Asteroid Orbits

Examples of Possible Academic Science Standards to Incorporate:

2nd Grade:

- 7.7.2 Observe rocks of different sizes with a hand lens and describe these materials according to their basic features.
- 7.7.4 Identify simple methods for reusing the earth's resources.
- 7.7.2 Describe rocks according to their origin, size, shape, texture, and color.

3rd Grade:

- 7.6.1 Identify and compare the major components of the solar system.
- 7.7.2 Analyze the physical characteristics of different kinds of rocks.
- 7.6.1 Identify the major components of the solar system, i.e., sun, planets, asteroids, and moons.
- 7.6.2 Compare and contrast major solar system components.
- 7.6.1 Create a model of the solar system depicting major components and their relative positions and sizes.
- 7.7.2Describe how rocks can be classified according to their physical characteristics.
- SPI 7.7.4 Determine methods for conserving natural resources.

4th Grade:

- 7.11.1 Describe the position of an object relative to fixed reference points.
- 7.11.2 Identify factors that influence the motion of an object.
- 7.11.3 Determine the relationship between speed and distance traveled over time.

5th Grade:

- 7.6.1 Compare planets (and bodies in the solar system) based on their known characteristics.
- 7.11.1 Design an investigation, collect data and draw conclusions about the relationship among mass, force, and distance traveled.
- 7.12.1 Recognize that the earth attracts objects without directly touching them.
- 7.12.3 Design and explain an investigation exploring the earth's pull on objects.

- 7.12.1 Explain and give examples of how forces act at a distance.

6th Grade:

- 7.6.2 Describe the relative distance of objects in the solar system from earth.
- 7.6.2 Explain how the relative distance of objects from the earth affects how they appear.

7th Grade:

- T/E.1 Explore how technology responds to social, political, and economic needs.
- Inq.5 Design a method to explain the results of an investigation using descriptions, explanations, or models.
- Inq.3 Synthesize information to determine cause and effect relationships between evidence and explanations.
- Inq.3 Interpret and translate data in a table, graph, or diagram.
- Inq.4 Draw a conclusion that establishes a cause and effect relationship supported by evidence.
- Inq.1 Design a simple experimental procedure with an identified control and appropriate variables.
- 7.11.4 Identify and explain how Newton's laws of motion relate to the movement of objects.
- 7.11.4 Recognize how a net force impacts an object's motion.

8th Grade:

- CU 7.12.5 Explain the difference between mass and weight.
- SPI 5.3.3 Recognize that rocks are composed of various combinations of minerals.
- CU 7.12.6 Identify factors that influence the amount of gravitational force between objects.
- CU 7.12.7 Explain how the motion of objects in the solar system is affected by gravity.
- SPI 7.12.4 Distinguish between mass and weight using appropriate measuring instruments and units.
- SPI 7.12.5 Determine the relationship among the mass of objects, the distance between these objects, and the amount of gravitational attraction.
- SPI 7.12.6 Illustrate how gravity controls the motion of objects in the solar system.

Examples of Possible Academic Vocabulary to Incorporate:

For the Academic Vocabulary we encourage you to use as many of these words as possible, not simply pick one or two. The more words we can introduce in a setting that makes sense to our students, the better.

Kindergarten:

- air
- change
- color
- day/night
- food
- natural
- observe
- parts
- senses
- shape
- size
- star
- sun
- temperature
- thermometer
- tools
- weather

1st Grade:

- adult
- balance
- classify
- environment
- freezing
- heat
- invent
- investigate
- light
- location
- matter
- mixed
- planet
- prediction
- property
- push/pull
- texture

2nd Grade:

- Celsius/Fahrenheit
- compare/contrast
- depend
- dissolve
- distance
- energy
- habitat
- infer
- investigate
- observation
- reasoning
- renewable/non-renewable
- scientific inquiry
- scientist
- similarities/differences
- sound
- universe

3rd Grade:

- atmosphere
- cross section
- force
- orbit
- revolution
- rotation
- solar system

4th Grade:

- electricity
- friction
- mass
- reflection
- refraction

5th Grade:

- conduction
- core
- crust
- dissipate
- gravity

6th Grade:

- asteroid
- bias
- cause and effect
- control
- criteria
- protocol
- prototype
- variable

7th Grade:

- acceleration
- momentum
- phenomenon
- speed
- velocity

8th Grade:

- density
- gravitation (universal law)
- magnetic field
- variation
- gravitational effects

Asteroid Orbits

[Accessing Prior Knowledge] : Dictionary Deception

Choose a word from the following lesson, which most students will not know the meaning. Write the word on the chalkboard and write the definition of the word on a sheet of paper from a small pad, ex. sticky notes. Then hand a sheet from the same pad to each student. The student must write on that sticky note his or her name and a definition of the word that was given. Collect all the definitions. One by one, the read the definitions. Students consider each definition. Then, as the teacher rereads them, the students vote for the definition that they believe is the *real* meaning of the word. Students earn a point if they guess the definition correctly; they *also* earn a point each time another student selects their (fake) definition as the true meaning of the word. The person with the most points at the end of the game wins.

Image Credit: Adrian C. Innott. Barking Hollow Studios, Inc. Copyright 2010. http://adriansinnott.com/wordpress/category/pets/page/2/

Some words to try & sample useful/basic definitions:

- Icarus: Greek myth character who fell and died from flying too close to the sun.
- Daedalus: Greek mythological inventor.
- Asteroid: small "planets" or bodies of rock or ice orbiting around the Sun.
- Meteoroid - a particle of debris in the solar system
- Meteor - a meteoroid that has entered the Earth's atmosphere
- Meteorite - a meteoroid that has reached the ground

Discussion Points:

- What is an asteroid?
- What do students think are they made of?
- When is the last time an asteroid hit the Earth, do students know?
- Where do asteroids hit?
- What usually happens in a movie when an asteroid hits the Earth?

Most meteorites are thought to be broken fragments of asteroids — small “planets” or bodies of rock or ice orbiting around the Sun.

To appreciate the Earth in respect to meteorites and asteroids in the solar system, it is important to know the how the inner solar system is laid out, including the proper relative sizes and distances of objects. Most charts of the solar system give the impression of our solar system as large planets huddled close together in the darkness of space and making the Earth appear as a rather large target for meteorite impacts. An exact scale model of the inner solar system, from the Sun through the asteroid belt, lets the students appreciate and approximate the true sizes and distances.

The asteroid belt is a roughly 180-million-kilometre-wide stretch of space between the orbits of Mars and Jupiter that contains millions of objects of various shapes and sizes. The surprising thing about these objects is that they show a wide range of diversity in their chemical composition (construction). On the belt's inner edge, the asteroids appear rocky and scorched, whereas the outer edge of the belt is filled with icy objects full of water and organic molecules. The largest asteroid is Ceres, 940 km in diameter, much smaller than our Moon (3,500 km diameter). Ceres was the first asteroid discovered (in 1801), and about 6,000 have been discovered since then. Asteroids are so small that telescopes on Earth can see them only as points of light. Recently the *Galileo* spacecraft passed close to the asteroids Gaspra and Ida and sent us pictures of them. Both are irregular masses of rock, seemingly broken and covered with impact craters. As indicated by their colors (reflectance spectra), most asteroids are mixtures of metal and silicate minerals, possibly like chondrite meteorites. A few are made of basalt rock, just like the

Asteroids Can Have Three Names?

When an asteroid is found, it is given a temporary name like l 1983RD, showing what year it was found. After the asteroid’s orbit is known well, it gets a number and can be given a ‘real’ name by the person who found it. The names of asteroids we are going to look at are “1 Ceres,” “1566 Icarus,” and “3551 1983" which doesn’t have a ‘real’ name assigned to it yet. Asteroid names often come from Greek myths, like Icarus, but sometimes they’re also named after famous people, including: “3352 McAuliffe ” (named after Chris t a McAuliffe, the teacher/astronaut who was killed when the Space Shuttle Challenger exploded), 2266 Tschaikovsky (after the Russian Composer), and 1744 Paavo Nurmi (after a Finnish Marathon Runner), and 1569 Evita (after Evita Peron, wife of ex-president Juan Peron of Argentina) and 2578 Saint -Exupéry” (after the author of “The Little Prince,” a very famous story about a visitor from space and an asteroid). This story is available in pdf format at http://cs.swan.ac.uk/~cswill/The_little_prince.pdf basalt meteorites (example: 1983RD in this activity).

Most asteroids orbit in the asteroid belt between 2.2 and 3.2 times the Earth's distance from the Sun; their orbits are ellipses, oval-shaped curves that carry them both nearer and farther from the Sun.

Only a few asteroids follow orbits that get near the Earth, and these asteroids are probably the sources of some meteorites that head towards our planet.

An asteroid that crosses the Earth's orbit could collide with the Earth and cause a devastating impact explosion. About 200 of these Earth crossing asteroids are known, and it is estimated that 20-40 percent of them will collide with the Earth over the next million years. [How many asteroids is 20-40% of 220?] No known asteroid will hit the Earth for at least 200 years. We will likely, we hope, have many years of warning before an asteroid collision like this, and the students will see from the solar system model that the Earth is really a very small target. But when there are potentially a million shots over a long period time, there is a good probability that at least one is likely to hit.

Crater Hunters: Exploring Meteorite Mysteries

Students will:

- develop criteria for identifying craters on Earth.
- search maps for potential impact sites.
- create a fieldwork plan to investigate possible craters.

Materials:

- Large physical maps of any region of the world, one per team
- North American Maps
- Paper and pencil
- Printouts

Preparation:

- Prepare sample crater if desired using materials such as those found in the Moon lesson.

Ask students, "If you were a scientist, what would you look for at the site to help prove that you have found the remnants of an impact?" Brainstorm an example crater and investigation if necessary.

Possible answers might be:

- look for meteorites
- map the geologic formations looking for: a basin shape, overturned rim layers, possible uplift in the central crater region, multiple ring structures.
- look for minerals changed by impact shocks
- look for melted rocks
- Test deposits around the site, looking for elements that are much more abundant in meteorites (i.e., Iridium).

Scientists have to do a lot of field and laboratory research before they are able to verify that a geologic feature is an impact site and it requires a lot of work, including drilling. The scientists are looking for round structures, however geologic forces may have changed the crater shape through faulting or other movement associated with plate tectonics. Ice, water, and wind, through weathering and erosion processes, have caused great changes in craters. Some craters have been filled with water, or completely covered by soil or water, and we can't see any signs of them on the surface.

Hunting for Craters:

Divide class into teams of two to four students.

Assign each team a different map area of the globe to observe, looking for any feature that might be the site of an impact. Allow students to be very creative in choosing the possible sites. Specific sites are not important. They are likely to choose obviously round structures such as lakes in Canada, Hudson Bay, the Gulf of Mexico, the Aral Sea in Uzbekistan (former Soviet Union), Lake Okeechobee in Florida, and Lake Victoria in Africa.

