National Aeronautics and Space Administration

The Scientific Method: An Investigation of Impact Craters

Recommended for Grades 5,6,7

www.nasa.gov

Table of Contents

Digital Learning Network (DLN)

A DLN interactive videoconferencing event is a one time connection that allows students to experience NASA first-hand. Each event features an integrated educational package of grade-appropriate instruction and activities centered around a 50 minute videoconference. Students participate in a Question and Answer session with a NASA Education Specialist or a NASA Subject Matter Expert.

Overview

This interactive videoconference event provides students with an opportunity to apply their knowledge of the scientific method. They will investigate the factors that determine the appearance of impact craters on surfaces found in space. Students will be guided to follow the scientific method and formulate a hypothesis about various aspects of projectiles that may strike a surface, causing impact craters. Each step of the scientific method is explored and discussed as a visually demonstrated experiment unfolds.

Grade Levels: 4-6

Focus Question: *How do scientists apply the scientific method to investigate the formation of impact craters on the moon?*

Instructional Objectives:

- **Engage:** The students will describe personal experiences in conducting a scientific experiment and determine which steps of the scientific method were applied.
- **Explore:** The students will conduct background research on the topic of impact craters and apply this knowledge to hypothesize the results of an experiment.
- **Explain:** The students will peer share their hypotheses and provide supporting details for the predictions.
- **Elaborate:** The students will assess and suggest alternative methods to performing this experiment.
- **Evaluate:** The students will formulate conclusions while analyzing data, compare their hypotheses to the results, and modify their hypotheses based on experiment observations.

National Standards

National Science Education Content Standards:

Unifying Concepts and Processes

- Evidence, models, and explanation
- Change, constancy, and measurement

Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understandings of scientific inquiry

Earth and Space Science

- Earth in the Solar System
- Objects in the sky

Physical Science

- Properties of objects and materials

National Mathematics Content Standards:

Measurement

- Understand measurable attributes of objects and the units, systems, and processes of measurement
    - Understand such attributes as length, area, weight, volume, and size of angle and select the appropriate type of unit for measuring each attribute.

Data Analysis and Probability

- Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them
    - Collect data using observations, surveys, and experiments.

Sequence of Events

Pre-Conference Requirements

Pre-assessment

A pre-assessment tool is available to determine the students' level of understanding prior to the videoconference. Suggested answers are included. Also, please collect the materials needed for activity as outlined below.

Pre-Videoconference Activity

See page 15.

Videoconference

1 - 50 minute conference

Post-Conference Requirements

Post-assessment

A post-assessment tool is available to determine changes in student levels of understanding.

Post Videoconference Activity

See page 14.

Videoconference Outline

I. Welcome

II. Discussion of experiments and the scientific method

III. Inquiry Session: What do we know about impact craters?
   a. Formation of impact craters
   b. Craters on the Moon vs. craters on the Earth
   c. Activity #1 – Conducting research on your topic
   d. Video clip with Dr. Jim Garvin
   e. Vocabulary review

IV. Experiment overview
   a. Explanation of recorded experiment

V. Hypothesis development
   a. Effect of impactor's mass on crater appearance
   b. Effect of impactor's drop height on crater appearance

VI. Experiment: Creating an Impact Crater
   a. Observing the appearance of the craters
   b. Recording data using a data table

VII. Formulating conclusions
   a. Writing a conclusion based on experiment results
   b. Ideas for improving the experiment

VIII. Event conclusion

Videoconference Event

Pre-Videoconference Activities:

Activity #1

Pre-conference vocabulary activities are included for use before the scheduled event. These worksheets may be printed off and completed by the students with answers provided for the teacher (see pages 15-18).

Activity #2

Read the following fictional story aloud to your students and then ask the questions that follow. Students should record their answers on a piece of paper. Use their answers as an opportunity to discuss the steps of the scientific method.

Kayla is a star player on her middle school's basketball team. She practices daily at school and at home. When Kayla practices at school, she is inside a warm gym but when she is at home, she is playing outside. The cool, autumn weather changed to cold, winter air but that didn't stop Kayla from practicing her favorite sport.

One day in January, Kayla noticed a difference in the way the basketball performed while she was shooting hoops at home. The ball did not seem to bounce as high when she practiced dribbling at home. She was very surprised because it was the same ball that she had used earlier to practice dribbling in the school gym. This made Kayla very interested to find out what was going on with her ball.

She decided to conduct an experiment for her upcoming school Science Fair that helped her solve the mystery of the deflating basketball. She had a guess that air temperature may be affecting the performance of the basketball.

What is the problem that is identified by Kayla?

What could Kayla use as a research question for her Science Fair experiment?

Based on the information in the story, what might Kayla use for a hypothesis?

Describe an experiment that Kayla could conduct in order to solve the problem?

Pre-Videoconference Procedure:

One activity in this event will require students to work in groups to conduct research. Please have students divided into four (4) working groups prior to the start of the event. Each group will need some scissors and tape available to complete the first activity.

Students will also need a location to affix facts about impact craters based on given categories. Please prepare an open space in your classroom to display the categories and the facts that are organized by student groups. Some examples may include using chart paper (4 pieces total), a bulletin board, open wall space, or a chalkboard. Please print out and post the category titles at this location prior to the start of the activity (see page 24).

Each individual student will need a pencil and a copy of the *Experiment Data Sheet* to record the data and their observations of the experiment.

During the Videoconference:

1. Assist student volunteers as they work in groups to categorize the facts given to them into the four posted categories. Remind students to work very carefully with scissors as they cut out the impact craters facts.

2. Assist students in recording the experiment data in the correct location on the data sheet.

Activity Summary

Activity 1: Building background knowledge by conducting research

Students will participate in an interactive session to demonstrate their understanding of categorizing facts into given categories. After the groups have been assigned, students will work together to cut out the facts given to them and arrange them into the following categories:

- Earth's Impact Craters
- How Impact Craters are Formed
- The Moon's Impact Craters
- Describing an Impact Crater

Activity 2: Hypothesis development and recording observations and data

Students will learn specific details about the recorded experiment and begin to make an initial hypothesis based on the research question and knowledge that was gained from Activity 1.

Students will be expected to hypothesize about the resulting impact crater created by three different impactors (a marble, a golf ball, and a baseball) and record the hypothesis on the *Experiment Data Sheet*. The impactors are dropped from three heights (30 cm, 60 cm, and 90 cm) and have different mass measurements. Students should include how the variables of mass and height would affect the resulting crater.

While observing the experiment, students will be asked to record data and personal observations on the student worksheet. At the end of the event, students will be asked to create a conclusion statement based on the results they have recorded.

Vocabulary

Floor - Bowl shaped or flat, characteristically below surrounding ground level unless filled in with lava.

Ejecta- Material surrounding the crater that was excavated during the impact event. Ejecta becomes thinner away from the crater.

Raised Rim - Rock thrown out of the crater and deposited as a ring-shaped pile of debris at the crater's edge during the explosion and excavation of an impact event.

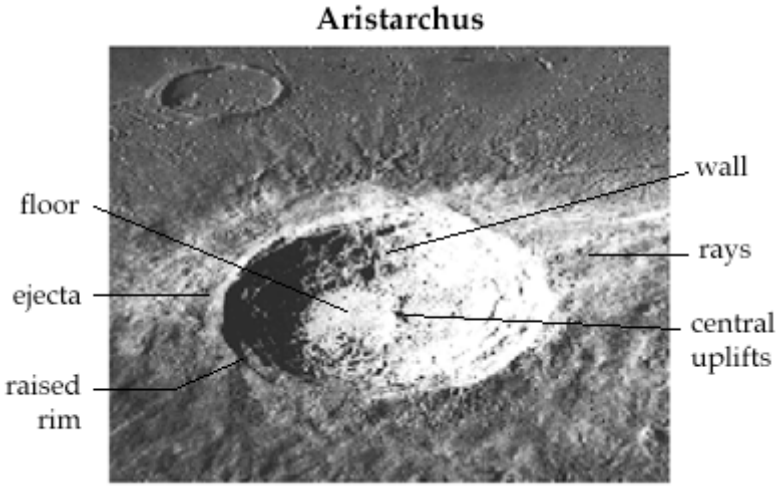
Walls - Characteristically steep and may have giant stairs called terraces.

