Guess My Shape

Purpose

Understanding how light hits things of different shape and form necessitates an understanding of shape and form. Becoming familiar with the shapes around us and having a language to talk about them helps us when we describe other things which are happening in our world. The National Science Education Standards suggest introducing the rectangular solids in elementary school and the manipulation of shapes and perspectives throughout the school year. Older students will benefit from the application of math skills to shape and structure. Vocabulary words which can be introduced to help us talk about our experiences are shapes, edges, sides, cylinder, sphere, triangular solid, rectangular solid, cone, pyramid, and cube.

Teacher Background

You will need: buckets of wooden solids, overhead projector, flashlights, paper, pencils. K-2 will need paper plates, ball, clay or a clay substitute and drawing materials. 2-4 will need a cardboard shield constructed ahead of time, and 4-6 needs pipe cleaners and tape.

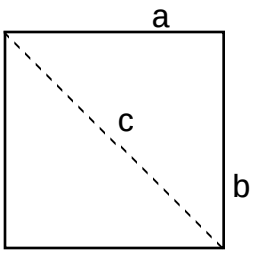
Depending upon the level of your students, you may need more or less time to talk about shapes. However, a few class periods is probably sufficient, although referring to shapes throughout the year is a fine way of keeping the topic alive. The amount of time needed to collect materials is minimal, unless you need to order the wooden solids.

There are several basic shapes in our world which show up time and again. We call these the regular solids because their construction is from simple shapes like circles, triangles, and rectangles. To make one of these shapes is to imagine a triangle, say, sitting flat on the table as if cut out from a piece of paper. Flat as it is, it is nearly two-dimensional. What if you could give it height? Imagine being able to grab hold of the three sides and stretch them upwards. From above, it would still look like a triangle, but from the sides, it would look like a building with three sides. This is called a triangular solid. The same technique is

used to make a cube or cylinder. These shapes are often called “prisms”, but are quite unlike rainbow prisms, so we should not refer to these shapes as such. Instead, they are rectangular solids, because a shadow cast from the long side is always a rectangle.

To make something like a pyramid or cone, you must imagine a similar procedure. Instead of stretching the sides up to make the solid, you imagine that you pull them up and together to a point at the top. Or imagine you cut paper into smaller and smaller versions of the flat shape and place them on top of one another until you have cut out a single point, which is the very top. So, a four-sided pyramid is a square onto which is placed a smaller square and so on. The sides slope as the size of the square shrinks. The same with a cone, but you start with a circle as the flat shape and build up on that.

Pulling shapes through a third dimension means that light shining on these shapes can fool the eye when looking at their shadows. The shadow cast by a light shining on the face of a triangular solid will produce a rectangle. If you knocked the triangular solid on to one of its long sides and cast a shadow from a light shining at one of its ends, you would see a triangle. This is the nature of the regular solids. They have the capacity to fool you when seen only in shadow.



$c^2 = a^2 + b^2$

Thinking about the way light hits objects is a good way of thinking about the geometry of these solids. In math, we say that the length of the diagonal cut across the face of a square, let’s call it “c”, is equal to the square root of the squared lengths of the two sides, a and b. This means that the diagonal is longer than the sides by a little bit. You can find this out yourself with shadows cast on a rectangular solid. If the light is aimed at a side of the solid, the shadow will be a certain width. However, if the solid is turned slightly so that the light is aimed at a corner, the shape of the shadow will still be slightly wider than before. This is the nature of the projection effect of shadows cast from different angles of a rectangular solid.

The ability to roll is something only the circle-based solids have. We cannot talk about corners with these shapes, as there are none. There are edges and surfaces, but no corners. A corner is a point where in flat space, two sides would meet. In three-dimensional space, it is where three or more edges meet. An edge is a meeting of two sides, or faces, like the spine of a book or the sharp lines down the cube.

"For having lived long, I have experienced many instances of being obliged, by better information or fuller consideration, to change opinions, even on important subjects, which I once thought right but found to be otherwise."

—Benjamin Franklin

Kindergarten through Second Grade

Developmental Issues

For Kindergarten through second grade, this Thread focuses on manipulating shapes and sorting objects. This is a great exercise for this age group. They are quite capable of sorting by size and are learning about classification. Geometrical classification by shadow casting may be a bit too complex for them, because children at this age tend to find hierarchical categories confusing. In part because, they tend to assume that categories are mutually exclusive! Superordinate categories create the most difficulty.

Inquiry Introduction

Let's play with shapes in the light to get a feel for shadows of shapes.What is a cube? Which of these shapes are round in some way? How could you sort these objects into groups? What are some things about these shapes that make them different from other shapes? What names would you give for these shapes?

Inquiry Investigation

A tabletop full of geometric solids and their flat counterparts is a good visual. If there are enough shapes, one set at each group table would be great. How could we sort this group? Students may find links between the triangle and the pyramid or the cone and the pyramid. Can anyone explain why they made the grouping that they did? What does the group look like when placed on the overhead projector? Is there a way of making a group on the overhead projector whose shadows look alike?

How do some shapes when put together look like other shapes? What kinds of pictures can we make from just moving these shapes around? Where have we seen these shapes in the world? Why aren't tires made from cubes? Why aren't ice cream cones made from box shapes?

What is the shape of our world? They will likely say round. What is round? Have them draw the world as seen from a rocket in space. What colors did you use? What sizes would you see? How many of you put more planets in or made a crescent moon? Have them talk to you and the class about their drawing. Most every child will have drawn a circle Earth.

Hold up a paper plate and a ball. Which one of these is round? They will say both are, but the world is like the ball. How do we know that? Could you walk all around it? Could you sail around it? Could you dig through it? What if the world were like the plate? Could you travel around it, or might you fall off the edge?

Have them make clay or clay substitute planet Earths. What kinds of things are on the Earth? Water, land, ice, clouds, air? What does light look like when it hits the world shape? Make a mark for where you are on your world. Face your mark towards the light of the projector. What time of the day is it for you? Is there someone on your world having night? Where? Make your mark on your world have night. Are there other people on your world having day while you have night? How much of your world is having night with you? Is this how it works on the big world?

"If you try to impose a rigid discipline while teaching a child or a chimp you are working against the boundless curiosity and need for relaxed play that make learning possible in the first place... learning cannot be controlled; it is out of control by design. Learning emerges spontaneously, it proceeds in an individualistic and unpredictable way, and it achieves its goal in its own good time. Once triggered, learning will not stop--unless it is hijacked by conditioning."

—Roger Fouts

"Great inventors and discoverers seem to have made their discoveries and inventions as it were by the way, in the course of their everyday life."

—Elizabeth Rundle Charles

"Our species needs, and deserves, a citizenry with minds wide awake and a basic understanding of how the world works."

—Carl Sagan

Second Grade through Fourth Grade

Developmental Issues

This age group can think about multiple variables and is capable of imagining other viewpoints and places. For this age level the Thread is focused on speculating about projection of a shape before jumping right into shadow images of them. It engages students in thinking about the function of edges, sides, and corners.

Inquiry Introduction

What is a three-sided shape? What is a four sided shape? what is the shape of our world?

Gather the sets of rectangular solids into groups and give them out to teams of students at desks. Have them list the different groups of shapes in their pile: which have sharp edges, which can roll around, which have four sides, five sides, etc. They will find many different ways of classifying their shapes. Have them talk to the class about their shapes and the groups they made from them.

Inquiry Investigation

What do shadows of these shapes look like? What if the shapes were not sitting on the paper and were instead floating in space? What would the shape of the shadow of our world look like? It is in space with a big light source shining on it. Shouldn't the Earth have a big shadow behind it?