More to Look For

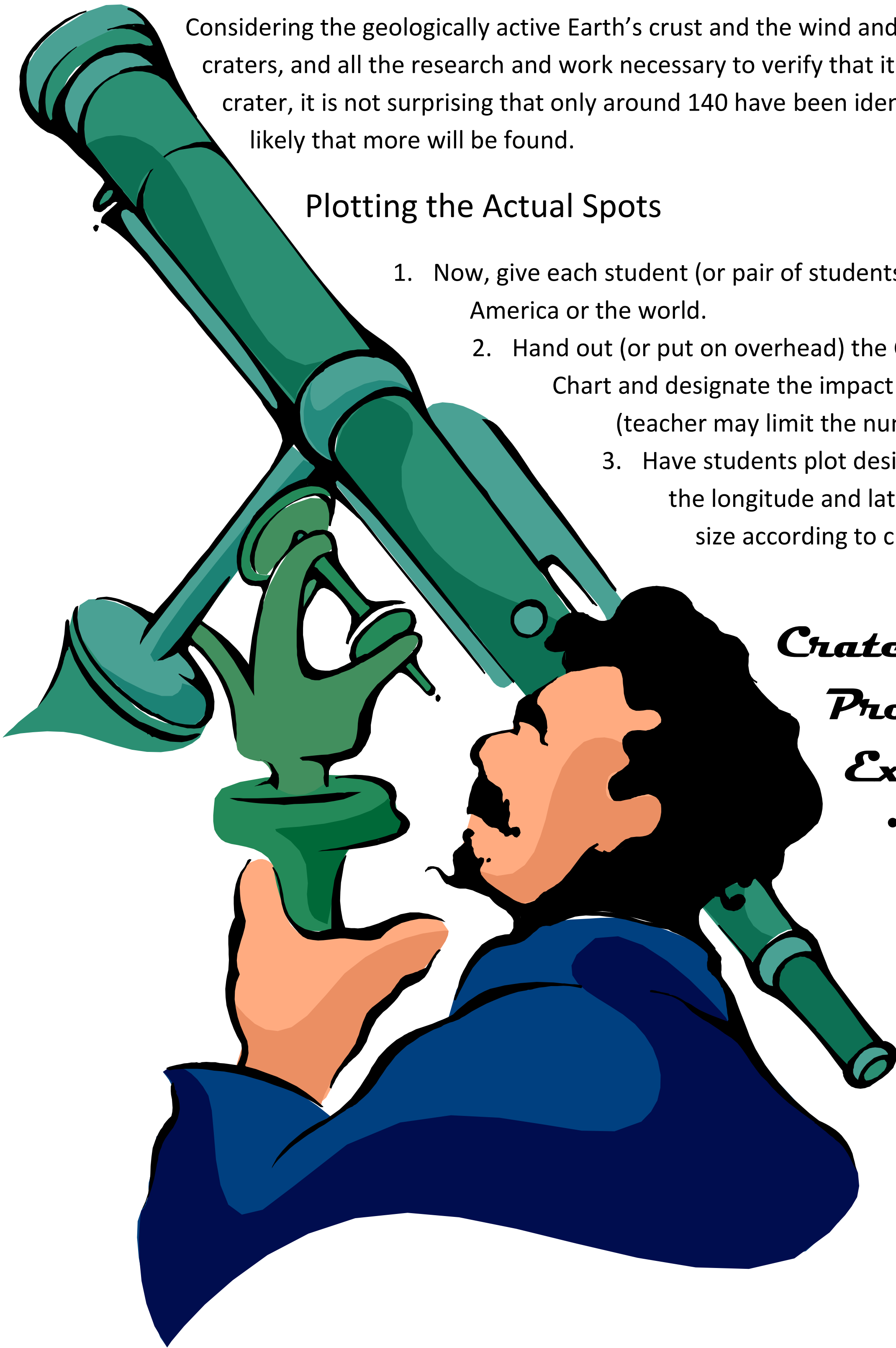
In addition to the crater's round shape, scientists look for layers of rock that have been turned over at the edge of the crater. A large uplift or mountain at the center is also common in impact craters. Highly fractured [broken] rocks are usually found at impact sites but they could be from other causes too, so they aren't a guaranteed sign of an impact. However, scientists find shatter cones, which are highly shocked rocks with unique and unusual structures, only at areas stressed by huge impacts. Investigations usually identify large amounts of excavated material deposited around and in the craters. This material is called ejecta and may form thick layers of breccia, a mixed broken rock material.

Sometimes a large amount old melted rock [glassy rock] is found in and around the craters and is frequently thrown far from the impact, like a splash when you drop a rock in a pond. Another way to get important information about an impact is from chemistry. The impact melted rock sometimes contains melted meteorites. By doing really careful research, scientists can detect very small amounts of rare metals and minerals that are more common in meteorites than they are on our planet. These chemical signatures are very important in meteorite research. To find a meteorite sample would be the best discovery! Unfortunately this does not happen very often because meteorites may completely vaporize during the

impact process, or they may be washed away or moved by erosion.

Early geologists misinterpreted some impact craters. Scientists reported Meteor Crater in Arizona as the crater of a old volcano. The Chicxulub site on the Yucatan peninsula was also wrongly labeled. Early oil explorers misinterpreted extensive deposits around the Chicxulub area. Scientists now know that the material is ejecta from a huge impact and not from a volcano.

Considering the geologically active Earth's crust and the wind and weather that erase craters, and all the research and work necessary to verify that it really is an impact crater, it is not surprising that only around 140 have been identified so far. But it is likely that more will be found.



Plotting the Actual Spots

1. Now, give each student (or pair of students) a map of North America or the world.
2. Hand out (or put on overhead) the Craters on Earth Data Chart and designate the impact craters to be used (teacher may limit the number to be plotted).
3. Have students plot designated craters using the longitude and latitude data, varying dot size according to crater diameter.

Crater Hunters Project Extensions:

- Students write a short "proposal" asking for support money to their "foundation" or possible investors to conduct their research and fund an expedition. They will need to explain and justify the planned research and consider time, travel, personnel, laboratory expenses, and data gathering.

- Astronomers have discovered that a killer asteroid will hit the Earth in a matter of weeks, but no one knows exactly where. What would students do if they were in charge of preparing the world for the impact? Have students create a three-part plan to divert the space rock, lessen its impact, and save as many lives as possible.

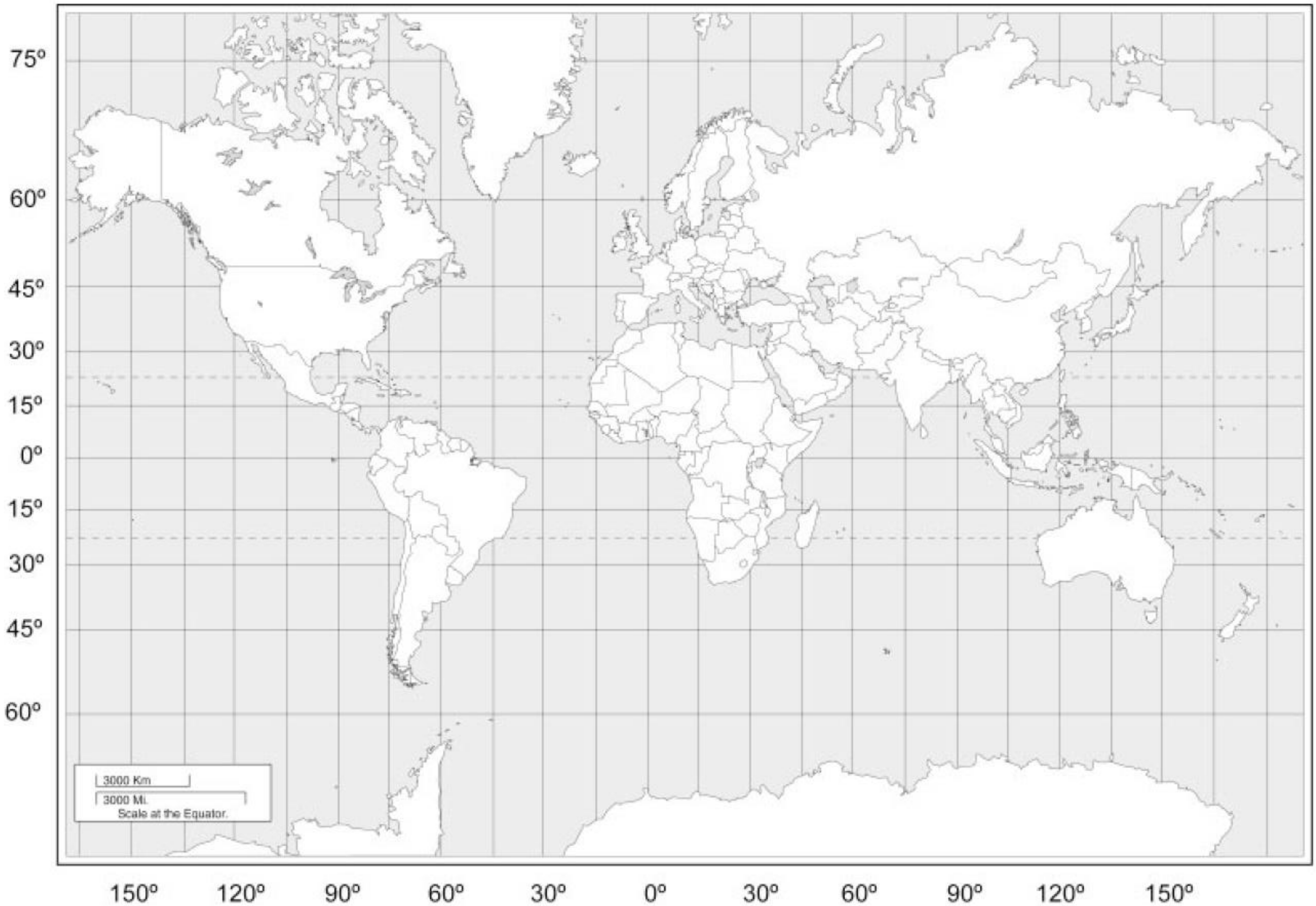
Craters on Earth Data Chart

Crater	Latitude	Longitude	Diameter (km)	Age (yr)
Meteor Crater, Arizona	35°N	111°W	1.2	50,000
*Manicouagan, Canada	51°N	69°W	70-100	212 million
Middlesboro, Kentucky	37°N	83°W	6	< 300 million
*Clearwater Lakes, Canada	56°00'N	74°07'W	22	290 million
	56°15'N	74°30'W	32	290 million
Pilot Lake, Canada	60°N	111°W	6	440 million
Chicxulub, Mexico	23°N	90°W	200	65 million
Sierra Madera, Texas	31°N	103°W	13	100 million
Vredefort, South Africa	27°S	28°E	140	1.97 billion
Sikhote Alin, Russia	46°N	135°E	breakup	46 years
Ramgarh, India	25°N	77°E	5.5	unknown
*Spider, Australia	17°S	126°E	13	< 600 million
Grover Bluff, Wisconsin	43°N	90°E	6	< 500 million
Red Wing Creek, N. Dakota	48°N	104°W	9	200 Million
Odessa, Texas	32°N	102°W	0.2	<50,000
Kentland, Indiana	41°N	87°W	13	< 300 million
Manson, Iowa	43°N	95°W	3	65 million ??
Wells Creek, Tennessee	36°N	88°W	14	200 million

**Craters used in Activity A - Part 2*

Crater Hunters Map

Activity A, Part 1 “Where Are the Craters on Earth?”



Plotting Orbits

http://curator.jsc.nasa.gov/outreach/expmetmys/Lesson4.pdf

To hunt for asteroids, astronomers use telescopes and photograph the night sky, looking for "stars" that move compared to real stars. A long exposure photograph would show a background of stars as spots, with a streak from an asteroid, due to the asteroid's motion across the sky. To discover the orbit of an asteroid, it is not necessary to observe the asteroid as it follows its whole orbit; knowing its location a few times, over several weeks or months, is good enough to get a good idea of where an asteroid has been, and where it is headed.

How do we know? We draw an orbit.

In this activity, students will learn how to draw circles and ellipses using a pencil, pushpins and string. They will learn what an ellipse is, how it is different from a circle, and how an astronomer can determine the elliptical orbit of an asteroid.

Materials:

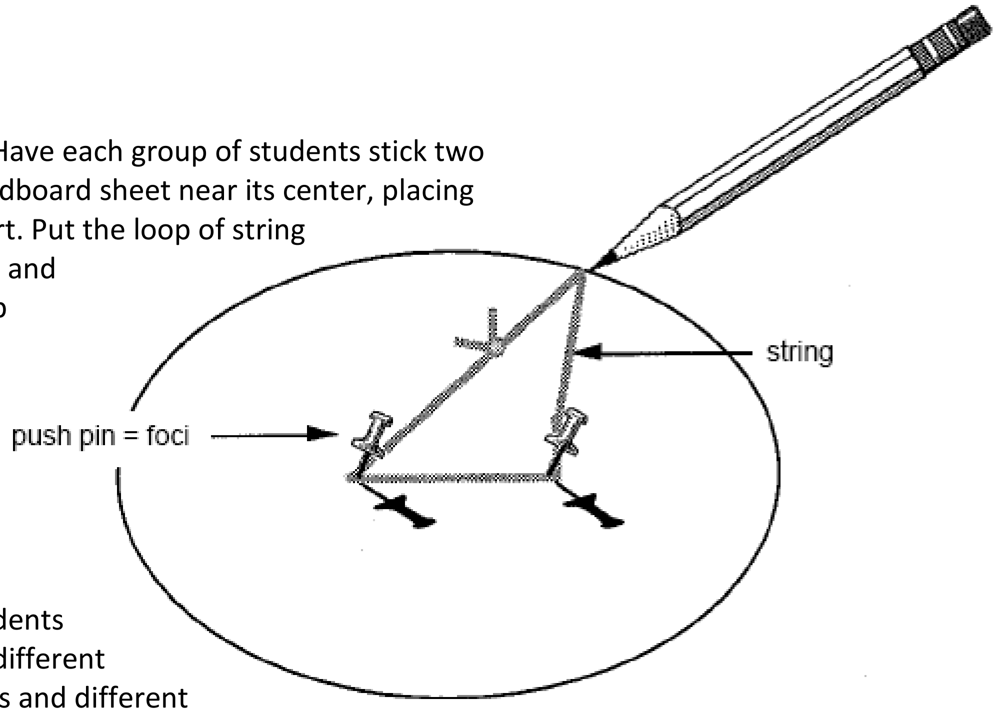
- poster board or cardboard, about 60 cm x 60 cm [24 in x 24 in] It needs to be thick enough to hold a pushpin (old trifolds work well), one for each group
- tracing paper, about 60 cm x 60 cm, one or more for each group
- pushpins, 6 per group
- pencil/pen
- string
- scissors

The instructor should prepare a loop of string, approximately 40 cm in circumference, for each group. Additional loops of string of different sizes may be used for experimentation.
Tip: It's always a good idea to practice a project before doing it with the kids, so you will want to practice drawing ellipses.