Rays - Bright streaks starting from a crater and extending away for great distances. See Copernicus crater for another example.

Central Uplifts - Mountains formed because of the huge increase and rapid decrease in pressure during the impact event. They occur only in the center of craters that are larger than 40 km diameter.

Impactors – A projectile that crashes into the surface of another object. It is typically referred to as a meteorite.

Velocity – The rate of speed of an object moving in a specific direction.



Typical characteristics of an impact crater are labeled on this photograph of Aristarchus, a crater on the Moon. It is 42 km in diameter and located west of Mare Imbrium.

Videoconference Guidelines

Teachers, please review the following points with your students prior to the event:

- Videoconference is a two-way event. Students and NASA presenters can see and hear one another.
- Students are sometimes initially shy about responding to questions during a distance learning session. Explain to the students that this is an interactive medium and we encourage all questions.
- Students should speak in a loud, clear voice. If a microphone is placed in a central location instruct the students to walk up and speak into the microphone.
- Teacher(s) should moderate students' questions and answers.

Teacher Event Checklist

Date Completed	Pre-Conference Requirements
	1. Print a copy of the module for your reference.
	2. Have the students complete the pre-assessment.
	3. Email questions for the presenter. This will help focus the presentation on the groups' specific needs.
	4. Review the Audience Guidelines listed above with your students.

	Day of the Conference Requirements
	1. The students are encouraged to ask the NASA presenter relevant questions about the videoconference event.
	2. Follow up questions can be continued after the conference through e-mail.

	Post - Conference Requirements
	1. Have the students take the Post-Assessment to demonstrate their knowledge of the subject.
	2. Teacher(s) and students fill out the event feedback.

Pre- and Post-Assessment

1. It is not important to write down your procedures when conducting an experiment.

   True False

2. Scientists who conduct investigations about solid materials on the moon by following the scientific method are called

   a. Lunar Examiners
   b. Lunar Geologists
   c. Lunar Engineers

3. A hypothesis is proven when results from an experiment can be repeated over and over again, especially when the experiment is conducted by someone else.

   True False

4. The scientific method is

   a. Only used by NASA scientists.
   b. Used only by students.
   c. Used by everyone, young and old, to conduct research or perform experiments.

5. The _____ is the set of steps followed by scientists, students, and others when conducting research and performing experiments on different topics.

6. When making measurements for scientific purposes, you should use metric units.

   True False

7. What is the first step of the scientific method?

   a. Identify the problem and develop a research question.
   b. Develop a hypothesis based on what you know about the topic.
   c. Compose a conclusion from data you have recorded.

