Moon Craters

Unit Introduction: This unit is based upon FOSS Planetary Science curriculum, in which students explore how impact is one of the major processes that shapes and changes the surface of planets and satellites. This unit, Moon Craters, will build upon the students' enthusiasm for astronomy while they explore several scientific concepts, build process skills and reinforce scientific habits of mind. At different times students will work alone, in pairs, in groups of three or four and as a class. The tempo, strategies and peer groups will change somewhat to provide variety in which the students can be kept interested at the inquiry at hand.

This unit is the fifth investigation to be taught under the greater Astronomy theme. During this theme, students become astronomers as they investigate the kinds and numbers of objects in our galaxy, the composition of objects and the interactions of the objects with one another. A theme as huge as Astronomy needs some specification. We started with general phenomena such as stars, black holes, comets and meteors. Gravity was introduced and the Moon and Earth were compared and contrasted regarding gravity and atmospheric composition. Computer simulations were done using NASA's Stardust mission website http://stardust.jpl.nasa.gov to show the students an example of real science happening currently. The students were able to see interactive images, how the data was being analyzed and even what the objects that cause craters look like. The Moon is the next extraterrestrial body covered, followed by the planets. Following this Moon Craters unit, the students will go on to map the Moon and study the history and exploration of the Moon. The students' next unit on the Moon includes a month long observation of appearance and phases. We will end with Earth, as the most familiar object in our solar system. Students will gain familiarity with maps, review evidence supporting theories for both a round and flat Earth and explore the motions that produce day, night and seasons on Earth.

Brief Description of Group to be Taught: Three sections of sixth graders with 18 students per class. The students have looked at the moon and craters in 3rd grade. However, it was a general overview and the concepts were not looked at in depth. Also, it is unknown how many of the current students were in that 3rd grade class. The process skills and desired habits of mind will be built upon from previous activities. This class regularly works in small groups but they have not had specific roles within groups. No students have specific IEP's, but three receive tutoring from the skills departments, primarily with organization and focus. These students will be monitored during the activities.

Science module: *Moon Craters,* FOSS Planetary Science Curriculum (Delta Education, 2001).

Unit Length: Minimum of eight 45-minute science sessions.

Activity 1
The Moon-Crater Controversy

Relationship of this Lesson to the unit: This is the first in a series of lessons focusing on lunar craters. This activity will challenge students to formulate hypotheses and test them based on evidence from their own simulations and theories from readings.

Massachusetts Frameworks Strand and Learning Standard:
- ***Earth Science*** 8. Gravity plays a major role in the formation of the planets, stars and solar system and in determining their motions.
- ***Earth Science*** 10. Compare and contrast properties and conditions of objects in the solar system to those of the Earth.

Science Concepts:
- Craters of various sizes result when meteoroids of various sizes hit the Moon's surface. Students will recover evidence that supports this theory. Students will also simulate impact events to discover the variables (i.e. size and speed) that determine crater characteristics.

Process Skills:
- Formulating hypotheses

Science Habits of Mind:
- Be open-minded and willing to change your mind in the face of reliable evidence.
- Use reliable sources for evidence

English Objectives:
- Being able to identify main ideas and supporting details in a passage
- Persuasive writing

Activity 1 Materials for Class:
- 4 cocoa shakers
- 2 ½ liter containers
- 1 container of cocoa powder – 1lb per class
- sand
- newspaper
- overhead projector
- Lunar crater formation transparency

Activity 1 Materials for each Group:
- 1 basin of sand
- 4 different size balls
- 1 piece of 10cm x 20cm cardboard
- 1 plastic cup

Science Activity Unit

Session Length: Two 45-minute sessions.

TIME	PROCEDURE
Prep	• Make a copy of moon questions for each student • For homework 2 nights before, have students bring in old newspapers to use during crater experiments • Get flour and measure into basins • Prepare cocoa shakers and cardboard graders
Day 1 10 min	**Introduction:** 1. Introduce the unit, Moon Craters. Ask students what the surface of the moon looks like? Explain that during this unit, they will survey lunar terrain, observe and describe features and will understand why the Moon looks that way it does. 2. Explain to students that we will be discussing a scientific controversy that emerged in the 1950s around what really caused craters. Some scientists argued that craters were formed by impact while others believed it was volcanism.
Day 1 5 min	**Moon-Crater Dialogue:** 1. Introduce the moon-crater dialogue. Ask for 2 students to volunteer to assume the roles of Green and Shoemaker. 2. Ask the students to take out their science notebooks and take notes when the scientists present evidence that supports one or the other of the two theories. 3. Have the volunteers read the dialogue straight through in front of the class.
Day 1 20 min	**Discussion:** 1. When dialogue is finished being read, break students into smaller groups of four. Give each group a copy of what they just heard in order to re-read Instruct each group to have discussion based on: • Recount points in the arguments offered by both Shoemaker and Green that were compelling • What additional information could help settle the matter? • Which position do you support and cite the convincing evidence 2. Assign roles in each group. Model how students are to work together and what each role is to do during the following discussion. Also, point out the need for respect and trust as a whole class. Students will be sharing opinions and thoughts during which everyone else should be actively listening with an open mind.
Day 1 10 min	**Summary and Wrap-up:** 1. Ask students to stop working with their groups and come back together as a class. Ask the reporter from each group to share which position they supported and why. 2. Homework: Green and Shoemaker needed more information to settle the controversy. Can you think of a way to get more evidence to decide if volcanoes or impacts created the craters? Think of how you could set up some simulated impact events in the classroom tomorrow. Form a hypothesis on how craters form.