Block the overhead projector from the class with a cardboard shield so that they can't see what sits on the projector but can see the projection. Put a shape on the table of the projector and have them try to guess the shape that is sitting there from the projection. It may be hard to figure it out because of how sometime two very different shapes can make similar shadows. Ask them which shape this could be and why. For example, a

triangular solid sitting lengthwise on the projector table will look like a rectangle. Ask them what they could do to be really sure of what the shape was, besides moving the blocking screen you have constructed? They will hopefully say to rotate the object or turn it over on the projector table. A triangle will show up, and then it is obvious. Lift the shape so everyone sees it and go to the next.

Play around with these shapes, asking if this is the shape of the world. Keep the sphere last. When you put the sphere on, ask them which shape this is. It is the sphere or ball shape. This is the shape of the world, so what does that mean about its shadow as cast behind it through space? Let's be sure. No matter how you rotate the sphere, it always casts a circular shadow. So, if the Earth's shadow were to hit anything, it would be a circle-shape, and that would let us know we were right about the shape of the world. Are there any other shapes that can make a circle shadow? Put a quarter coin or other larger circle shape on the projector table. You see a circle. How can you be sure? You will have to turn it or rotate it. It is then a thin line.

Does the world ever turn around? What would that mean about its shadow? If it were a flat circle, then its shadow will change from a circle to a line. But if it is a sphere, its shadow should always be a circle. Is there anything in space the Earth's shadow would hit? Is there anything that is somewhere close by us in space? The Moon is the closest object to the Earth. Does it ever get in line with the Earth's shadow? (Please note that many models of the Solar System show the planets' orbits all in line with the Earth's as well as cramming all of the planets very close together. These models have confused and misinformed students and teachers alike for decades.)

If there is a lunar eclipse soon, this obviously would be a great introduction to it. Otherwise, locate pictures of past eclipses. What is the shadow's edge shape? It is definitely circular. What does that mean about the shape of our world? Cool. We have provided supplementary material about solar eclipses as well at the end of this Thread, to demonstrate how the straight line, Sun/Blocker/Shadow, works even in space.

"Ignorance more frequently begets confidence than does knowledge; it is those who know little, and not those who know much, who so positively assert that this or that problem will never be solved by science."

—Charles Darwin, *The Descent of Man*

Fourth Grade through Sixth Grade

Developmental Issues

We will approach this Thread from the geometry of the light/solids interaction. Projection from two dimensions to three or vice versa is possible with this age group, as is trying to relate this to how light "sees" objects in the third dimension. Manipulation of rulers and pencils and working carefully in groups is easier for this age group as well.

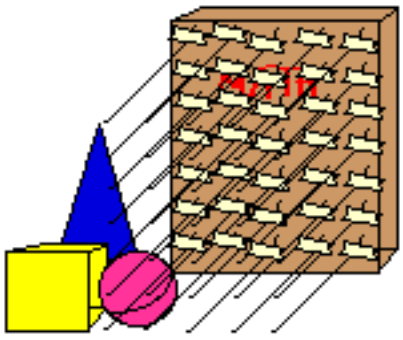
Inquiry Introduction

What are shapes? What makes a shape three-dimensional? Why are shadows the outlines of objects? Why do they seem to sometimes not quite look like the object they are hitting? When light travels past an object, it catches the edges of the object. Is there a way we could make "shadows" just by thinking about the outlines of objects?

Inquiry Investigation

Draw a square on the board. How can I make this square look like it is three-dimensional? Hopefully they will say you need to give it some kind of depth. Extend its sides outward and then connect them again in a square until you have a cube. What is this shape called? Hold up a wooden cube block and orient it to the drawing. Draw a triangle and repeat the depth idea until there is a triangular solid. Hold up a wooden triangular solid and orient it to the drawing. What would these shapes look like if we were looking at them from here, in front of a face of the cube or triangular solid? Many should be able to see it would just be a square or triangle.

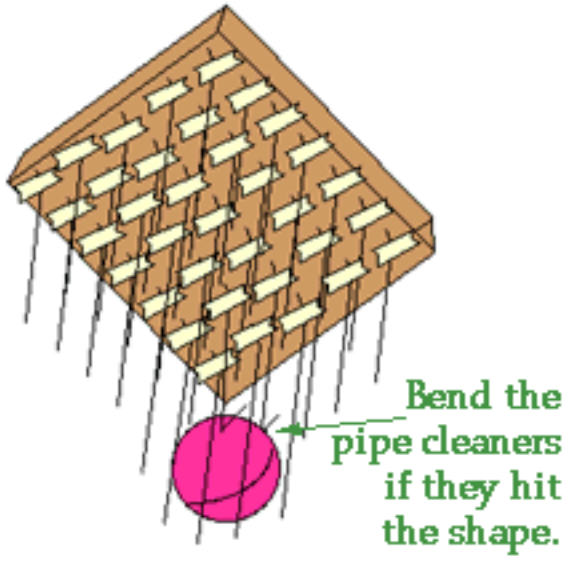
Encourage everyone to try making three dimensional shapes on paper in front of them. How does light see three dimensional shapes? Can we even try to model that?



Have teams of three or more people pick a large and solid shape from a selection of shapes. Give these instructions to the students. Place the blocks on big sheets of paper and trace their position. (Note: This can lead into or follow a multiplication exercise.) Take 35 pipe cleaners, tape each one by an end to the front of a covered textbook, forming a neat 5 x 7 grid pat-

tern. An array of pipe cleaners should now be sticking straight out from the textbook, making the book look like a big hairbrush. Have one student aim the pipe cleaners on the book from some angle above and to the side of the block. They may want to measure the height of the book above the desk top.

What is this representing? What are the pipe cleaners supposed to be? Have them move the book along in the direction the pipe cleaners point until they hit the paper and the block. Any pipe cleaners that hit the block can be bent back out of the way, while the other pipe cleaners reach past the block to the paper. Tape the pipe cleaner ends to the paper or block where they hit. Move around the class to make sure every team and/or student understands the procedure. One student should carefully trace and darken the area where there are no pipe cleaners touching the paper. What is this area called? What is the shape? Teams with triangular solids, for example, will find that their pipe cleaner shadows are very rectangular. Why is this?



Can any of the groups explain what they are seeing happening here? Urge them to think about what the shape "looks like" to light. Can you close one eye and peer at the shapes and see the projection effect? If light really does travel in straight lines, then these shadows are correct. How could we be sure? Get a bright portable lamp and place it at the same height the book was. Don't turn it on yet. Slide the lamp in front of the block, still at the same height as the book. What shadow did it make? Is it the same shape of shadow which the pipe cleaners made?

What if the light were coming from directly on top of the block? Move the lamp above it. They will see there is little to no shadow. Where is the shadow? Does anyone lift the block to see the shadow below? Remember, to have a shadow, you need a light, a blocker, and something to cast the shadow on.

What is the shape of the world? Hold up a sphere. What kind of shadow would this make? When light rays hit it, what shape do they make? Students should be able to see they make a circular shadow. Move the ball to a different orientation, which won't look very different. Now what kind of shadow will be made? The same.

What about in space? Is there anything the shadows can land on? Does the Earth have a shadow? Is there a light, the Sun? Is there a blocker, the Earth? Where could

the shadow fall? What else is out there? Many will suggest the Moon or other planets. So, the Earth makes a circular shadow. If this is true, the world would make a circular shadow on the Moon sometimes.

If there is a lunar eclipse happening soon, this would be a great introduction to eclipses. Otherwise, locate eclipse photographs to show them some pictures of a real eclipse. What is the shape? It is definitely circular. How long does an eclipse take? Hours. What does the Earth do in a few hours of time? It spins. So, if the Earth were a flat circle that spins, would it always cast a round shadow during the eclipse. What does that mean about the shape of our world? Cool.

There is a diagram included showing how the eclipses of the Sun occur. It is important to know that theSun/Blocker/Shadow rule works even with objects such as the Sun, Moon, and the Earth. This is why seeing a total solar eclipse usually requires traveling to some other place: you have to be on the exact place on the Earth where the shadow lands along the Sun/Moon/Earth line!

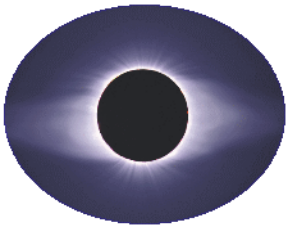
"My mother made me a scientist without ever intending it. Every other Jewish mother in Brooklyn would ask her child after school: 'So? Did you learn anything today?' But not my mother. She always asked me a different question. 'Izzy,' she would say, 'did you ask a good question today?' That difference--asking good questions--made me become a scientist!"

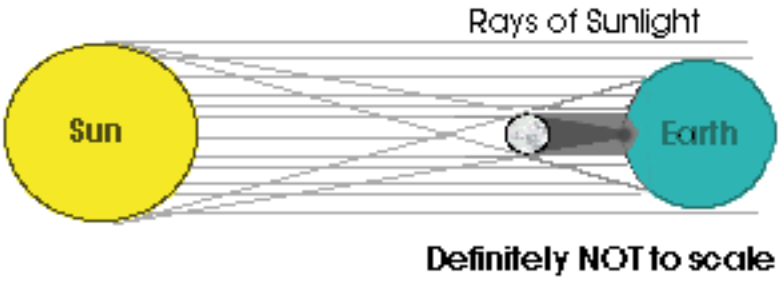
—Isidor I. Rabi

"There are many hypotheses in science which are wrong. That's perfectly all right; they're the aperture to finding out what's right. Science is a self-correcting process. To be accepted, new ideas must survive the most rigorous standards of evidence and scrutiny."

—Carl Sagan

Solar Eclipses





Notice that both the Sun and the Moon appear in the sky to be about the same size: half of a degree. You can figure this out yourself, because the system has scaled itself. The Sun is around 400 times the size of the Moon in diameter. But, the Moon is about 400 times closer to us than is the Sun. These cancel out distance effects and scale the apparent sizes of the objects in the sky to the same size. Great! This means, geometrically, that if you could line them up one day, you could blot one out with the other. Because of the distances involved, which one would block the other? The Moon would block out the further Sun. What about when the Moon is on the other side of the Earth? The Earth would cast a shadow on the Moon when they were all three lined up.

We've tried to draw in the rays of sunlight coming off of the Sun to demonstrate how it comes from the Sun in all directions. See the rays hitting the Moon straight on? These would normally cause a spot the size of the Moon to hit dead on the Earth. However, the Sun is large shining ball, so light can reach the Moon at other angles than just straight on. This effect causes two shadows to form from the Moon. The darkest part where no light is passing at all is called the umbra. The larger shadow, which you can see still gets sunlight in places so it is not as dark, is the penumbra.

When the Moon blocks the Sun, we call it a solar eclipse. (A lunar eclipse is when the Earth's shadow lands on the Moon.) What would a solar eclipse look like from space? What phase is the Moon for a solar eclipse? It is in New Moon (and conversely in Full Moon during a lunar eclipse.

Does the Moon always block the Sun each time it moves into the Sun-Moon-Earth alignment? Do you experience an eclipse of the Sun each month? No. Why not? As it is, the Moon does not orbit in the same plane as the Earth orbits the Sun; the Moon orbits 5 degrees tilted to the Earth's orbital plane. So that small number of degrees is enough to limit the solar eclipses to around once a year. The fact that the Moon's shadow is so tiny also means that the number of solar eclipses which happen for a certain place are also limited. People who want to view a solar eclipse usually have to travel to go see one. Lunar eclipses, however, are easier to see, since the shadow of the Earth on the Moon is quite large.