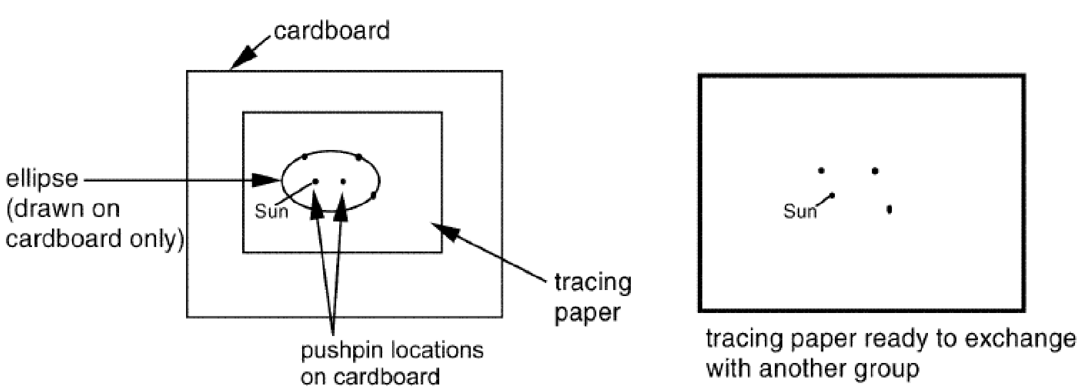
Classroom Procedure

Drawing a Circle. Have each group of students stick one pushpin into the center of their cardboard sheet. Put the loop of string around the pushpin, put the point of the pencil within the loop, and draw the loop tight with the pencil tip (not so tight as to pull out the pin!). Draw a line with the pencil, keeping the string tight. The pencil line will be a circle around the pushpin.

Drawing Ellipses. Have each group of students stick two pushpins into their cardboard sheet near its center, placing the pins 10-15 cm apart. Put the loop of string around both pushpins, and carefully draw the loop tight with the pencil tip forming a triangle. Draw with the pencil, keeping the string tight around both pins. The pencil line will be an oval, or ellipse. Students may experiment with different distances between pins and different lengths of string. Optional: paper may be taped to the cardboard if desired.



Find the Asteroid Orbits. The orbits of asteroids are ellipses, not circles, around the Sun. Astronomers can figure out the whole elliptical orbit of an asteroid by knowing just three points in the orbit. In this activity, a team will draw an ellipse, and another team will work like astronomers to try to reconstruct that ellipse knowing only the locations of three points and the "Sun." It is important that all the teams have strings of the same length.
Have each team draw an orbit for an asteroid on their cardboard by drawing an ellipse (Part 2), and designating one pushpin as the "Sun." Have each team remove the pushpins, place the tracing paper over the orbit drawing, tack the tracing paper to the cardboard at the corners, and using a pen, mark on the tracing paper the "Sun" position and three points on the orbit ellipse (do not draw the entire ellipse). These three "data points" represent observations made by astronomers which are used to plot the orbit of an asteroid.



Teams label their ellipses, trade tracing papers, tack their new paper down at the corners, and put a pushpin in at the “Sun” position. Each team of “astronomers” then tries to find a placement for the second pushpin, so that an ellipse drawn with their loop passes through the three points on the tracing paper. When complete, compare with the original group’s ellipse that includes the three data points.

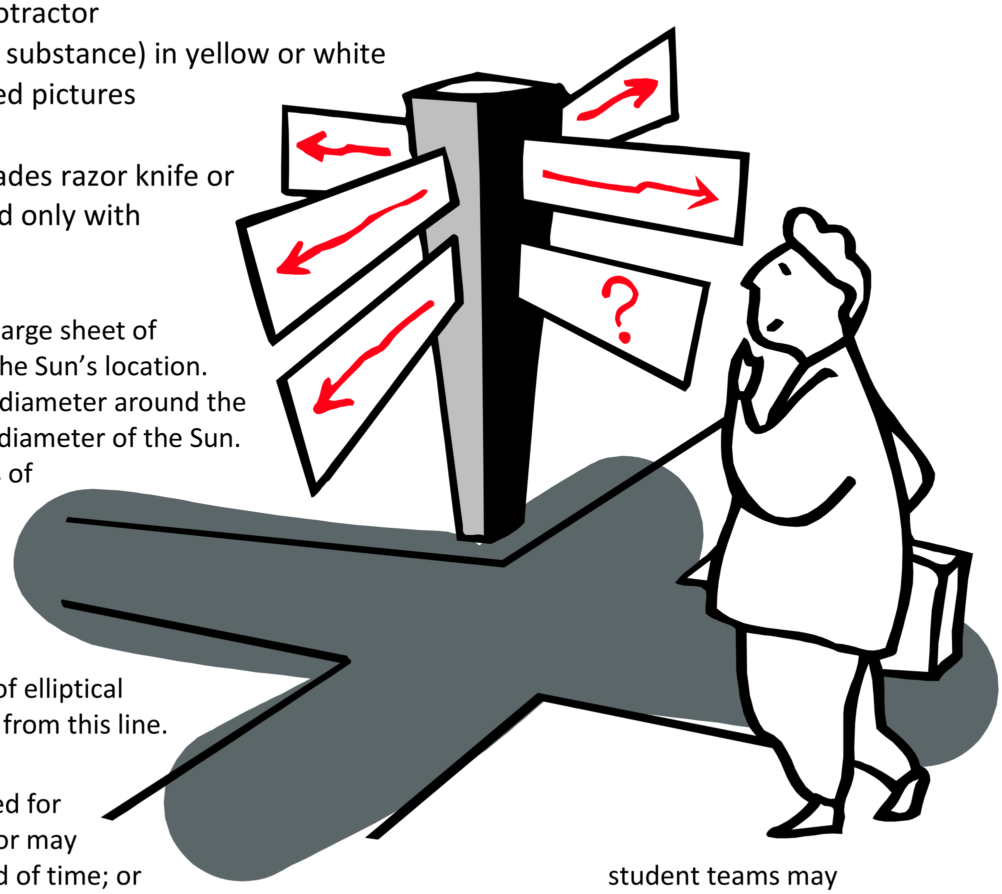
Extension: Have the asteroid orbits drawn with different lengths of string, and having each “astronomer” team determine the string length in addition to the location of the second pin. Discuss: If you wanted to describe an ellipse to another person, what would you say? (length of string, length of ellipse, breadth of ellipse, orientation) What more would you need if the ellipse could be in the air oriented in any way?

The Long and Winding Road to Earth

In this activity, the class will learn how meteorites and asteroids travel from the asteroid belt to the Earth. The focus here is on construction of an exact scale model of the inner solar system (Sun to asteroid belt), including some asteroids that might hit the Earth. At the given scale (which can be expanded or reduced), the model will fit on a 1.2 m x 1.2 m piece of cardboard or poster board, and the Earth will be just large enough to be seen.

Materials:

- 1.2 m square or larger piece of corrugated cardboard (refrigerator box?) or very stiff posterboard
- 60 cm x 30 cm piece of corrugated cardboard or very stiff poster board (upper grades)
- pushpins, two per group colored and regular pencils string, or loops of string in the lengths indicated in Table 1
- scissors, ruler, and protractor
- clay-dough (or similar substance) in yellow or white
- magazines with colored pictures
- Table 1 and Table 2
- Optional for upper grades razor knife or other knife (to be used only with supervision)



1. Mark the center of the large sheet of cardboard; this will be the Sun's location. Draw a circle 1.8-2 mm diameter around the point; this is the scaled diameter of the Sun. If the exact orientations of orbits are desired for upper grades, draw a light reference pencil line from the Sun's center toward a side; angles for orientations of elliptical orbits will be measured from this line.
2. Prepare Strings.
   A loop of string is needed for each orbit. The instructor may prepare the loops ahead of time; or student teams may

measure, cut, and knot a loop for their own orbit. To keep the proper scale, use the string lengths in Table 1. If the loop turns out too long, it can be shortened with an overhand knot.

Table 1. Drawing Orbits in Scale Model

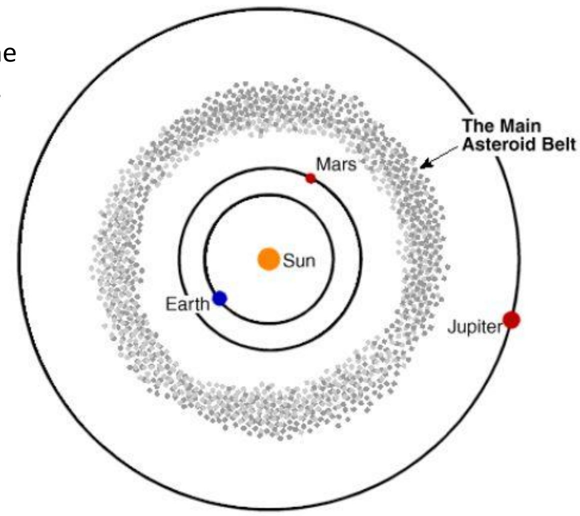
Orbit	Loop Circumference (knot to knot)	# pins	Pin 2 from Sun Distance	Pin 2 from Sun Angle
Mercury	18 cm	2	3.1 cm	270°
Venus	27 cm	1	--	--
Earth	39 cm	1	--	--
Mars	64 cm	2	5.6 cm	45°
Asteroid Belt: Inner Edge	84 cm	1	--	--
Asteroid Belt: Outer Edge	122 cm	1	--	--
Asteroid Ceres	114 cm	2	8.4 cm	78°
Asteroid 1983RD	118 cm	2	39 cm	173°
Asteroid Icarus	85 cm	2	38 cm	330°

3. Draw the Orbits.
   Each student team should draw their orbit on the cardboard, using the pin(s) and string technique in Activity A, Part 2 and the data of Table 1; lower grades include the asteroid Icarus here, upper grades may do Icarus separately (See optional section below—Asteroid Icarus in the Third Dimension.).
   Circular orbits require one pin at the Sun position. Elliptical orbits require two pins each: one at the Sun and the other at the distance from the Sun shown in Table 1. The ellipses may be oriented at any convenient angle on the board; to make the model exact, the second pins should be oriented at the angles in Table 1 from the pencil line drawn in Part 1 (exact orientations are not used later). To draw the orbit of the Earth's moon, pick a point on the Earth's orbit to be the Earth's position. Around that point, draw a circle of 5 mm radius (10 mm or 1 cm diameter) to represent the Moon's orbit.
4. Adding the Sun and Planets.
   To complete the model, add the Sun and planets at the same scale as their orbits. Real and to scale diameters are given in Table 2. At this scale the Sun should be a ball just under 2 mm diameter, about the size of a BB or a ball bearing from a bicycle. The Earth and Venus should be 1/50 mm across, which is almost invisible; smaller than a grain of salt or a pin-prick in paper (~1/5 mm), and about the thickness of standard copier paper. A single dot out of a half-tone print (as in a magazine) is about 3 times too large, but gives the

Table 2. Real and Scaled Diameters of Solar System Objects

Object	Real Diameter	Scaled Diameter
Sun	1,400,000 km	1.8 mm
Mercury	4,880 km	1/150 mm
Venus	12,100 km	~1/50 mm
Earth	12,800 km	~1/50 mm
Moon	3,480 km	1/200 mm
Mars	6,800 km	~1/100 mm
Ceres	940 km	~1/1000 mm
1983RD	0.8 km	~1x10-6 mm
Icarus	0.9 km	~1x10-6 mm

right idea of scale. The individual dots in a half-tone print can be seen with a 5 or 10X magnifying glass. The Moon, Mercury, Mars and the asteroids are too small to be visible at this scale!



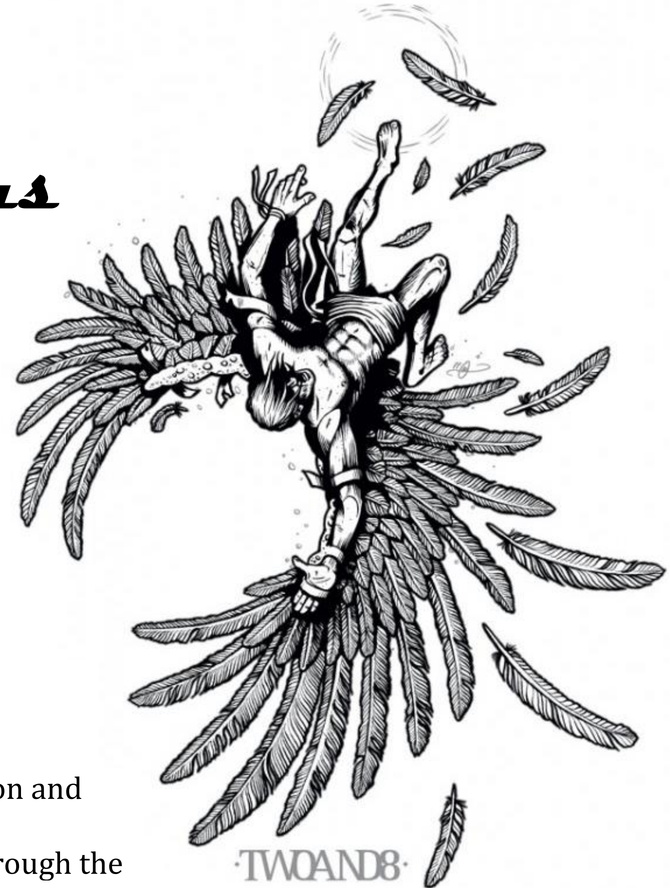
(Orbits drawn approximately to scale)

Discussion

Encourage students to share their observations about size and scale as they construct and view the scale model. Help students to observe that there is mostly open space in the solar system.

Lead students to the observation that Earth is a small moving target and is not frequently hit by large impacting asteroids or comets.

The Myth of Icarus



Read the included Greek legend with your students, have them fill out the sheets, and as a group discuss the included questions. After your discussion, reinforce the concepts with the following fun activities.

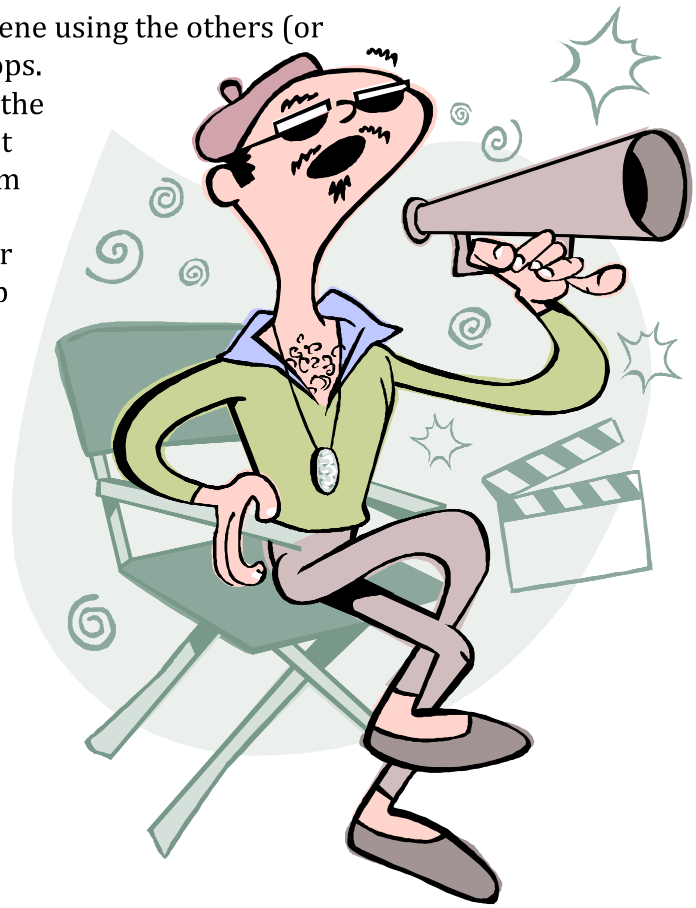
Bringing Legends to Life: Talk Shows and Courtroom Drama

Using the following format, and adding in improvisation and speaking skills practice, students can practice reading comprehension, speaking, logic, and listening skills through the following fun extensions like put on a skit about some of the minor adventures which take place in the Greek myth. For example, after reading the story of Daedalus, students can use their imaginations as to which characters should be interviewed on the talk show and which controversies should be addressed.

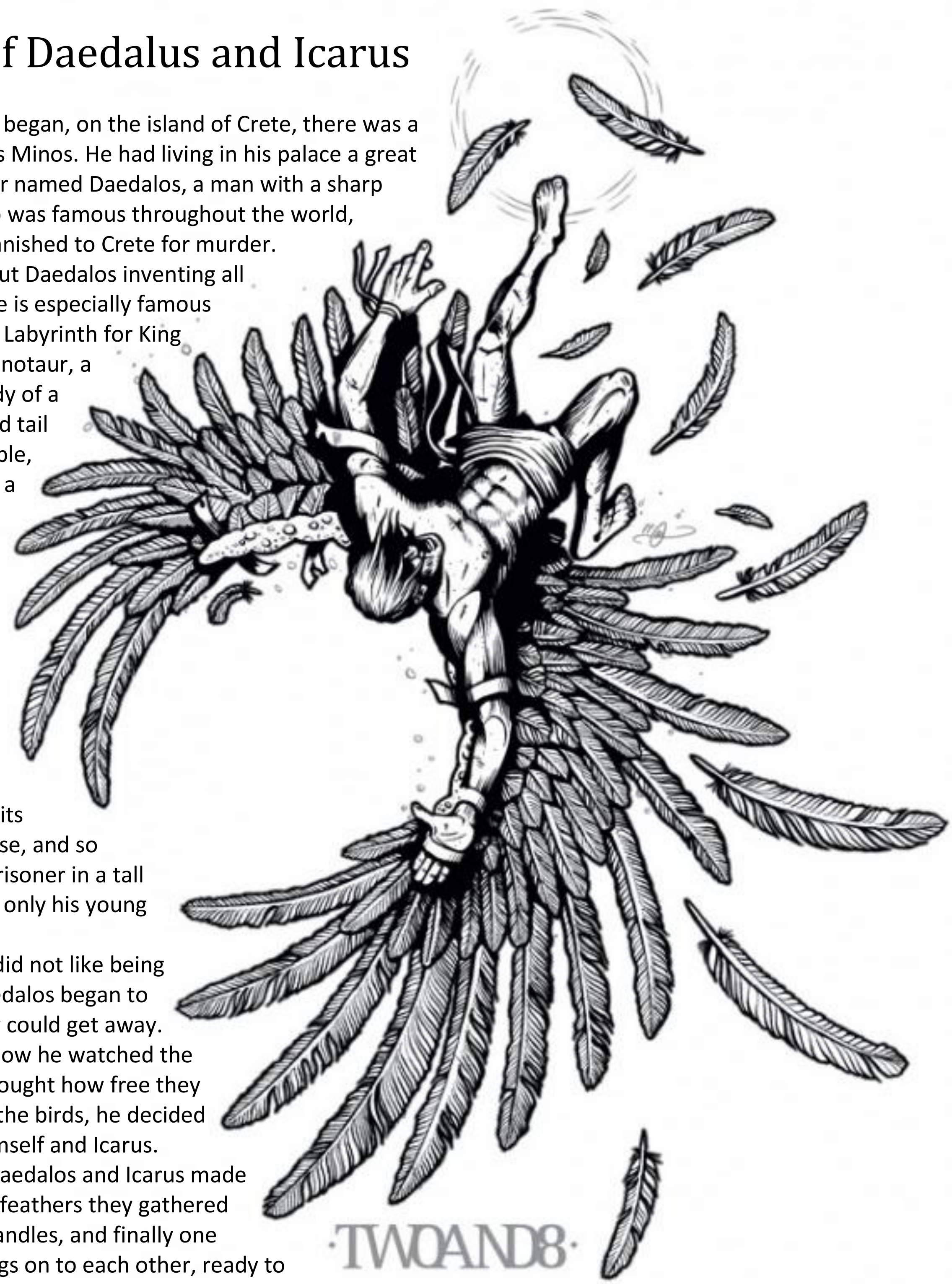
Have students take roles, appropriate to your format, ex: "The Case of the Stolen Chicken Feathers", with one student as the judge, another as the prosecutor, another as the accused and accuser, and the rest as the witnesses. Perhaps Daedalus would be confronted by his son Icarus because Hades enabled him to visit his father on the show. Or there is a confrontation between Daedalus and Minos. Or Daedalus meets the "wax" salesman and accuses him of causing his son's death. The possibilities seem endless, and they are when it comes to the imagination of our students.

Variations:

- Director: Two [or more] students perform a scene directed by a third, the director, based on audience suggestions.
- Daytime Talk Show: The students act out a talk show with one as host, two or more guests and the rest are audience member.
- Interrogation: Two students interrogate another about the bizarre crime suggested by the audience.
- Living Scenery: Two students act a scene using the others (or audience/guests) as any required props.
- Press Conference: Student will leave the room and when they return they must work out what character they are from the story and their achievement from the questions asked them by the other students [which they have to make up answers for] at a press conference they give.
- Sports Commentators/Sportscasters: Students act out a scene in slow motion [Ex. Daedalus and Icarus flying], while the other two commentate.
- Sound Effects: Students act out the story whilst audience members provide the effects.



The Myth of Daedalus and Icarus



Long before our time began, on the island of Crete, there was a king whose name was Minos. He had living in his palace a great architect and inventor named Daedalos, a man with a sharp and clever mind, who was famous throughout the world, and who had been banished to Crete for murder. There are stories about Daedalos inventing all kinds of things, but he is especially famous for building the great Labyrinth for King Minos to keep the Minotaur, a creature with the body of a man and the head and tail of a bull that ate people, in. The Labyrinth was a structure with many twists and turns that someone could get lost forever in, even Daedalos had a hard time finding his way out. After Daedalos built the Labyrinth, King Minos did not want him to be able to tell its secrets to anybody else, and so he kept Daedalos a prisoner in a tall tower, all alone, with only his young son Icarus. Daedalos and Icarus did not like being prisoners, and so Daedalos began to think about how they could get away. Out of their tiny window he watched the birds flying and he thought how free they were. After studying the birds, he decided to make wings for himself and Icarus. Bit by bit, in secret, Daedalos and Icarus made the wings out of bird feathers they gathered and wax from their candles, and finally one day they tied the wings on to each other, ready to escape. Daedalos warned his son to be careful when he was flying: if he went too close to the sea, he might fall in, and the waves would get his feathers wet, but if he flew too high in the sky, the heat of the sun would melt the wax on his wings and he would fall. Icarus promised to be careful.

Icarus Image Credit: 99seconds.com. http://99seconds.com/illustration/icarus.

So they set off for freedom. At first everything went well, but after a little while Icarus was so excited about his ability to fly that he forgot his father's warning and he kept on going up, higher and higher. Suddenly he realized his wings really were melting! He tried to go back down again, but it was too late. His wings came apart, and he fell down, down, down into the ocean, where he drowned.
Daedalus was heartbroken but he could do nothing to save his son, only fly on, weeping for his loss. The sea where Icarus drowned was named the Icarian Sea and a nearby island Icaria, in honor of Daedalos' lost son.

After reading answer the following questions and be prepared to discuss:

What happened to Icarus when he disobeyed his father? ___________________________________

____

Why might they have named an asteroid Icarus? ______________________________________

____

What could be some similarities between the asteroid, its orbit, and Icarus' tragic flight?

____

If you could talk to a character from this story, who would you want to talk to? ____________

Why or why not? ____

What would you say? ____

What would you have done differently if you were Dedalus? ____________________________

____

Minos? ____

Icarus' mom? ____

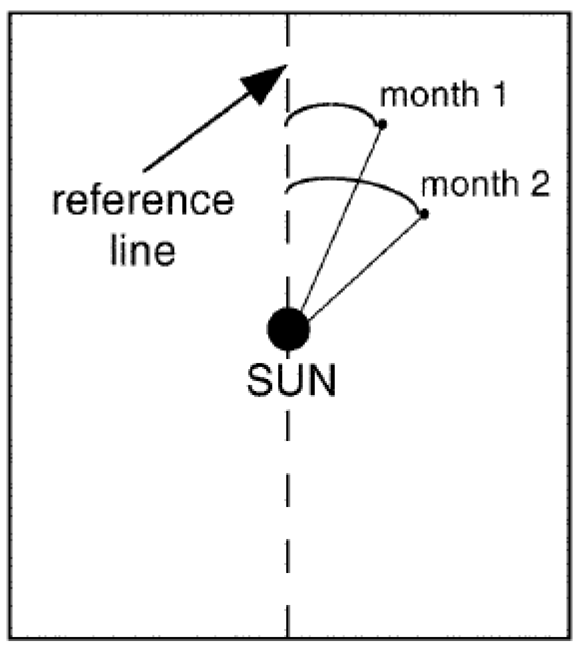
Collision Course!?

Even if the orbit of an asteroid crosses the orbit of the Earth, there may be no collision if the asteroid and Earth are at different places in their orbits. In this exercise, each group of students will graph orbit positions of the Earth and an asteroid. Students compare their results, and see which asteroid makes the closest approach. Note: The scale used is not the same as in the previous activity!

Materials:

- Kraft or butcher paper, approx. 60 cm x 60 cm for each group
- pencil/pen (colored pencils optional)
- rulers, one per group
- protractors, one per group
- Table 4

Instructor may prepare the papers and the circular Earth orbit as in Part 1. Use a string, 30 cm knot to knot. The instructor may choose to draw the Earth orbit with a pushpin and string, or any other method. Distances in Table 4 assume that the Earth orbit is 30 cm diameter, and can be scaled for other sizes.



Graphing Asteroid Orbits

Get Set . . . (Earth's orbit)

Each team should mark the Sun point at the center of its paper, and a pencil line from the Sun extending 30 cm in any direction. This will be the reference line from which angles are measured (see diagram below).

Go! (Graphing orbits)

Each team should graph the orbit of the Earth and the orbit of one asteroid on their paper. To draw an orbit from the numbers in Table 4, begin with a single time at the left of the Table 4. On that line in the Table, read the angle and distance for that time in the orbit. On the large piece of paper, use a protractor to measure the angle (clockwise) from the Sun and the reference line, and draw a line at that angle. Measure outward along that line to the distance listed in the table, and draw a mark at that distance (color-coded, perhaps). Label the mark with the month and half-month. After all the points are graphed and labeled, connect them freehand to make a smooth curve. The points may not make a full orbit.

And the Winner Is . . .

Each team should then estimate when (month number and a fraction) their asteroid crosses the Earth's orbit. Then, each team should measure the closest approach between their asteroid and the Earth, by measuring the distance between corresponding time steps in their orbits. Which asteroid comes closest to hitting the Earth? How close does the closest asteroid really come to the Earth?

The scale here is 1 cm = 10,000,000 kilometers, and the Earth (to scale) would be 1/100 mm.

Note: This scale is not the same as in Activity B!

Extensions

1. The speed of an asteroid (distance/time) can be estimated here as the distance between successive points from Table 4.
2. How does the speed of an asteroid change as it goes through its orbit (have students graph speed versus distance from the Sun)?
3. How fast is each asteroid going as it passes Earth's orbit?
4. If the asteroid(s) hit the Earth, would the differences in speed have any effect on the force of the impact or the size of a resulting crater?
5. The distance between the Earth and an asteroid depends on the relative positions of both the asteroid and the Earth. Have students tabulate the distances between the Earth and the asteroids through time and make graphs of distance versus time. Why do the graphs have hills and valleys?
6. Astronomers have to know where in the sky to look for asteroids in order to study them. They measure directions in the sky as angles compared to a reference direction, just as on the drawings in students completed. For students find out where in the sky they would look for their team's asteroid, pick a time point for the Earth, and draw a

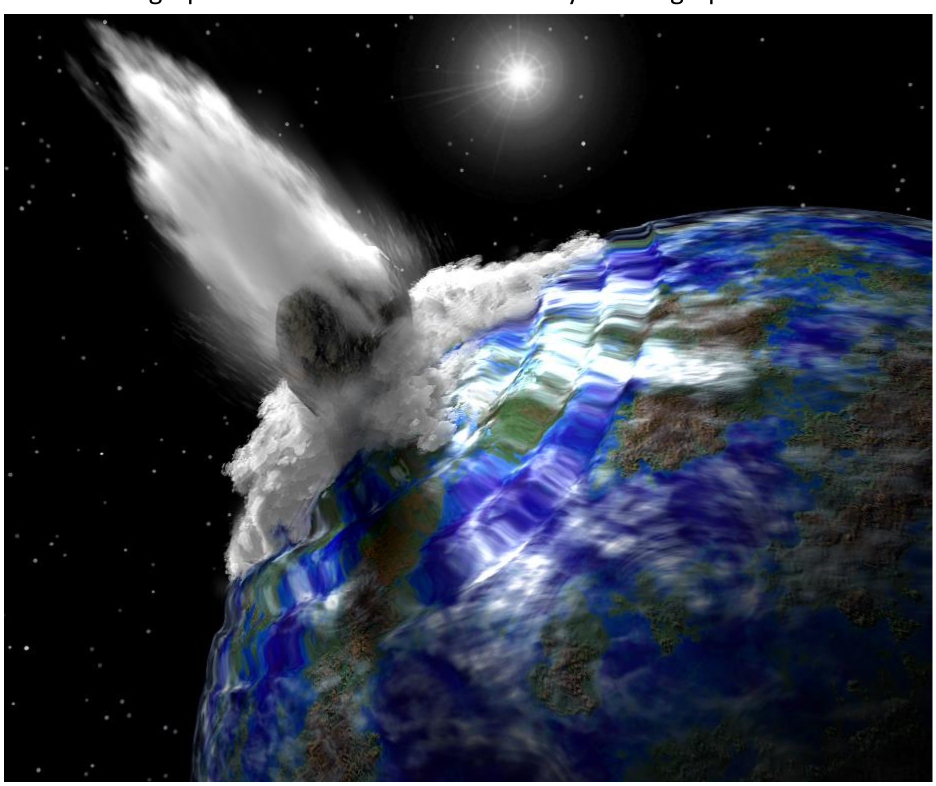


Image Credit: http://cosmologistic.blogspot.com/2011/11/doomsday-meteor-yu55.html.

line through that point parallel to your reference line (that goes through the Sun). Draw another line from the Earth to the asteroid's position at that time point. Measure and write down the angle between these two lines; this is the direction (the longitude) in the sky you would have to look (to an astronomer, the "right ascension").

7. For each team's asteroid, tabulate the directions they would have to look from Earth, and graph that angle versus time. Does their asteroid appear to move at a constant speed in the sky? Do any of the asteroids appear to move backwards (retrograde motion)?

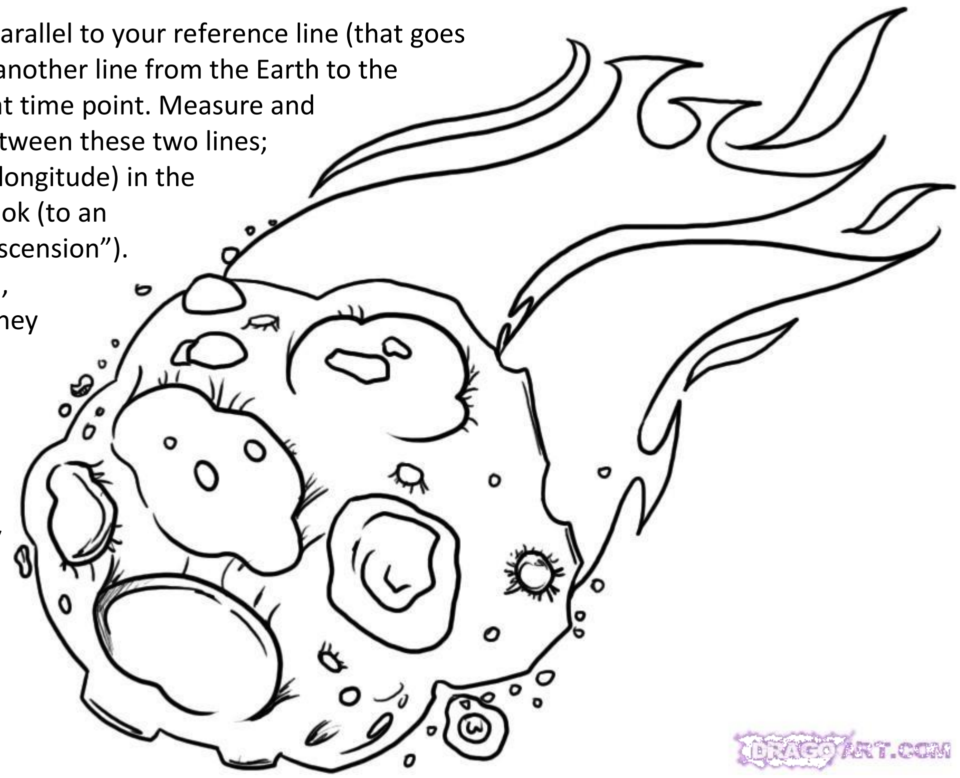


Table 4. Distances from Sun and Angles from Reference Line for Earth and Asteroids

	Earth		Asteroid 1		Asteroid 2		Asteroid 3		Asteroid 4		Asteroid 5		Asteroid 6	
Month	Dist	Angle	Dist	Angle	Dist	Angle	Dist	Angle	Dist	Angle	Dist	Angel	Dist	Angle
0	15 cm	0°	8.4 cm	0°	23.7 cm	322°	30.6 cm	195°	55.4 cm	50°	23.6 cm	56°	51.1 cm	261°
1	15 cm	30°	10.8 cm	72°	23.5 cm	333°	27.0 cm	205°	53.9 cm	48°	21.4 cm	71°	49.5 cm	264°
2	15 cm	60°	14.8 cm	110°	22.6 cm	344°	23.1 cm	218°	52.1 cm	46°	19.0 cm	90°	47.7 cm	267°
3	15 cm	90°	18.2 cm	133°	20.8 cm	356°	19.2 cm	236°	50.1 cm	44°	16.7 cm	115°	45.6 cm	270°
4	15 cm	120°	20.7 cm	149°	18.2 cm	11°	15.6 cm	263°	47.7 cm	42°	15.0 cm	146°	43.2 cm	273°
5	15 cm	150°	22.4 cm	162°	14.7 cm	30°	13.4 cm	303°	45.1 cm	40°	14.6 cm	182°	40.4 cm	277°
6	15 cm	180°	23.3 cm	174°	10.8 cm	59°	14.1 cm	347°	42.0 cm	37°	15.5 cm	216°	37.4 cm	282°
7	15 cm	210°	23.3 cm	185°	8.6 cm	113°	17.2 cm	21°	38.6 cm	33°	17.5 cm	245°	33.9 cm	288°
8	15 cm	240°	22.5 cm	197°	11.1 cm	192°	21.0 cm	43°	34.7 cm	29°	19.9 cm	276°	30.1 cm	294°
9	15 cm	270°	20.9 cm	210°	15.0 cm	244°	25.0 cm	59°	30.3 cm	24°	22.2 cm	285°	25.8 cm	303°
10	15 cm	300°	18.5 cm	225°	18.4 cm	272°	28.8 cm	70°	25.2 cm	17°	24.4 cm	299°	20.9 cm	316°
11	15 cm	330°	15.2 cm	247°	20.9 cm	290°	32.2 cm	79°	19.1 cm	6°	26.2 cm	311°	15.6 cm	338°
12	15 cm	0°	11.2 cm	283°	22.7 cm	304°	35.4 cm	86°	11.9 cm	342°	27.7 cm	321°	10.7 cm	21°
13	15 cm	30°	8.5 cm	352°	23.6 cm	317°	38.3 cm	92°	5.4 cm	240°	28.8 cm	331°	10.0 cm	94°

Asteroid 1 = Castalia, (0 month is 1.5 months after perihelion at 0°)
Asteroid 2 = Cerebrus, (oriented so perihelion is on-line with Earth and Sun)
Asteroid 3 = Antinous, (starting 71 half-months after perihelion)
Asteroid 4 = Hephiastos, (starting at perihelion, but turned to retrograde orbit)
Asteroid 5 = Nereus, (arranged for a near-miss)
Asteroid 6 = Oljato, (starting at 51 half-months after perihelion, angle advanced by 85°)

Eating Dirt? Edible Asteroids

Meteorites are mostly pieces of rock, though a few are metal, that fall to Earth from space. Most meteorites come from the break-up of small asteroids that never gathered together to form a planet. Meteorites give us clues to the origin and history of the solar system.

Scientists studying meteorites use various types of observations. They make qualitative (color, shape, texture, etc.) and quantitative (mass, volume, linear measurement, etc.) observations, recording all data carefully. They use special tools to chip off parts and saw through meteorites to make closer visual observations. They write careful descriptions throughout their investigations.

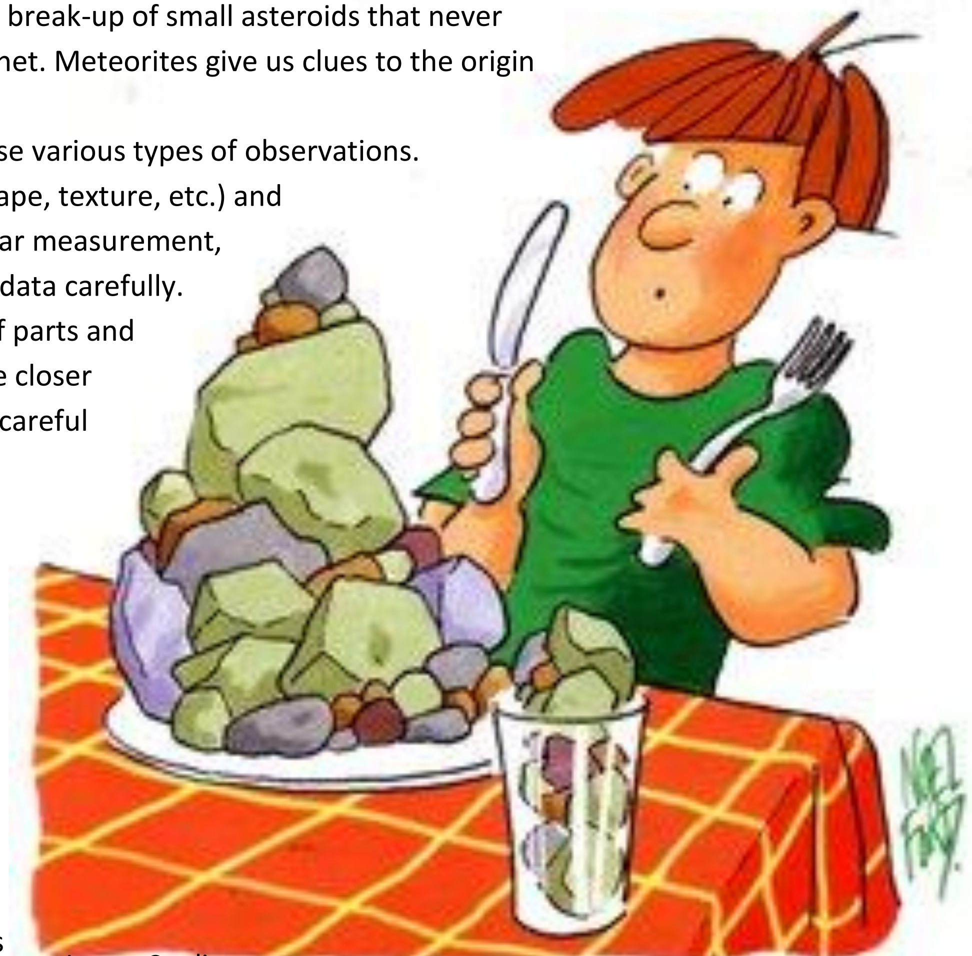


Image Credit: http://www.filosofeando.com/index.php?option=com_content&view=article&id=379:sindrome-de-pica&catid=69:2o-de-bachillerato.

Very thin sections are cut and put on thin glass slides so they can be looked at under microscopes. Meteorites are classified based on the types, amounts and textures of minerals they contain. The primary classification [grouping] into stony, iron and stony-iron is based on the amount of metal in the meteorites. Stony meteorites are divided into chondrites, which contain round objects inside them called chondrules, and achondrites, which do not contain chondrules. Meteorites that have been classified before are used as references for new meteorites so they can compare them to see what kind of meteorite the new one is. As new information is learned about a meteorite, scientists may change their initial classification. The progression from general to more specific observations helps scientists to narrow the possibilities in determining what kind of meteorite they've found. The study of these rocks from outer space helps to answer questions about how our solar system formed and the relationships of planetary bodies to each other.

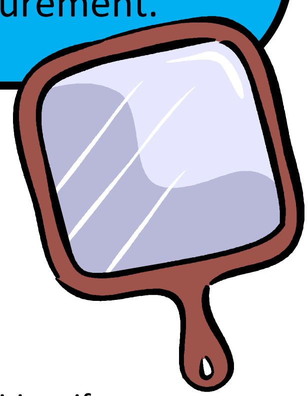
As we've seen, meteorites come in a variety of types and a wide range of sizes and shapes, but most meteorites have three things in common:

1. They have dark brown or black glassy crusts on the outside,
2. They contain enough iron metal to attract a magnet.
3. They aren't something you'd want to snack on.

The outside crust of the meteorite is created when the rock is heated by friction when it comes through the atmosphere. It gets so hot that the outer part melts into liquid rock and when it cools back down that liquid rock forms a dark crust that often has flow marks, or indentations like thumbprints. The inside stays cool and is usually light gray to black in color, but some may be tan or, if weathered and rusted, brown.

Classy Reflections

Asteroids are classified based on color and brightness, also known collectively as spectra. Spectra measurements are called albedo and refer to the amount of light reflected. This is measured from zero, which equates uniformly black [like black cardstock] and one which means an absolutely perfect reflection [like a mirror]. Scientists use telescopes and classify asteroids based on where they fall in this measurement.



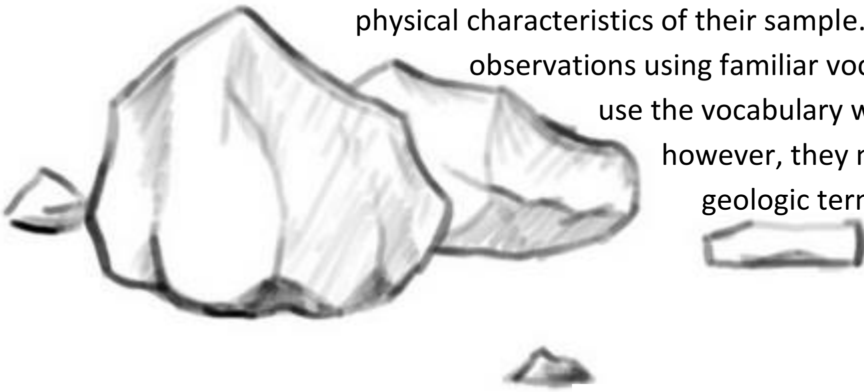
What do we notice first?

- Color-Color is the first thing people notice when looking an object. Color can be an important characteristic when determining chemical composition.
- Luster-Luster is how light interacts with an object. Such descriptions include: shiny, dull, fibrous, earthy, metallic, greasy, pearly, or waxy.
- Hardness-Hardness describes the resistance to pressure when applied to the object. Normally, scientists would use Mohs Hardness Scale to determine hardness; but for this activity we will use informal terms.
- Odor-Odor can be a powerful tool when determining chemical composition, if you've ever smelled sulfur, like rotten eggs, you'd be able to detect it and recognize it again.
- Inclusions-Inclusions are added crystals or objects that form in the interior [inside] of an object, like a meteor.
- Texture-Texture is the characteristic appearance of an object, i.e. rough or smooth.

These are just a few physical characteristics that can be emphasized for this activity.

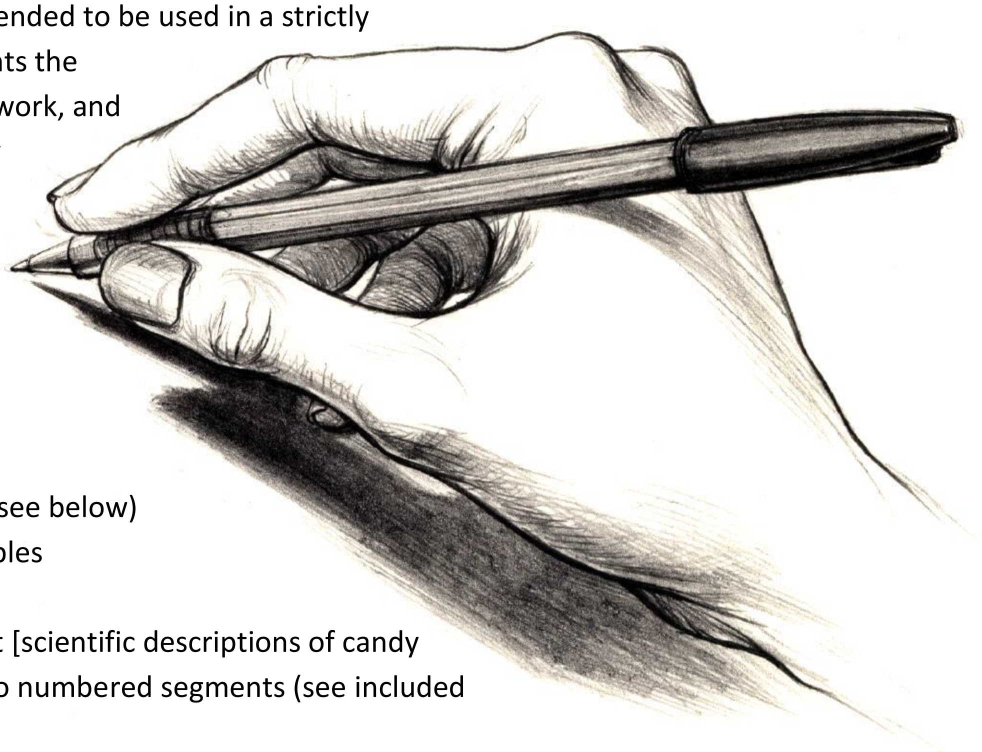
Inform students that today they have a special assignment. NASA has asked for their help in a very important science investigation. NASA needs their help analyzing various asteroid samples. It will be up to them to analyze and describe their particular sample.

Students will draw their sample so that the interior of the sample can be seen. Students will then measure the size, weight, width, and length of their sample. Older students may also then write the mass of their sample. They will then write an overall description of the physical characteristics of their sample. Encourage teams to describe their observations using familiar vocabulary; especially make sure students use the vocabulary words of color, texture, and shape, however, they must use no food terms. Appropriate geologic terminology may be substituted by the teacher and be used and understood by even very young students.



Objectives:

This activity is designed so that students will become better observers by making a connection between the familiar (small pieces of candy bars) and the unfamiliar (meteorites). Small amounts of edible "rocks" are intended to be used in a strictly scientific context, showing students the importance of observation, teamwork, and communication skills. In everyday terms, students draw and describe the food. Students will pair their observations with short descriptions that are in geologic "Field Note" style.



Materials

- prepared edible samples (see below)
- small plastic bags for samples
- knife
- "Field Note" Sample Sheet [scientific descriptions of candy bars] enlarged and cut into numbered segments (see included sheet).

Note: If included recipes are not used, then the descriptions may easily be revised to more accurately describe the actual samples.

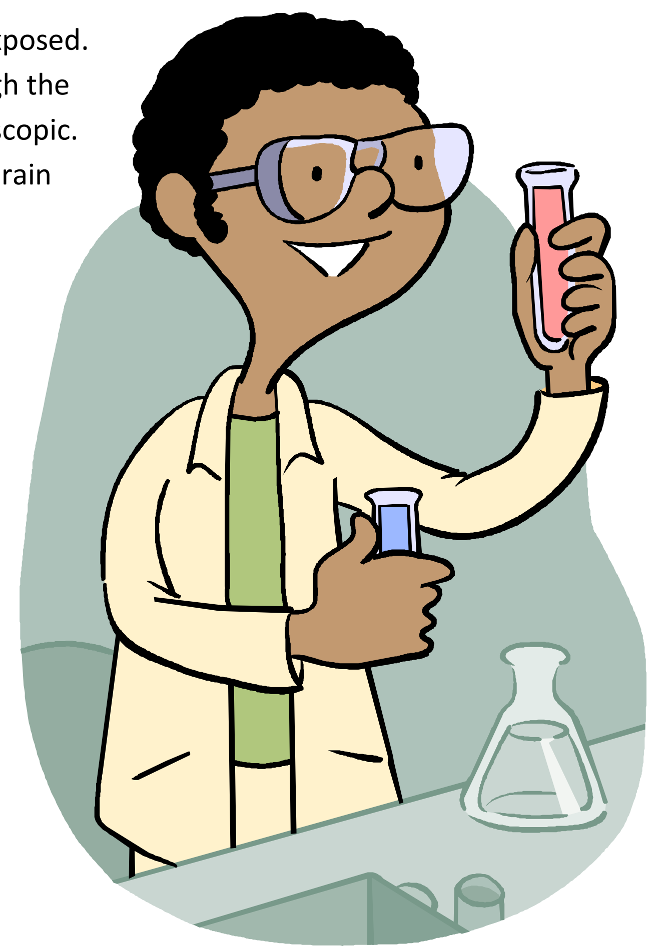
- Student Procedure (see below, one sheet per team of two)
- colored pencils for each team
- pen or pencil
- Magnifying glasses for observations [optional]

Procedure

Advanced Preparation

1. Prepare samples. Simple recipes are included for some samples. The first six listed on the answer key are especially important since they closely represent major meteorite characteristics. The other samples on the list are good for meeting the objectives of this activity and are included to offer more variety, though it is not necessary, or required to use all. Use as many as needed for the size of your group and you may add a few extras to add challenge to the exercise.

2. Cut the small samples so that a flat interior surface is exposed. Note: Most meteorites that make it down to earth, through the atmosphere, are really quite small, most in fact are microscopic. Many tiny meteorites land on our roofs and end up in our rain gutters, all without our being aware.



3. Place each small sample for student teams in a small plastic bag. Each team of two students will have one bag containing one sample.

4. Copy Student Procedure sheets, one for each team of two.

5. Cut enlarged “Field Note” Sample Descriptions into numbered segments. Descriptions are written the way a scientist/geologist might actually take notes in a field record book.

6. Arrange one set of the prepared “Field Note” sheet descriptions on a table(s) so that students may easily read and reach each of them (numbered sequence is not important).

