2:

Step 1 Step 2 Step 3

SEGMENT 1 & 2:



SEGMENT 3 + SEGMENT 1 & 2: