# *From Space to Earth: Meteor Crater*

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## Lesson 3: Experiments - Create Impact Craters!

**OVERVIEW**

Scientists who study impacts must rely on models and experiments to help them understand impact processes. In this lab, students will create their own impact crater models, experimenting with mass and height (velocity) of the projectiles.

In this series of group experiments, students will form hypotheses about the relationship of the mass, velocity, and angle of a projectile to the resulting crater. In the first experiment, students will test 'asteroids' of different masses. In the second experiment, they will drop asteroids from a series of heights onto a prepared "Earth's surface," testing for velocity. For the third experiment, they will design their own experiments using slingshots to test for angle.

Ideally, the students will have the time to work through two to three iterations of their experiment procedures, refining their approach to getting accurate data.

After each experiment, students will graph their data and analyze to what extent their hypotheses were correct.

**PURPOSE**

To design experiments to examine how the mass, velocity, and angle of impact of a projectile will affect the resulting impact crater's dimensions.

**COMPLETION TIME**

6 class periods/6 hours

- Two classes to create and refine the lab that experiments with mass of the projectile, collect data, and create graphs and analyze results.
- Two classes to create and refine the lab that experiments with the velocity of the projectile, collect data, and create graphs and analyze results.
- Two classes to create and refine the lab that experiments with the angle of the projectile, collect data, and create graphs and analyze results.

**LEARNING OUTCOMES**

1. Students will develop and use a model to describe a phenomena.

2. Students will define a design problem that can be solved through the development of a model and process, which includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

3. Students will observe other group results and collect final data to see patterns and trends within the data.

4. Students will apply mathematics to calculate velocity, momentum, and kinetic energy of their projectiles.

**Materials for Each Group:**

- Student Handouts for each team member and one Final Group Data Table
- Earth surface material: Moist sand
- 1 pan (plastic tubs, aluminum pans or cardboard)
- Balance (to weigh projectiles)
- Projectiles (spheres such as golf balls, steel shot, ball bearings, lacrosse balls or empty spheres to be filled with different weighted materials)
- meter sticks and rulers for each group --ideally the smaller rulers for better maneuverability.
- Tarp, newspaper, or plastic sheet to protect floor
- surgical tubing and duct tape for slingshots

**BEFORE THE ACTIVITY**

Copy student handouts

Gather the materials: Teacher Choice

> Type of Projectiles - We recommend using modeling clay and creating different weights by using plastic balls, styrofoam balls of different sizes as your base. The heaviest projectile will be solid clay.
>
> Your students could make their own projectiles out of different materials: modeling clay, string balls, tape balls, or anything else you/they can think of.
>
> The same size spheres that can be filled with different materials also works well. Then the students will be creating their own projectiles. We've had success with clear Christmas tree bulbs :https://www.amazon.com/gp/product/B013I48KA6/ref=oh_aui_detailpage_o03_s00?ie=UTF8&psc=1
>
> The students filled them with different weighted materials (empty, plastic beads, moist sand) and then we taped them up to prevent the bulbs from breaking when dropped on the 'Earth's surface.'

**DAY 1-2: Intro and Testing for Mass**

Distribute handout: Create Impact Crater Experiment, Interactive Student Handout, Testing for Mass

1. **Story Time! Ignite Curiosity about Impact Crater Size (10 minutes)**

(Source: Southgate, Nancy, and Felicity Barringer. *A Grand Obsession: Daniel Moreau Barringer and His Crater*. Flagstaff: Barringer Crater, 2002.)

**You and/or your students read this story out loud to students with great flair and drama and show pictures.**

- Show a picture of Daniel Barringer
https://en.wikipedia.org/wiki/Daniel_Barringer_(geologist)#/media/File:Daniel_Barringer.jpg

*You are Daniel Barringer, Philadelphia Mining Engineer and Geologist.*

*In 1903, having taking a train from the East Coast, you are exploring the Western United States searching for a way to make a fortune. Sitting on a porch of a local hotel in Tucson Arizona, you hear a story about a massive hole in the ground near Flagstaff, Arizona that certain people theorized was formed by a huge hunk of iron from outer space hitting the Earth.*

- Show a picture of Barringer Meteorite Crater
http://meteorcrater.com/wp-content/uploads/2014/03/meteor_no_sunset1100x469.jpg

*Scientists of the day think it was formed by a volcanic explosion, but you are intrigued and get iron samples from around the rim tested. They are 92% iron and 5% nickel with minor quantities of other elements found in meteorites. You are excited! At that time, a ton of iron is worth about $125 (almost $4000 in today's dollars). You reason that if the crater had been formed by a meteorite impact, there must be an ENORMOUS mass of meteoritic iron buried beneath it. What if the meteorite is 1,000 tons? It would be worth the modern equivalent of $4,000,000. What if it is 1,000,000 tons????? How much would that would be worth? Here is your chance to make your family wealthy and prove yourself the to the business and scientific world!*

*Despite the entire scientific community speaking and writing against your impact theory, you spring into frenzied action, starting Standard Iron Company with a business partner and securing the mining patents for the crater.*

*Now you have to convince investors of the size of the meteorite buried beneath the surface of the crater.* ***Can you estimate what the mass of the meteorite is by looking at the resulting crater?*** *(Teacher: You can read the ending of the story at end of day 3 below)*

Give students a few minutes to THINK about this problem. Take and consider all answers. (OK if answers are wrong - this is just the beginning)

Question:
How could we make an experiment in our class today to get an estimation for the size of the meteorite? (What would be the best independent variables? Do we test for mass, velocity, gravity, wind, atmosphere, Earth's surface, angle of impact, other…) Take all answers and validate possibilities.

2. **Lecture: Review Key Terms and Definitions for Controlled Experiments and Variables (10 minutes)**

- Explain that they will design and conduct controlled experiments.

- Remind them that this is a controlled experiment where one condition or variable affects the outcome of another condition, while all other conditions remain the same. These variables are known as controlled variables. (You could also introduce the idea of constants being smaller aspects of the experiment that have potential for human error such as different students dropping the projectile.)

- Write Definitions on Board: Independent or Manipulated Variable, Dependent or Responding Variables, and Controlled Variables (Independent - What I change; Dependent - What I Observe (results); Controlled Variables- What I keep the same.) Have students write definitions on handout.

- Write Example on Board: Apply definition to an example (baking cookies). See if the class can use the terms correctly. (possible baking cookies example: Independent Variable - length of time in oven/ Dependent Variable- chewiness/Controlled Variables- ingredients, heat of oven) Have students write this example on the handout.
  For more practice with this concept, they can come up with their own examples from their own life such as waking up late for school.

3. **Distribute experiment materials and review the procedure with the groups. (5 minutes)**

- Review safety expectations with projectiles.

- Remind students that better experimental control is achieved with consistent handling of the materials. For example, crater shape results may vary if the material is packed down for some trials and not for others.

4. **TEACHER CHECK IN before data collection**
   Check the groups' experiment constraints. Probe, ask questions. Make them explain their decisions and their reasoning. Make sure their drop height is a controlled variable (when mass is independent variable)

5. **Conduct Experiments and Collect Data (40 minutes)**

6. **Students graph and analyze data.**

**DAY 3-4: Testing for Velocity**

1. **Briefly discuss findings from Mass experiments. (10 minutes)**
   If MASS was the independent variable, what HAD to be a CONTROL VARIABLE? (drop height) What problems did the students encounter in getting scientifically accurate data? How did they revise their approach? What lessons were learned about how to get consistent data? Have students share tips with class on consistent handling of their material.

   Ask Class: Besides the MASS of the meteorite, what other variables affect the size the impact crater? Lead them to VELOCITY.

2. VELOCITY: Share formula for velocity ($m/s^2$) = 2(gravity)(height)
   gravity (g) = $9.8m/s^2$ (This is the gravitational quantity on Earth)
   Ask class - If this is the formula, how are we going to get an accurate test of velocity? What should be the independent variable? Accept all answers. They may immediately figure out the importance of the 90 degree drop to get accurate height. If not, let them design their experiment and when you review their experiment parameters, steer them gently but firmly to doing dead drops.

3. Students experiment with the Earth's surface and projectiles and design a scientific procedure to test for the height -variable for velocity. (10 minutes) **Possibly let them experiment with angles of impact, but make sure they have figured out to do dead drops by data collection time.**

4. **TEACHER CHECK IN before data collection**
   Check the groups' experiment constraints. Probe, ask questions. Make them explain their decisions and their reasoning. Make sure their mass is a controlled variable (when drop height is independent variable).

5. **Conduct Experiments and Collect Data (40 minutes)**

6. **Students graph and analyze data.**

**DAY 5-6: Testing for Angle**

1. **Briefly discuss findings from Velocity experiments. (10 minutes)** If HEIGHT was the independent variable, what HAD to be a CONTROL VARIABLE? What problems did the students encounter in getting scientifically accurate data? How did they revise their approach? What lessons were learned about how to get consistent data? Have students share tips with class on consistent handling of their material.

2. Angle: Explain how for this experiment, a 'dead drop' is 0 degrees, and the angle increases as it moves away from the dead drop, up to 90 degrees. Model how to measure the angle of the impact.

3. If you think they are ready, let them design the procedure and write out the steps for their angle experiment.

4. **TEACHER CHECK IN before data collection**
Check the groups' experiment constraints. Probe, ask questions. Make them explain their decisions and their reasoning. Make sure their mass is a controlled variable (when drop height is independent variable).

5. **Conduct Experiments and Collect Data (40 minutes)**

6. **Students graph and analyze data.**

**Group Discussion/Analysis/Reflection**

1. **Distribute and Review 'Create Impact Craters: Data Analysis and Reflection'**
Possible Demonstrations of Mastery (time depending) that show students' analysis and supporting evidence.
    - Each group responsible for a presentation of one question
    - Each group responsible for a visual aid connected with answer (poster, drawing on board, digital image or graph, physical demonstration)
    - Each group turns in group data sheet with written report

2. **Groups work on Group Data Table as well as answers to reflective and analytical questions. (25 minutes)**

3. **Discuss group and class results. (10 minutes) or have longer presentations (50 minutes)**
   Make sure students justify their answers using data and scientific thinking.

4. **Answer to Group question #7: Scientific and Narrative Conclusion**

Question 7.
Daniel Barringer told investors in 1907 there were "in excess of a million tons" of iron meteorite and later, in 1925, Barringer claimed the iron meteorite weighed "in the neighborhood of 10 million tons." The Barringer Meteorite Crater is nearly a mile wide and 750 feet deep. Do you think either of Daniel Barringer's claims are accurate? What information did he need to figure out the mass of the meteorite?
Answer to Question 7 - **End of the Story**

*"Daniel Barringer dedicated his adult life from 1903 to his death in 1929 to mining this crater. He spent more than 5 million in today's dollars, oversaw more than 28 drills, and in the end never found the massive meteorite he believed formed the crater.*

*How big was it? Were Daniel Barringer's claims correct? (Get students' opinions first.)*
***Scientists today approximate the mass of the meteorite that formed Barringer Meteorite Crater to be 100,000 metric tons.***

*So where was this meteorite? Did one of his six sons or two daughters find it? Was this giant hole really formed from a meteorite impact? Stay tuned for the Battle for Impact Theory (next lesson) where the truth about the meteorite and the Barringer Meteorite Crater origin is revealed!!!"*

*(Teacher spoiler alert - the kinetic energy from the impact was soooo hot that almost all of the meteorite evaporated upon impact, leaving only little meteorite fragments which are now called "Canyon Diablo Meteorite," named after the closest community to the impact site.)*

**Extensions:**
Note- Extension Activities can be…
1. worked into "Create Impact Craters!" activities by assigning different

groups these different questions about observation, angles, rock layers, and real-world impact scenarios.
2. additional full class labs and experiments
3. extra credit assignments

1. Do your students like recording videos?
**Slow-Motion Video**: See "Make Impact Craters! Extension: Slow Motion Impacts." (1-2 class periods)
Videotape the experiments (some new phones have 240 frames per second - slow motion video) and have students present the slow-motion footage to the class using vocabulary taught in this lesson.

2. Do you have colored sand or flour?
**Rock Layers**: "When Was Upside Down the Right Side Up?" (1 class period)
Students can test for how rock layers are affected by a meteorite impact.

3. Do your students like math and doomsday scenarios?
**Impact Scenarios**: "What If…? Experimenting with Impact Scenarios"(1-2 class periods) Students can input different variables into an online simulation tool, Earth Impact Effects Program, to see the resulting crater size and environmental damage on planet Earth.

*Activity design by middle school science teacher Celeste Sweeney in collaboration with Jennie Wadsworth, President of The Barringer Crater Company.*