PRIMARY + STEM

Teaching Resource

ACTIVITY: Strong Shapes

ACTIVITY OVERVIEW

Three-dimensional shapes provide a fun link between geometry and engineering. One of the reasons that we learn about shapes is so we can use them in construction. Architects and civil engineers learn about the best shapes to use in building situations. Sometimes we need strong shapes, sometimes we need flexible shapes, and sometimes we want a weak shape that breaks at just the right time. Using easy-to-source materials, students will identify and name shapes that are used in building strong structures.

This activity also allows cross-over into the science curriculum, with students changing materials to change their properties, and creating experiments that are a fair test.

SYNOPSIS

Three-dimensional shapes provide a fun link between geometry and engineering. One of the reasons that we learn about shapes is so we can use them in construction.

Architects and civil engineers learn about the best shapes to use in building situations.

Sometimes we need strong shapes, sometimes we need flexible shapes, and sometimes we want a weak shape that breaks at just the right time. Using easy-to-source materials, students will identify and name shapes that are used in building strong structures.

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Foundation – Year 2

- F: Sort, describe and name familiar two-dimensional shapes and three-dimensional objects in the environment. (VCMMG081)
- Y1: Recognise and classify familiar two-dimensional shapes and three-dimensional objects using obvious features. (VCMMG098)
- Y2: Describe the features of three-dimensional objects. (VCMMG121)
- F – 2: Everyday materials can be physically changed or combined with other materials in a variety of ways for particular purposes. (VCSSU045)
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Years three - four

- Y3: Make models of three-dimensional objects and describe key features. (VCMMG142)
- Y4: Explain and compare the geometric properties of two-dimensional shapes and three-dimensional objects. (VCMMG171)

Years five - six

- Y5: Connect three-dimensional objects with their nets and other two-dimensional representations. (VCMMG198)
- Y6: Construct simple prisms and pyramids. (VCMMG228)

ACTIVITY, MATERIALS AND INSTRUCTIONS

Activity

A piece of paper is a weak, flippy-floppy material. Students are challenged to change the shape of a piece of A4 paper to make it strong enough to lift the weight of a shoe off the ground.

Materials for class of 30 students

- A4 paper (preferably used) x 60 sheets
- Sticky tape x 1 roll per table group
- Shoes x 1 per child (presumably they are already wearing shoes!)
- Optional - Books (from your classroom shelves)

Instructions

1. Teacher demonstration:

   Teacher asks students about the properties of paper. What can it do? What do we use it for?

   So, paper is not a strong material, is it? Can it hold up the weight of my shoe? I want it to lift my shoe up off the ground.

   Teacher demonstrates trying to get the paper to hold up a shoe, trying along the short and the long edge. Of course, a flat sheet of paper cannot hold up a shoe, but it's fun to get a laugh out of the class!

   Can you change the shape of the paper and make it strong?

2. What are some strong shapes that we could try to change our paper to? Students can suggest ideas, perhaps make note on the board, or allow students to draw some shapes.

   Use this brainstorming point to clearly differentiate between suggestions of two-dimensional and three-dimensional shapes.

   We can't change the paper into a rectangle, but we can change it into a rectangular prism or cube. We can't change the paper into a triangle, but we can change it into a pyramid or a cone. We can't change the paper into a circle, but we can change it into a cylinder.

   Which is the strongest shape that we can make from one sheet of paper and some sticky-tape? Which shape will hold up my shoe?

3. Students test folding and rolling paper shapes, to work out which shape can hold up their shoes. This activity is best completed on the ground, to avoid getting dirt from the soles of shoes on your classroom tables.

   The easiest strong shape that students can make from a single sheet of A4 paper is a cylinder. A paper cylinder, rolled from the top down, and secured with a single piece of tape, will hold up the weight of at least one shoe.

   Other students are likely to fold rectangular and triangular prisms, which may hold up the weight of a shoe.

4. Where do we see cylinder shapes used? Students may suggest toilet rolls, poles, trees, bones, columns. Our leg bones are shaped like cylinders, giving them a strong shape to help support the weight of our bodies.

   Note - a true cylinder is made up of two circles and a rectangle. Our paper cylinders are missing the circles on the end.

5. Optional - Let's all make cylinders. Students find a partner and place their cylinders next to each other on the ground. How many books can you hold up with two strong paper cylinders? Make a prediction first, then use books in your classroom to test out the strength of your shapes.

HOW TO USE THIS ACTIVITY WITH YOUR STUDENTS

Foundation - Year 2

These students may need more assistance to think of ideas for making strong paper shapes (Step two). One way to help is to have a more detailed class discussion about strong shapes before you start folding/sticking the paper. What can you think of that is really strong? What's a strong part of our bodies? What is something that is very tall and strong? You may like to prepare a few photos or have a quick tour around your school to show students strong shapes in action (e.g. some buildings are rectangular prisms, cylinders holding up basketball rings, shade sails, roofs can look like triangular prisms). Draw/display a rectangular prism, a triangular prism and a cylinder on the board as a guide.

After paper folding/rolling/sticking, students should be encouraged to describe the shapes that they have formed from the paper. Some pictures of common 3D shapes can be displayed, so that they can see the similarities and differences between the strong paper shapes that they create and the common 3D shapes they will encounter during mathematics lessons. For example, 'that looks a bit like a cylinder, but it has an edge down one side', 'this looks like a rectangular prism', 'my shape has a lot of edges. Students may also describe objects that look like the shapes that they have created. 'My shape looks like a tissue box', 'my shape looks like a tent'.

Combine this activity with part of the science curriculum for these year levels, by emphasising the properties of the paper before and after the folding/rolling. Before the shape-changing, the paper is very weak - it is really only good for drawing or writing on. After we change the shape of the paper, we make it stronger! To make really strong paper, we join many layers together and create cardboard. Students may be able to think of some strong cardboard structures that they have seen, or amazing cubby houses that they have built themselves.

Years 3/4

Use this activity to combine science and mathematics by challenging the Years three and four students to make it into a fair test.

What will we be testing? Different 3D shapes, types of paper, shoe sizes, etc.

What things do we need to keep the same? The testing shoe, the person placing the shoe, the person folding/sticking the paper, the type of paper, etc.

This will work best if students work in small groups and share their experiment results at the end.

Years 5/6

Students in Years five and six extend this activity by testing out whether other folded three-dimensional shapes are able to hold up the weight of a shoe. Work in groups, to provide constructive dialogue, and use the printable nets (in link below) to provide students with more shapes to create from paper.

Which of these shapes are strong enough to hold up a shoe? Will it take two triangular prisms to be as strong as one cylinder? How will I arrange pyramids to test out their strength? How many icosahedrons do I need to hold up my shoe?

Is there a link between the number of edges and vertices and how strong or weak a shape is? How many faces does the strongest shape have? You may need to compare results between groups to fully answer these questions.

DISCUSSION SECTION AND KEY THEMES

KEY THEMES

Three-dimensional (3D) shapes

To have three dimensions a shape must have length, width, and height. Three-dimensional shapes have faces, vertices (corners) and edges.

- Cube
- Rectangular prism (also known as cuboid)
- Cone
- Triangular prism
- Square pyramid
- Cylinder
- Sphere

Nets

A net is what a three-dimensional shape looks like when it is opened out flat. You can draw or print a net on paper, then take this two-dimensional shape and fold it, and stick the edges together to make the 3D shape. Note – it is difficult to make a sphere from a flat piece of paper.

Here are nets of three-dimensional shapes (with and without tabs to help with sticking):

- https://www.math-salamanders.com/3d-geometric-shapes.html
- https://www.math-salamanders.com/paper-models-for-download.html
- https://mathgeekmama.com/wp-content/uploads/2015/03/Geometric-Nets-Printable-Pack.pdf

Examples of cylinders

- Table-legs
- Trees
- Bones
- Columns
- Poles
- Pipes
- Water tanks
- Drink cans
- Fire extinguishers
- Food tins
- Drink bottles

Properties of cylinders

A cylinder is a three-dimensional shape that is made up of two congruent bases (usually circles), joined by a curved surface. Congruent means that they have the same shape and dimensions. The bases of a cylinder are always parallel (the same distance apart over their entire surface). Cylinders have a radius (the distance between the centre of either base and the edge of the circle) and a height.

A cylinder does not have any vertices or corners, just edges and faces.

A special type of cylinder is an oblique cylinder, like the Leaning Tower of Pisa, where the sides lean over the base of the cylinder. Another type of cylinder is the elliptic cylinder, where the bases are oval-shaped.

QUESTIONS AND ANSWERS

Why did Ancient Romans and Greeks put lots of columns on their buildings?

Columns were used for support and decoration. Columns allow for a ceiling to be supported without the presence of a solid wall, making buildings look more interesting and letting more light into some areas.

Architects use names for the different parts that make up a column, including the base, shaft, and capital. Some stone columns have lasted for hundreds of years, with examples seen in famous buildings including the Acropolis of Athens, Roman Forum, and the Parthenon.

What other materials change their properties when we change their shape?

Another fun shape-changing activity that you can do with primary school students is changing the shape of a ball of plasticine (or Blu-tak). A ball of plasticine will sink in water. Can you change the shape of the plasticine so that it will float? This will require some good shape-changing.

Hint – think about something you know that floats and try to make its shape (e.g. a boat, a leaf).

Why are most food tins and drink cans cylinders, when rectangular prisms would stack much better on shelves?

Cylindrical tins and cans are the best shape to make with metals. For food tins, the metal can easily be rolled into a cylinder shape and capped with a base and lid. Tins/cans that are cylinder shaped can be packed efficiently, taking up about 90 per cent of the space of rectangular prisms.

The curved surface leaves no weak edges, making this shape stronger than a similar rectangular prism, which would have four edges down its body. Can-openers work well on a curved surface and would probably be less efficient on a rectangular shape. Aluminium drink cans can be thin (less than 1/10 of a millimetre thick!) but also strong enough to hold liquids. There are some exceptions to the round tin food rule, including Spam and sardines.

What 3D shape has the most faces?

It could be infinite! There are many different-sided dice that you can find, including one hundred-sided. Looking at different-sided dice can be a fun way for students to explore polyhedra.

What do you call the shape of a soccer ball?

A soccer ball is a truncated icosahedron. Its surface is made up of twelve pentagons and twenty hexagons. Each pentagon is surrounded by six hexagons. An icosahedron is a 20-sided shape. To make a soccer ball you take an icosahedron, made up of 20 triangles, and slice off each of the vertices (corners) to create the pentagon/hexagon pattern that we recognise. Each vertex becomes a flat pentagon shape.

How did all these 3D shapes get their names?

This area of mathematics is called geometry, coming from the Greek 'geo' meaning Earth, and 'metric' meaning measurement.

- Cylinder – comes from a Latin word 'cylindrus' meaning roller
- Sphere – comes from Latin word 'sphaera' meaning globe or ball
- Prism – from Greek, used by the famous mathematician Euclid
- Rectangle – from Latin 'rectus' meaning right, plus angle/corner

What are polyhedra?

Polyhedra are three-dimensional solids with faces made up of regular polygons (two-dimensional shapes with all sides of equal length. The name comes from the Greek 'poly' meaning many, plus 'hedron' meaning seat. Polyhedra is the plural for polyhedron.

Are a whole lot of triangles stronger than a cylinder?

In modern bridges and buildings, we see the use of triangles more than cylinders, or columns. Many triangles together are often used to support parts of both buildings and bridges.

Triangles, with straight equal edges, are usually easier to form from materials than cylinders and they fit together better to create even stronger supports.

If I am making a bridge out of matchsticks, icy-pole sticks, or Lego, I will be able to build more easily using repeated triangles, rather than many cylinders.

A triangle shape is harder to bend or break than a rectangle. If you built a triangular or rectangular prism using your A4 sheet of paper, you could try making some triangular supports inside the hollow shape, to see if this makes it stronger.

If cardboard is many layers of paper, what are some strong things made from cardboard?

You can buy many items of furniture for your house made from cardboard.

The designers of these furniture items have used strong shapes to make their designs able to hold body weights similar to wood or metal materials.

Try a:

- cardboard bed (https://yona.com.au/)
- table or stool (https://www.papertigerproducts.com/products)
- desk (https://www.ecodesk360.com/)

Does anyone actually need to know about 3D shape nets for their job?

Yes! 3D shape nets are important to packaging. Every cardboard box in your pantry has been formed from a shape net.

Next time you finish a cereal box, or get some takeaway food in a cardboard container, try pulling it apart to see the net.

It's not just the person who makes the cardboard shape that needs to understand it - the graphic designers for every company that uses the packaging need to know which parts are printed on, and which parts are hidden under flaps and glue.

OUTSIDE OR SUPPLEMENTARY READING

3D Shapes Song for Kids (Numberock)

- https://www.youtube.com/watch?v=ZnZYK83utu0

When mathematicians think about soccer balls...

- https://www.americanscientist.org/article/the-topology-and-combinatorics-of-soccer-balls

Columns (World History Encyclopedia)

- https://www.worldhistory.org/column/

Columns (Encyclopedia Britannica)

- https://www.britannica.com/technology/column-architecture
- https://www.britannica.com/technology/order-architecture

3D shape nets

- https://www.math-salamanders.com/3d-geometric-shapes.html
- https://www.math-salamanders.com/paper-models-for-download.html
- https://mathgeekmama.com/wp-content/uploads/2015/03/Geometric-Nets-Printable-Pack.pdf

TOPIC WORDS

- Shape
- Three-dimensional
- Cylinder
- Triangular prism
- Rectangular prism
- Materials
- Properties
- Strength
- Weight
- Net

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