7. Have a full sheet of the Field notes and the answer key available.

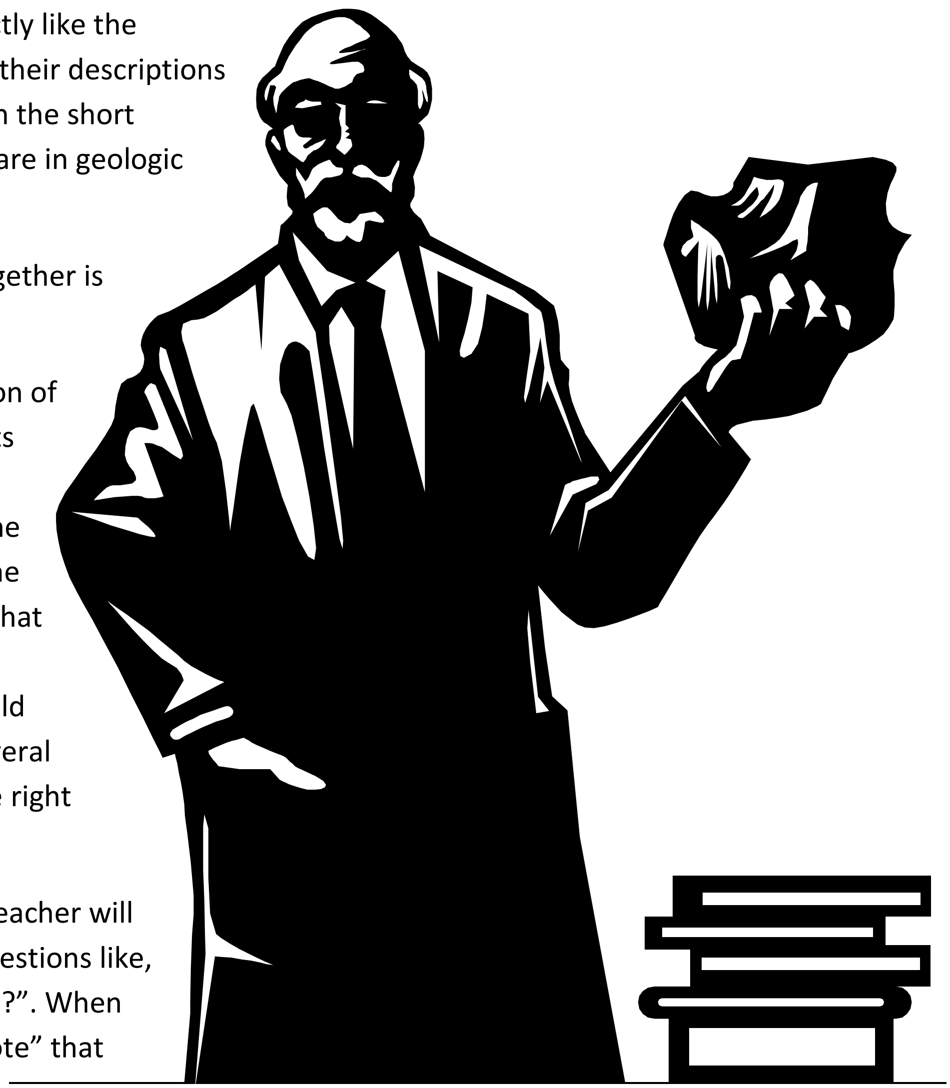
8. Have a variety of rock samples available (students may bring their own samples).

With the Students

1. Pass out a sample and procedure sheet to each team, you may want to allow student teams to choose sample if possible. Scientific vocabulary should not be expected initially and the processes of observing and recording should be kept simple.

2. Explain that each team is responsible for describing and sketching its sample. Encourage students to describe their observations using familiar vocabulary; however, they shouldn't use food terms.

Example: The outer layer is a thin coat of light brown material containing cream or tan colored round chunks (i.e., chocolate candy bar coating that contains peanuts). Student descriptions need not be exactly like the provided descriptions. In fact their descriptions may be far more detailed than the short descriptions provided, which are in geologic "Field Note" form.



3. Emphasize that working together is important.

4. When sketch and description of sample are complete, students take them, along with their sample, and pair them with the prepared descriptions from the Field Note Sheet. Emphasize that their observations will not be exactly like the scientist's "Field Notes." They will likely try several matches before they have the right match.

5. Throughout this step, the teacher will verify correct pairs. Expect questions like, "Is number one peanut brittle?". When they have found the "Field Note" that

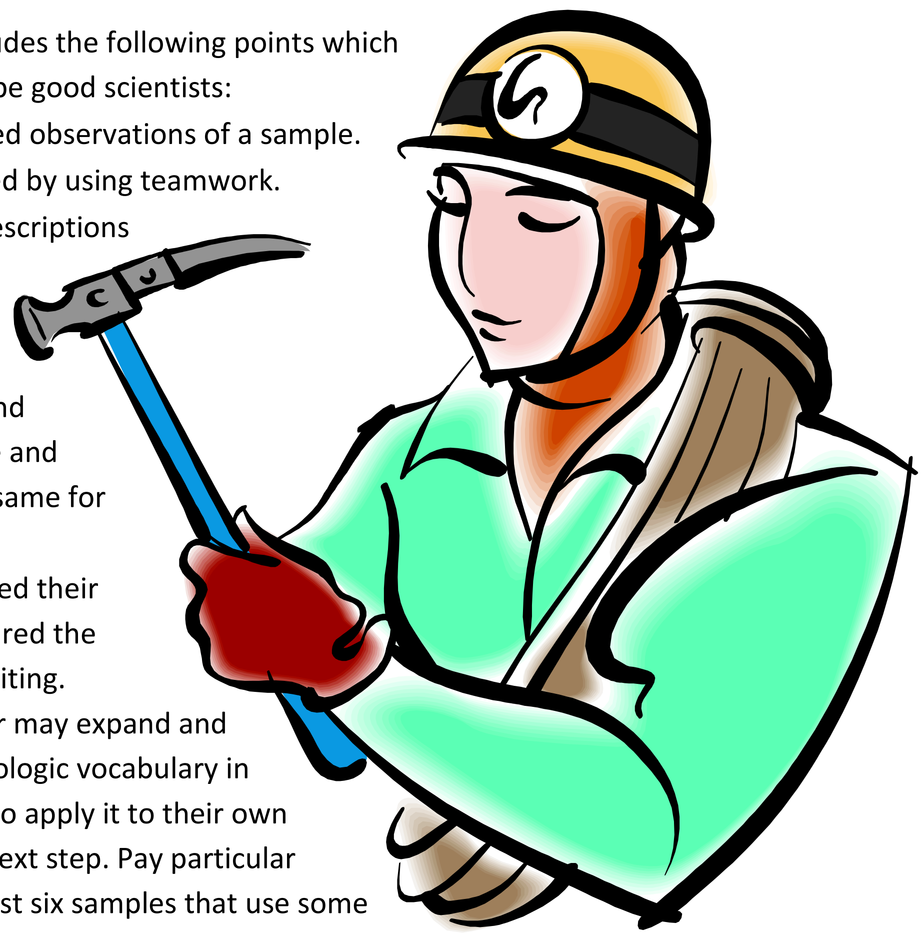
describes their sample, students should place their sketch, description, and sample next to the correct "Field Note" description.

6. If students have difficulty finding the description of their candy bar then the teacher should encourage them to interact with other groups for help. This step of the lesson will likely become a slightly noisy, cooperative process. As students find a match between "Field Note" descriptions and candy bars, some definitions may be supplied, and written on the board for everyone, if necessary, i.e. "Platy means flaky flat material."

7. When all students have successfully matched their samples, each team may describe its sample to the class. The class should have access to the sample and the prepared written description during this sharing. Sketches may be displayed.

8. Conduct a discussion that includes the following points which emphasize basic skills needed to be good scientists:

- The students made detailed observations of a sample.
- The task was accomplished by using teamwork.
- Although the student's descriptions differed from the Field Note descriptions and each team had a different style, the skills and processes used to observe and record the data were the same for each group.
- The students communicated their observations and then shared the findings verbally and in writing.



During the discussion, the teacher may expand and help define the meteorite and geologic vocabulary in context and encourage students to apply it to their own samples as they progress to the next step. Pay particular attention to vocabulary for the first six samples that use some words especially pertinent to meteorites.

Have students test their observation skills again by sketching and describing real rocks and trade descriptions with other groups, competing to see who can get the team to match the description to the real rock first.

Variation: Students play by spreading the cards out face down and turning over one at a time, identifying the appropriate rock. If they have a match, they get to keep the cards. If not, they turn the card back over and try to remember the location.

Meteorite Vocabulary

- Texture: the visual or tactile (touchable) surface characteristics and appearance of something
- Density: The amount of something in a particular space or area, the amount of matter in something that is shown by the relationship between its weight and size.
- Matrix: rock in which something hard (such as a diamond or a fossil) has been formed
- Breccia: a rock made up of sharp pieces surrounded by a fine-grained material, like sand.
- Phases: a physically different portion or kind of matter present in a mixed system
- Fusion crust: Fusion crust is a thin (1 to 2 mm) coating of glass that covers the outside of a freshly fallen meteorite. It is like the glaze on ceramic ware. Usually, fusion crust is black because of iron in the meteorite. But sometimes it is brown or greenish or even clear. It will usually have small cracks and a texture like leather.
- Chondrite: in general, any stony meteorite characterized by the presence of chondrules [small, rounded particle stuck in the rock].
- Inclusions: A gaseous, liquid, or solid foreign body enclosed in a mass (as of a mineral), the meteor has things stuck in it.
- Vesicles: a small cavity in a mineral or rock
- Bleb: small particle, bubble, or blister
- Friable: easily crumbled or pulverized
- Platy: made of plates or flaky layers
- Porous: having small holes that allow air or liquid to pass through
- Unfractured: un-cracked, unbroken, whole
- Unconsolidated: unjoined, separate
- Regolith: unconsolidated residual or transported material that overlies the solid rock on the earth, moon, or a planet. Ex. sandy layer of broken meteorites on the Moon.
- Homogeneous: of uniform structure, the same all the way through

Type of Sample Teacher Key

1. Peanut Brittle (chondrites)
2. Rocky Road (chondrites)
3. Chocolate (iron without fusion crust) use any thick chunk of solid chocolate
4. 3 Musketeers™ (a chondrite with fusion crust)
5. Rice Cereal Treats (meteorite regolith breccia)
6. Chocolate brownie (carbonaceous chondrites)
7. Snickers™
8. Milky Way™
9. “Bar None”™
10. Hershey Bar™
11. Twix™
12. Butterfinger™
13. Skor™
14. Rolo™
15. Kit Kat™
16. Symphony™
17. M & M™
18. Nestle Crunch™
19. Whatchamacallit™
20. Mounds™
21. P.B. Max™
22. Mr. Goodbar™
23. Hershey with Almonds™

Recipes and notes for samples not easily available commercially.
Note: Recipes are for a larger quantity than required for the lesson.

Rocky Road (#2 Edible Rock)

170 g (6 oz.) semi-sweet chocolate pieces (melted)
120 g (2 cups) mini-marshmallows

1. Butter loaf pan or folded foil
2. Pour about half of melted chocolate into pan
3. Pour marshmallows into pan and mix so they are coated with chocolate
4. Pour remaining chocolate over the marshmallows and spread flat
5. Refrigerate until cold
6. Cut a cube so vertical surface is exposed

Chocolate Brownies (#6 Edible Rock)

Add large chunks of semi-sweet baking chocolate or solid chocolate candy to the brownies (add enough so that the solid candy will be exposed on a cut surface) or get brownies with candies embedded
Cut, exposing some brownie and some solid chocolate; this surface will be described
To form the breccia texture, cut the cube in several places, then reassemble the cube in a jumbled manor, incorporating one or two jelly beans and or other edible chunks
Allow the sample to harden so that a good surface may be cut
- cut the sample so that chunks and various chocolate lines are exposed
- students will describe the cut surface

Regolith Breccia Simulant (# 5 Edible Rock)

(Marshmallow cereal treats)
Spread a prepackaged rice crispie with melted chocolate or chocolate glaze, or if possible, cut it in half and put the glaze on one half.

Put another rice crispie on top of the chocolate, or the second half of the cut bar.
Allow cookie to cool enough to cut but not until completely hardened (should still be partly moldable)
Per sample you want one cube about 5 cm square, then cut again once or twice
Embed one or two jelly beans in part of the cut cube
Mold cut pieces together again to form a “breccia”
Allow to harden
Re-cut to expose interior and jelly bean

Geologist Field Notes: Sample Descriptions

These food descriptions are in geologic "Field Note" style. Therefore, they may be short and sometimes cryptic. Use of geologic terms will encourage students to stretch their minds as they try to match them with their own descriptions.

1. Sample is a thin layer. There is a golden matrix surrounding tan rounded or broken inclusions. The inclusions have a reddish brown rim or crust.
2. Sample consists mainly of white, soft rounded to angular blebs completely surrounded by a uniform dark brown matrix.
3. Sample is a solid dark brown dense mass with no obvious fusion crust.
4. Sample has a homogeneous light brown interior with a few small vesicles. The exterior looks like a fairly regular, dark brown fusion crust with some patterning.
5. Sample appears to have been distorted. The dominant phase is made of rounded light tan fragments containing many void spaces. A dark brown thin layer fills spaces between some rounded fragments. There are some large foreign inclusions.
6. Sample is totally dark brown with two phases. The dominant phase is shiny and crumbly. The other phase is dense and slightly lighter in color. A light fusion crust appears on only one side.

7. Outside: Thin medium-brown layer with ripple-marks on the bottom. Inside: Bottom – (~1/3) flat dense buff layer. Top – (~2/3) pebbles consolidated in a fine grained tan matrix

8. Outside: Thin medium brown layer with wavy ripple marks on the bottom. Inside: Bottom – dense dark buff layer. Top – shiny, smooth, medium tan layer.

9. Outside: Medium brown layer, thin on the bottom, the thicker top contains angular inclusions Inside: Thin alternating horizontal layers of smooth dark brown and fragmented dark brown.