8. There is no need to repeat an experiment once you have the results that match your hypothesis.

   True False

9. A _____ is an educated guess or prediction for the result that will occur at the end of an experiment.

Answer Key

1. False
2. B.
3. True
4. C.
5. Scientific Method
6. True
7. A.
8. False
9. Hypothesis

Post-Conference Activity

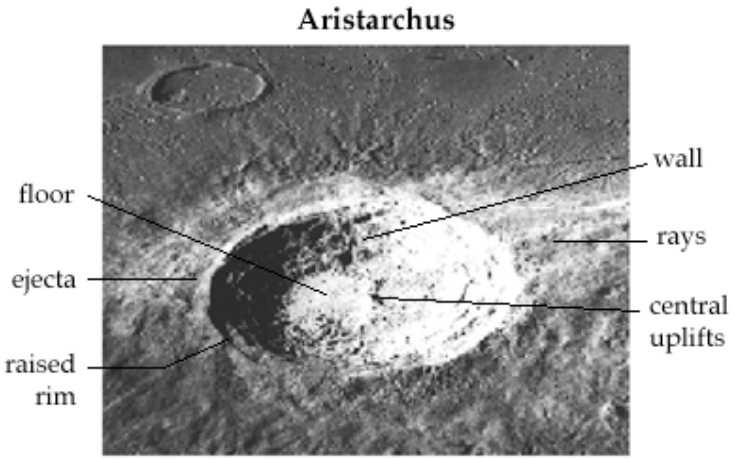
Applying the Scientific Method

Students should mentally transform themselves into NASA scientists to help conduct research on a new impact crater that just occurred on our planet Earth. Luckily, the impact was in a remote location and no humans were harmed during the impact.

Students will now conduct a scientific investigation of this newly formed crater. The assignment is to compose a report that explains each step of their investigation, following the scientific method, to determine how this crater was formed. They should use the vocabulary words from the event to describe the exterior and interior parts of the crater. In their report, they should also include a summary of the characteristics (mass, velocity, diameter, etc.) of the impactor that could have created the crater.

Students should include information for each step based on the crater investigation, including the research question, materials needed, places to find research on the topic, a starting hypothesis for the experiment, procedures to follow to complete the experiment, and how the data will be collected and analyzed.

Student Worksheets



Typical characteristics of an impact crater are labeled on this photograph of Aristarchus, a crater on the Moon. It is 42 km in diameter and located West of Mare Imbrium.

Common Definitions

Floor - Bowl shaped or flat, characteristically below surrounding ground level unless filled in with lava.

Ejecta- Material surrounding the crater that was excavated during the impact event. Ejecta becomes thinner away from the crater.

Raised Rim - Rock thrown out of the crater and deposited as a ring-shaped pile of debris at the crater's edge during the explosion and excavation of an impact event.

Walls - Characteristically steep and may have giant stairs called terraces.

Rays - Bright streaks starting from a crater and extending away for great distances. See Copernicus crater for another example.

Central Uplifts - Mountains formed because of the huge increase and rapid decrease in pressure during the impact event. They occur only in the center of craters that are larger than 40 km diameter. See Tycho crater for another example.

Impactors – A projectile that crashes into the surface of another object. Typically referred to as a meteorite.

The Scientific Method: An Investigation of Impact Craters

Excerpt from "Exploring the Moon -- A Teacher's Guide with Activities" – Courtesy of NASA EG-1997-10-116-HQ

Our Research Question is: What affects the appearance of impact craters?

Paragraph #1:

The circular features so obvious on the Moon's surface are **impact craters** that formed when **impactors** smashed into the surface. The explosion and excavation of materials at the impacted site created piles of rock (called **ejecta**) around the circular hole as well as bright streaks of target material (called **rays**) thrown for great distances.

Paragraph #2:

Two basic methods forming craters in nature are: 1) impact of a **projectile** (like a meteor) on the surface and 2) collapse of the top of a volcano creating a crater termed *caldera*. By studying all types of craters on Earth and by creating impact craters in experimental laboratories geologists concluded that the Moon's craters were in fact created by impactors.

Paragraph #3:

By recording the number, size, and extent of erosion of craters, **lunar geologists** can determine the ages of different surface units on the Moon and can piece together the geologic history. This technique works because older surfaces are exposed to impacting **meteorites** for a longer period of time than are younger surfaces. Impact craters are not unique to the Moon. They are found on all the terrestrial planets and on many moons of the outer planets.

Paragraph #4:

On Earth, impact craters are not as easily recognized because of weathering and erosion. Famous impact craters on Earth are Meteor Crater in Arizona, U.S.A.; Manicouagan in Quebec, Canada; Sudbury in Ontario, Canada; Ries Crater in Germany, and Chicxulub on the Yucatan coast in Mexico. Chicxulub is considered by most scientists as the source crater of the catastrophe that led to the extinction of the dinosaurs at the end of the Cretaceous period. An interesting fact about the Chicxulub crater is that you cannot see it. Its circular structure is nearly a kilometer below the surface and was originally identified from magnetic and gravity data.

