Lesson Title: Energy Transformations: Extra-Terrestrial Impacts on Earth

NSF GK-12 Fellow: Mari Elise Ewing (Boulder, CO)

Grade Level: Middle School

Type of Lesson: Physical Science

Objective: Students will learn about energy transformations. Based on the Boulder Valley School District's 6th Grade Science Curriculum Essentials Document: "Students can (a) gather, analyze, and interpret data to describe the different forms of energy and energy transfer." Nature of Discipline #3: "Use tools to gather, view, analyze, and report results for scientific investigations designed to answer questions about energy transformations."

Background Information: Students will need to first understand the difference between potential and kinetic energy, as well, as the concept of energy conservation. Also, an experimental lab on energy transformations during impacts should precede this lesson. In this lab, students will drop two different balls (marbles and golf balls) from two different heights (one meter and 1 ½ meters) into damp, lightly packed sand. They will measure the depth and diameter of each impact. Students can then use the data collected from the lab to help with this lesson on extra-terrestrial impacts as described below.

References:

1. CU News. "CU study provides new evidence ancient asteroid caused global firestorm on Earth." March 27, 2013. Online at http://www.colorado.edu/news/releases/2013/03/27/
2. Miller, A. "Asteroid Hunters." From QUEST funded by NSF. Posted Mar. 24, 2009. Online at http://science.kqed.org/quest/video/asteroid-hunters/
3. NASA. Science News. "What Exploded Over Russia?" Posted Feb. 26, 2013. Online at http://science.nasa.gov/science-news/science-at-nasa/2013/26feb_russianmeteor/
4. Nelson, S.A. "Meteorites, Impacts, and Mass Extinction." From Tulane University. Posted Jul. 17, 2012. Online at http://www.tulane.edu/~sanelson/Natural_Disasters/impacts.htm
5. B612 Foundation video demonstrating number and location of asteroid impacts over the past decade. https://b612foundation.org/list-of-impacts-from-impact-video/
5. Robertson, D.S. et al. (2013). K-Pg extinction: Reevaluation of the heat-fire hypothesis. *Journal of Geophysical Research* **118** (1): 329-336.

Lesson Vocabulary:
Conservation of Energy - A principle stating that the total energy of an isolated system remains constant regardless of changes within the system.
Energy Transformation - To convert energy from one form to another.

Materials Required: Copy of U.S. map for each student (supplied), colored pencils, and drafting compasses

Preparation: Make copies of U.S. map for each student. Put together a brief lecture for the students (see the associated PowerPoint for an example). First, differentiate the terms **asteroid**, **meteor**, and **meteorite**. Second, recount the recent meteor event in Russia (2013), the historical meteor event in Russia (1908), and the prehistorical K-Pg asteroid event in Mexico (66 mya). Third, connect this lesson to the lab on impacts by explaining the mechanics of craters. Incorporate the articles and video clips from the reference section into the lecture as appropriate.

Safety Information: There is no special safety information for this lesson.

Engagement: Begin by asking students to break into small groups and generate definitions for the terms **asteroid**, **meteor**, and **meteorite**. After about five minutes, discuss the terms as a class and help modify their definitions for their science notebooks. Then, show students video clips of recent meteor events in Russia. The video from February 15, 2013 will give students a glimpse into this incredible event: http://science.nasa.gov/science-news/science-at-nasa/2013/26feb_russianmeteor/. Next, use aerial photographs to show students the impacts of the historical Tunguska meteor event. Ask the students to make observations about the site in 1908 and 2008. Finally, elaborate on the asteroid that created the Chicxulub crater in Mexico and caused the extinction of 80% of all life on Earth including the dinosaurs: http://science.kqed.org/quest/video/asteroid-hunters/ . Help students understand that the asteroid itself was not the cause of the extinctions but rather the firestorm resulting from the impact event. Connect this extra-terrestrial impact to the concepts of energy conservation and transformation. Time permitting, ask students to consider how the other 20% of life forms survived this event.

Exploration: Establish a ratio of asteroid size to crater size using the 6-mile wide asteroid that created the 110-mile wide Chicxulub crater in Mexico. Use this ratio of 1:18 to estimate the crater that would result from the impact of one or more notable asteroids orbiting the sun in the asteroid belt. Provide a list of asteroids with corresponding diameters (Table 1). Students will select two asteroids and map the actual size of those asteroids. They will then choose two smaller asteroids and map the craters resulting from those asteroids. It is important for the students to see that the craters resulting from the largest asteroids are much too wide to fit onto a map of the United States. Therefore, the students will have to think carefully about which asteroids to select for mapping the actual size of those asteroids and which asteroids to select for mapping the craters resulting from those asteroids. Some of the asteroids can be used for both mapping the actual size and crater size.

Explanation: Ask the students to reconsider the known effects of the Russian meteor events and Mexico asteroid event. What then could they reasonably expect to happen if one of the asteroids they mapped actually hit the United States? Given that energy is neither created nor destroyed as an asteroid enters the earth's atmosphere and hits the earth's surface, what are the types of energy present at each stage of the event? Use this time to revisit **potential** and **kinetic energy**. This is also an opportunity to remind students that heat and light are forms of energy.

Extension: Can the students connect the concept of size and impact to other real-life energy transformations? For example, how does the size of vehicles involved in collisions influence the amount of damage?

Evaluation: Connect the assessment of this lesson to that of the previous lesson. Give students several objects of different diameters and ask them to draw the corresponding craters using any specified "asteroid" to crater ratio. Then, ask them to explain at least three ways they could increase the crater diameter without increasing the asteroid diameter. Finally, ask the students to draw one of these objects in motion on its way to hitting a sandy surface. In their drawing, they should indicate what types of energy are present and where each type of energy listed is highest in the system.

Wrap-Up: The objective of this lesson is to explore real-life implications of energy transformations. Conclude by asking students to write down one not-yet-discussed energy transformation that occurs in their life every single day. This slip of paper is their exit ticket out the door.

A map of the United States with scale for mapping asteroids.

Table 2. A list of some notable asteroids from the asteroid belt.

Notable Asteroids	**Diameter (km)**
Ceres (1st largest known asteroid)	952
Pallas (2nd largest known asteroid)	544
Vesta (3rd largest known asteroid)	525
Herculina	222
Psyche	186
Daphne	174
Mathilde	50
Toutatis	4.5

Energy Transformations: Extra-Terrestrial Impacts on Earth

6th Grade Physical Science

ME Ewing, GK-12 Fellow

Write ***Energy Transformations: Extra-Terrestrial Impacts on Earth*** in your science notebooks

With a partner, try to define these terms:

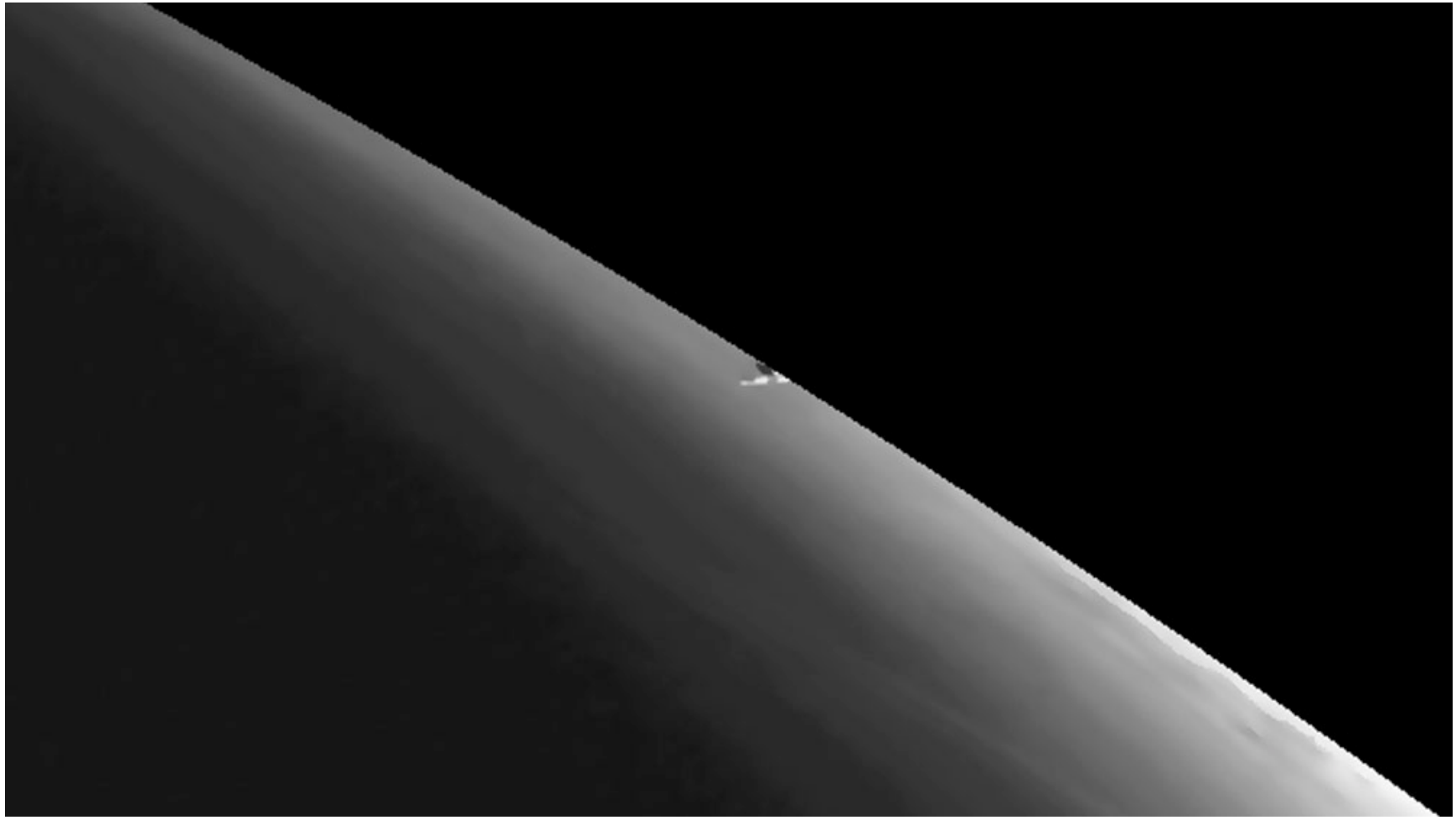
Asteroid

Meteor

Meteorite

An artist's impression of an asteroid like 2012 DA14 making a close pass of the Earth. Credit: ESA/NASA

The trail left by the Chelyabinsk fireball was recorded by Eumetsat's Meteosat-10 geostationary satellite. Credit: Eumetsat



http://tinyurl.com/RussianAsteroid13

Tunguska 1908

Tunguska 2008

Tunguska Event: Similar Size of Asteroid DA14 that flew close to Earth on February 15, 2013

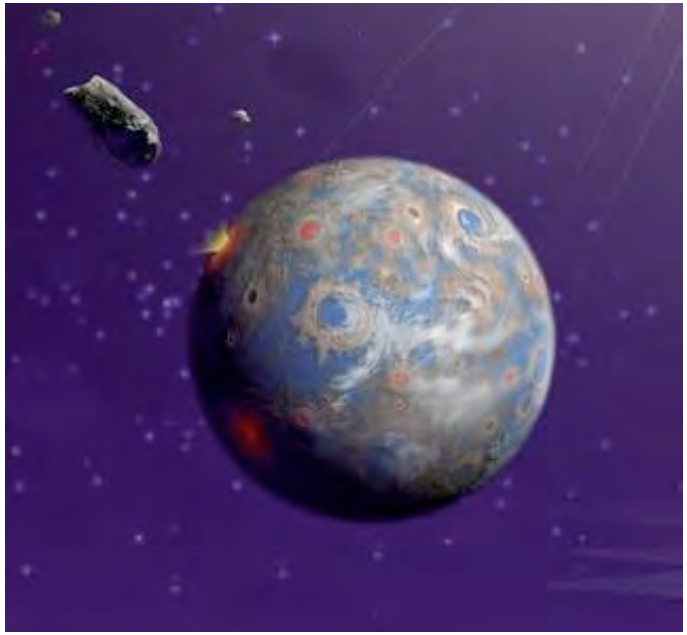
No crater at Tunguska but hundreds of miles of felled forests from the force of the burning rock above Earth's surface

“CU study provides new evidence ancient asteroid caused global firestorm on Earth” From CU News posted March 27, 2013

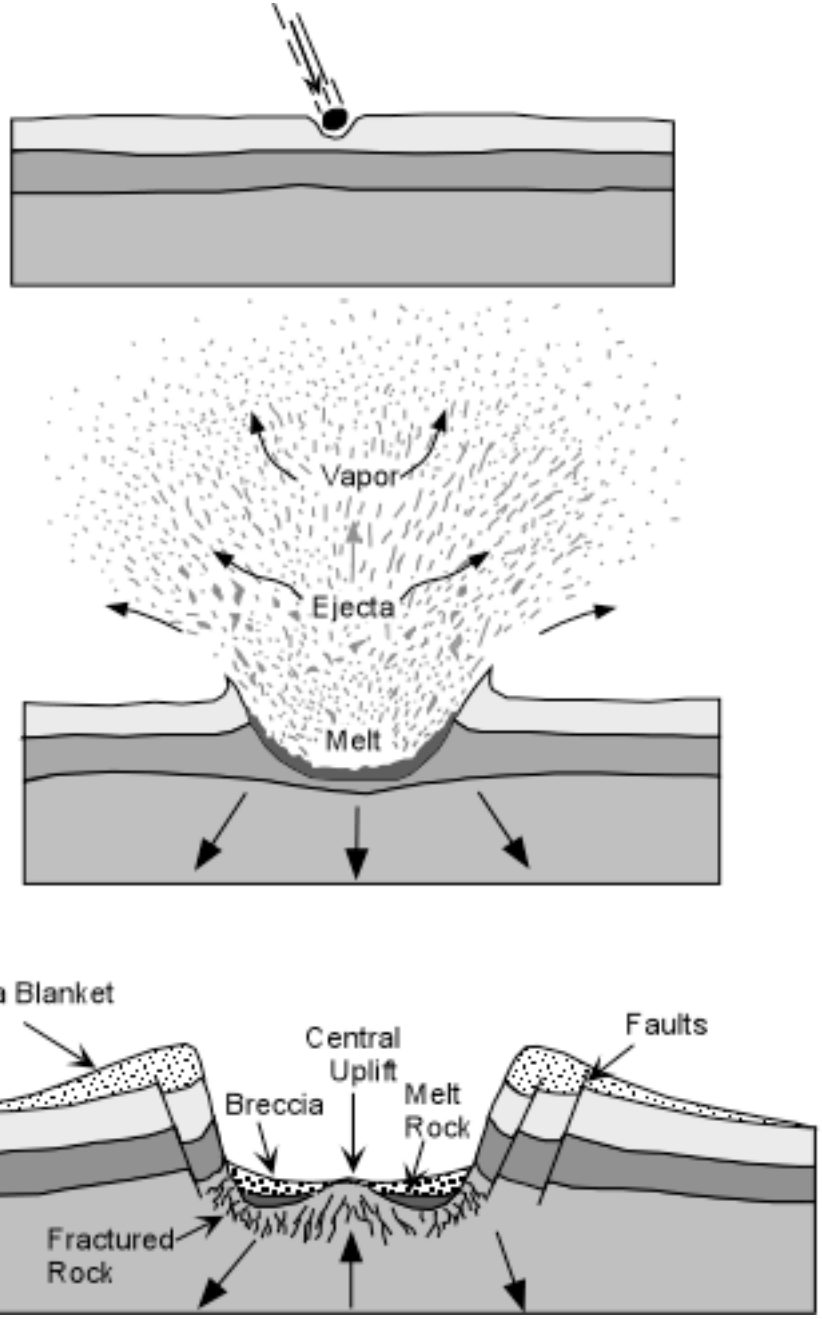
- 66 million years ago
- Manhattan-sized asteroid (6 miles in diameter)
- Chicxulub crater in Mexico (110 miles in diameter)
- Extinction of 80% of life on Earth including dinosaurs
- Evidence from the Cretaceous-Paleogene boundary?

Illustration from Mark Garlick taken from *Before It’s News*

Energy and Impact Lab



Recall: How did the size of the object relate to the diameter and depth of the crater?



From Professor Stephen Nelson at Tulane University

Mapping the Impact

- Map the actual size of one or two asteroids.
- Map the craters resulting from one or two asteroids.
- Consider the ratio of 6:110 or 1:18 for the asteroid:crater ratio.

Diameters of Notable Asteroids

#1 Ceres = 952 km
#2 Pallas = 544 km
#3 Vesta = 525 km
Herculina = 222 km
Psyche = 186 km
Daphne = 174 km
Mathilde = 50 km
Toutatis = 4.5 km