10. Dense medium brown sample, flat on the bottom with three parallel ridges on top.

11. Outside: Thin medium brown layer with wavy ripples on the bottom. Inside: Bottom – poorly consolidated light tan porous layer. Top – shiny smooth medium tan layer

12. Outside: Thin medium brown layer Inside: Poorly consolidated, friable, shiny to dull golden platy fragments.

13. Outside: Medium brown layer, very thin on bottom and side, thicker on top with large wavy ripples Inside: Thin dense layer of shiny light-golden unfractured material.

14. Outside: Thin, medium brown, edges higher on outside of top, sides slanted. Inside: Smooth material that is yellowish brown and sticky.

15. Four segments of layered material. Outside: Thin, medium brown Inside: Alternating light and medium colored material

16. Solid medium brown throughout, single dense layer with a valley or dip in the top.
17. Sample consists of unconsolidated pebbles with various colors and regular shape. Each individual pebble has a medium brown interior with a thin, hard colored shell.
18. Sample has a thin layer of dense brown material, containing very light inclusions at the bottom. The sample top has a depression in the middle with a ridge on each side.
19. Sample is a rectangular layer of rounded light pebbles surrounded by a thin coating of medium brown. Some yellowish brown sticky material is above the pebbles.
20. Sample interior consists of white, moist-looking fragments. These are surrounded by a dark brown exterior layer.
21. Irregular sample. Outside: Bumpy medium brown. Inside: Yellow brown solid material resting on light tan fragments, some large tan fragments are found near the top
22. Outside: Dense layer of medium brown with a dip in the top. Inside: Light tan pebbles that have settled to the bottom.
23. Dense sample of medium brown material, rounded on the top and flat on the bottom, with a few light brown pebble inclusions.

Student Procedure

Image Credit: http://www.filosofeando.com/index.php?option=com_content&view=article&id=379:sindrome-de-pica&catid=69:2o-de-bachillerato.

Materials – Per Two Students

- sample “rock”
- this procedure sheet
- pen or pencil
- map pencils

Procedure

1. With your partner, choose one sample to observe.
2. Carefully observe the sample. You may take the sample out of the bag, but handle it carefully and do not taste it.
3. Make a large, detailed sketch of the sample. Measure each side. The sketch should show the interior cut surface that is flat and any important details of the exterior as well as notes on the measurements.. Use the back of this paper for your sketch, or a sheet of graph paper

4. Write 2-3 sentences describing the cut surface of the sample. Do not use any food terms. For example, do not use the word chocolate. Make your description as clear and complete as you can.

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5. When you have completed Step 4 take your description, sketch and sample to the table where the “Field Note” descriptions of the food samples are located. Find the description that fits your sample. Check with your teacher to see if you identified the correct match. You will likely try several of the descriptions before you find the one that describes your sample. You may get help from others. Try checking with the teacher or a dictionary for help with unfamiliar words.

6. Place your description, sketch, and sample beside the “Field Note” description for your sample.

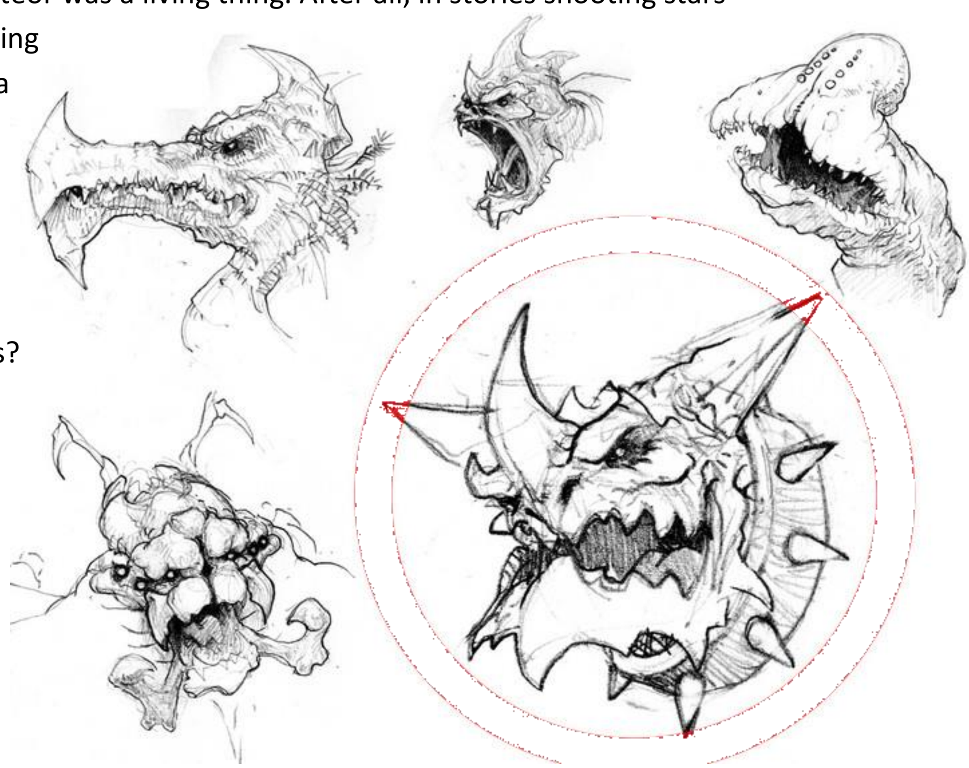
In the work space below, or another sheet draw, label and color your asteroid sample. Make sure you use correct colors when drawing your sample. Your illustration should show the interior cut surface that is flat and any important details of the exterior.

Sculpting the Screaming Meemies Meteorite

Materials:

- Pencils
- Paper
- Ovenbake or modeling clay
- Tools for texturing (ex. toothpicks, plastic forks, etc. Be creative and look for anything with and interesting texture) Detailing tools can be as simple or complicated, as inexpensive or expensive as you decide. You can even make your own! And fingers work great.
- Aluminum foil
- Thin jewelry wire
- Wire cutters
- Scissors

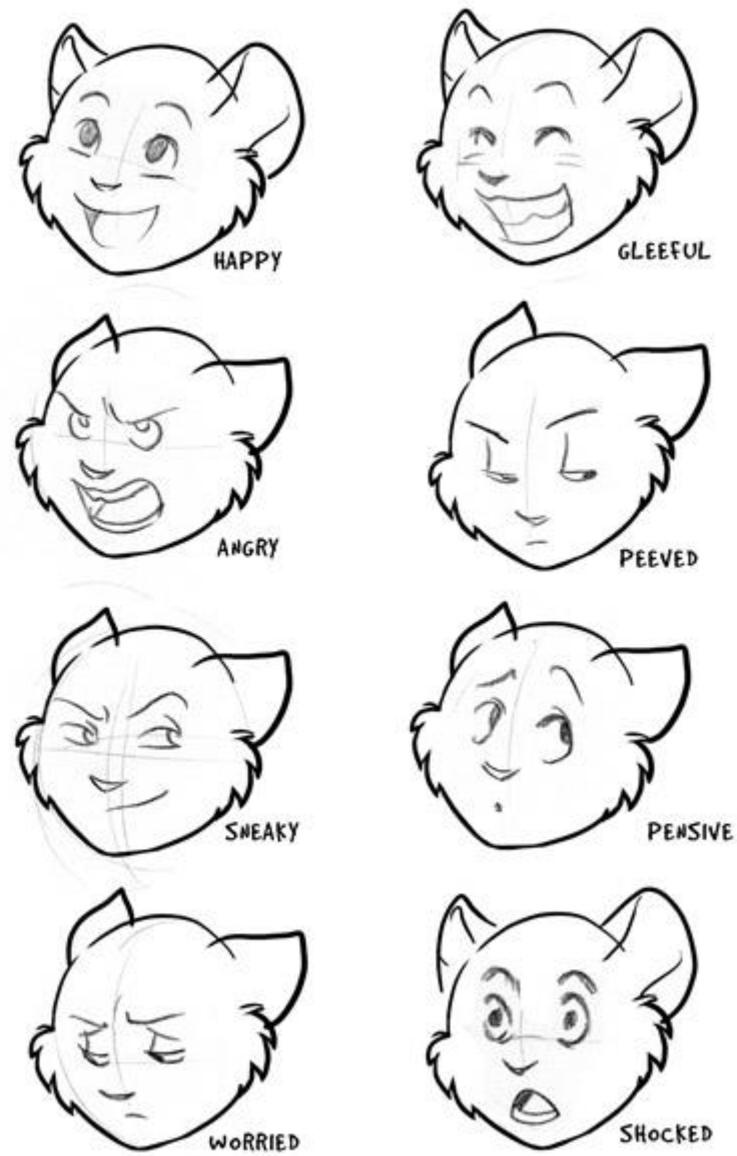
Have students imagine a meteor was a living thing. After all, in stories shooting stars are often living beings shooting through space. What might a meteor look like as it shoots towards Earth? Is it a baby, curled up in a ball? Is it an interstellar fish? An intergalactic cat? Is it a monster? Does it have horns? What kind of expression might it have? Excited, scared, screaming, triumphant, on fire? Does it have arms and legs or is it simply a rock with a crazy



cratered face and a shooting flame?

1. We must above all know where we're going and to do this, there's nothing better than a small drawing.

2. For your group, start with a directed line drawing. It's important to note that even though you may use, "directed line drawing", it's rare that you want to give your students just one option, most of the time you'll end up with many drawings on the white board. Look at pictures and brainstorm together what a screaming, flying, rocketing meteor can look like, and create sketches up on the board.



3. Give lots of examples! Draw a few different ones; some realistic, some silly, some animated, then talk with students how you could change the flame, the shape, the expression, the number of horns, that sort of thing. Should the tongue stick out like a dog with its head out the window? This technique works well, as you want the children to learn to draw but also want them to be as individual as possible.

4. When a person's face shows emotions, the eyes, eye brows, and mouth all move in specific ways. This movement is called facial expressions. Have students come up to the front and make faces, holding them for a certain emotion , while you sketch them, showing how facial features interact to form expression.

5. In the process of drawing on the white board, always incorporate mistakes. **Always**. Laugh at your “mistakes”, tell the kids to expect them and then show them how to turn mistakes into something else. It’s critical that you show your artistic side, no matter what you privately think of it, and inspire your students.

6. Have students sketch out their own drawing. Inspiration can come from the illustrations on the board, an illustration in a specialized book, or students can make up an entirely new drawing, or several, all on their own. They may want to look

7. After instructions are given, the paper handed out and the children are engaged in their project, begin a ten-minute quiet time. This is their time; the chance to reflect on their work, the opportunity to lose themselves in their art, and perhaps the most important of all, the permission *not* to speak to their best friend.

Now, once the page is full of sketches, have students take their favorite 2D drawing and turn it into 3D art with clay! The available time or the difficulty of such or such detail can factor into the decision and they can also choose the best drawing. Or the worst.

Make sure to stress how forgiving modeling clay is, it’s okay to make mistakes, sometimes it even turns out better. With groups new to clay, don’t worry about warning of improper techniques, simply show the kids the basics and teach them that if something isn’t working, they can figure out what it is and change it. calm
teacher= calm students

1. Have students begin by modeling the main masses, keeping an eye on global shape, with no consideration (yet) for details.

2. Have them continue to refine the general shape, give more detail to the surfaces, work with the shape of the nose and brow and give each part the appropriate texture.

3. Some more smoothing with fingers or a clay-shaper, and have them add the eyes:

a ball in each socket, which they can shape with a more precise tool. The ball becomes the eyeball plus the eyelids.

4. By successive additions, they can refine the main masses: jaws, brow, cheekbones, skull, horns, then the secondary masses: eyes, ears, teeth and veins, folds, buttons, flames, etc.

5. A good technique consists in turning the model to check the symmetry of the masses: a difference which students didn't see in the first place can be quite obvious once the model is upside down. In the same way, they can also look at it from below or above, in particular to compare cheekbones and brow.

6. Have students add additional details like the flames, craters, texture, little wrinkles and lines that follow the folds and the expression, etc.

Creating Textures:

Giving texture to a figure is one of the greatest challenges in creating a realistic piece. Whether the texture is fur, feathers, folds, or warts, the interest is in the details. Students should experiment with direct etching, using the tools of the trade, perhaps etching fur or feather lines with a needle held so it drags along the surface, rather than gouging. The process can be tedious, but the act of creating these details teaches stduents a great deal.

Note: During the sculpting process, if aspects need support an armature [an inner skeleton of stiff jewelry wire or wadded aluminum foil in the limbs and body] can be added for support. Think of wire armatures as crude, sturdy skeletons for the portions of your sculpture that should be reinforced (e.g. thin limbs such as an arms outstretched, or legs in standing figures). The foil armature is used to reduce the amount of clay needed to complete a bulky figure and has the added advantages of reducing curing time and making the figure stronger. For bulky figures (eg. a toad or rabbit), it is best begin with a well compressed ball of aluminum foil pounded into the general shape of the final form, then build the clay over the armature. A combination of the two kinds of armatures can be used.

Image Credit: http://drawinghowtodraw.com/stepbystepdrawinglessons/wp-content/uploads/2010/04/Cartooning-Army-expressions-bigger.png.