Group #1 – Activity Fact Sheet

Directions: Cut out each box and attach it under the correct category in your classroom. The categories you have to choose from are: The Moon's Impact Craters, Earth's Impact Craters, How Impact Craters are Formed, and Describing an Impact Crater.

Craters are found on all the terrestrial planets and on many moons of the outer planets.

Famous impact craters on Earth are Meteor Crater in Arizona; Manicouagan in Quebec; Sudbury in Ontario; Ries Crater in Germany, & Chicxulub in Mexico.

Craters can be formed naturally by the collapse of the top of a volcano creating a crater termed **caldera**.

The circular features on the Moon's surface are **impact craters** that formed when **impactors** smashed into the surface.

Group #2 – Activity Fact Sheet

Directions: Cut out each box and attach it under the correct category in your classroom. The categories you have to choose from are: The Moon's Impact Craters, Earth's Impact Craters, How Impact Craters are Formed, and Describing an Impact Crater.

The number of impact craters on the Moon is much higher than Earth because the moon has no atmosphere.

A ring-shaped pile of rock that piles up around the edge of a crater is called a **raised rim**.

When craters first form, rocks are melted or crushed and shock waves are sent out through both the surface that was hit and the impactor itself.

An interesting fact about the Chicxulub crater is that it is nearly a kilometer below the Earth's surface.

Group #3 – Activity Fact Sheet

Directions: Cut out each box and attach it under the correct category in your classroom. The categories you have to choose from are: The Moon's Impact Craters, Earth's Impact Craters, How Impact Craters are Formed, and Describing an Impact Crater.

A crater can be formed by the impact of a **projectile** (like a meteor) on the surface or a planet or moon.

The explosion of materials at the crater site creates bright streaks of material called **rays.**

Lunar Geologists record the number and size of craters and the amount of erosion of craters to help determine their ages.

All of the Moon's craters were created by impactors in space, and not by volcanoes.

Group #4 – Activity Fact Sheet

Directions: Cut out each box and attach it under the correct category in your classroom. The categories you have to choose from are: The Moon's Impact Craters, Earth's Impact Craters, How Impact Craters are Formed, and Describing an Impact Crater.

The explosion of materials at the impacted site creates piles of rock called **ejecta** around the crater.

The crater found near Chicxulub, Mexico is considered by most scientists as the source crater of the catastrophe that led to the extinction of the dinosaurs.

On Earth, impact craters are not as easily recognized because of weathering and erosion.

A scientist who studies the solid matter found on the Moon is called a Lunar Geologist.

Experiment Data Sheet

Hypothesis

		30 cm drop	60 cm drop	90 cm drop
Object 1 - Marble	Marble Mass:			
	Crater Diameter:			
	Length of Ray:			
Object 2 – Golf Ball	Golf Ball Mass:			
	Crater Diameter:			
	Length of Ray:			
Object 3 - Baseball	Baseball Mass:			
	Crater Diameter:			
	Length of Ray:			

Conclusion Statement:

Activity Categories

Teacher Directions: Cut out the four (4) category titles below and post them for student use during Activity 1.

Earth's Impact Craters

The Moon's Impact Craters

How Impact Craters are Formed

Describing an Impact Crater

NASA Education Evaluation

Currently the Office of Education is undergoing a major system change for its on-line interface for education evaluation. The new website will be announced later this year. We may need a few minutes of your time before or after a DLN event to answer questions that we will need to record until the new system is up and running.

But remember, to continue to receive these events for free, we need your feedback!

Additional Resources

Educator's Guide: Exploring the Moon

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html

Moon Lithograph:

http://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Earths_Moon_Lithograph.html

Finding Impact Craters with Landsat:

http://craters.gsfc.nasa.gov/index.html

NASA's Near Earth Object Program:

http://neo.jpl.nasa.gov/images/meteorcrater.html

NASA's Lunar Reconnaissance Orbiter

http://lunar.gsfc.nasa.gov/forkids.html

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