Day 2 5 min	**Introduction:** 1. Review the previous day by asking for student volunteers to summarize Green and Shoemaker's controversy. 2. Have class brainstorm a list of ideas they came up with for homework about ways in class each student can simulate their own impact events. Write ideas on board.
Day 2 15 min	**Pre-Activity:** 1. Introduce the simulated lunar surface the class will use during today's lesson. Show students a basin of sand. Identify the sand as regolith (lunar soil) and have them take down the new vocab word in their science notebooks. Demonstrate how to use the cocoa shaker to deposit a thin layer over the entire surface. 2. Introduce the meteoroid by holding up a marble. Review previous knowledge of meteoroids, meteors and meteorites. Ask for student volunteers to explain each concept to rest of class. Explain that in this activity, marbles will act as the meteoroids that collide with the surface of the moon and that the crash is called an impact. 3. View Lunar Crater Formation transparency. Explain that the goal for this activity is to discover what happens when a marble crashes into the basin.
Day 2 20 min	**Activity:** 1. Establish rules and procedures for the activity. Tell students: • Balls are to be dropped into the basin, not thrown • Place basin on newspaper • Use the piece of cardboard to level the flour surface between drops. 2. Students will work in groups of four. The getters from each group will gather the materials needed for this activity. **3.** Allow students to "play" and investigate on their own. They should be encouraged to compare and contrast craters formed by high and low elevation drops.
Day 2 5 min	**Summary and Wrap-up:** 1. Ask students to stop working with their groups and put all sand back in their basins. **2.** Getters return basins, shakers and balls.

Assessment

	Method	Novice	Competent	Expert
Science Concept: Craters of various sizes result when meteoroids of various sizes hit the Moon's surface	Observe during classroom investigations	Unable to conclude that altering the height from which the ball drops or that the size of the ball dropped has an impact on the crater formed in the basin.	Can explain that crater size changes with size of ball dropped and that balls dropped from a higher elevation forms a deeper crater.	Can explain that larger balls form larger craters than smaller balls. Also that the depth of the crater changes with the height of the dropped ball because of speed. Begins to evaluate other ways in which craters can differ such as angle of ball dropped and/or how the crater walls appear differently.
Process Skill: Formulating hypotheses	Homework	Will not be able to identify a correct way in which a lunar crater forms and cannot come up with a reasonable classroom simulation.	Will be able to identify at least one correct way in which a lunar crater forms and can list at least one reasonable classroom simulation to test.	Will be able to explain how lunar craters form and give multiple ways in which to test hypothesis in simulated classroom environment.
Habit of Mind: Be open-minded	Observe during classroom discussion and small group discussions	Will not be open to the opinions of group members or reliable evidence given during dialogue.	Will be generally willing to discuss the possibilities of the two sides of the crater controversy with group members.	Will suggest and accept others ideas and evidence given during the dialogue.

Activity 2
Variable Speed Impact Simulations

Relationship of this Lesson to the unit: This is the second lesson in a series of lessons focusing on lunar craters. During this activity students will conduct experiments to determine the effects of meteoroid sped on crater characteristics. They will collect data and graph the results in order to establish a cause and effect relationship.

Massachusetts Frameworks Strand and Learning Standard:

- ***Earth Science*** 8. Gravity plays a major role in the formation of the planets, stars and solar system and in determining their motions.
- ***Earth Science*** 10. Compare and contrast properties and conditions of objects in the solar system to those of the Earth.

Science Concepts:

- Building upon previous experience with meteoroids and lunar craters, students begin to explore how meteoroid speed impacts crater size, depth and ray length.

Science Processes:

- Collect, organize and graph data

Science Habit of Mind:

- Respect for Evidence

Math Objectives:

- Measurements of drop heights and crater diameter
- Graphing of data points to form a line

Activity 2 Materials for Class:

- 4 cocoa shakers
- 1 zip lock bag
- 1 container of cocoa powder
- newspaper
- overhead projector
- transparencies model impact craters and crater diameter and ray length graphs

Activity 2 Materials for each Group:

- 1 basin of sand
- 4 balls of different sizes
- 1 piece of 10cm x 20cm cardboard
- 1 plastic cup
- 1 scissors
- 1 meter stick
- 1 divider
- pencil compass
- 1 millimeter ruler
- handouts of model impact craters and graph paper

Session Length: Two 45-minute sessions.

TIME	PROCEDURE
Prep	• Check materials from Activity 1 • Make copies of each of the handouts for each student
Day 1 15 min	**Review:** 1. Review the informal crater experiments from Activity 1. Ask students if they observed any evidence to suggest that the theory of lunar craters forming from impact could be true. 2. Reinforce vocab words: meteors, meteoroids, meteorites, crater, ejecta and rays. Have students explain to each other what they mean and then take notes on these words in their science notebooks.
Day 1 15 min	**Discussion:** 1. Have students meet in their small groups from Activity 1. Ask them to discuss and make a list of how the craters they made differed from one another. If they need focus points, tell them to specifically focus on differences in depth, diameter and length of ray/ how far sand was ejected out of basin. 2. After about 5 min, ask students to come back together and as a class make a list of these differences observed on the board. 3. Ask each student to take a minute to think about what change caused these three dimensions to vary from crater to crater. 4. Ask for a student volunteer to offer to share a reason. Confirm that the differences observed depend on the height from which the ball drops. 5. Ask students to get back with their groups and come up with an experiment that would provide more exact information about the relationship between the speed of the incoming meteoroid and the size and shape of the resulting crater.
Day 1 10 min	**Summary and Wrap-up:** 1. Ask students to stop working with their groups and come back together as a class. Ask the reporter from groups that volunteer to describe their plan. 2. Homework: Think about ways in which to measure the data for tomorrow's lab.

Day 2 15 min	**Introduction:** 1. Review previous day's lesson by describing a plan that includes the characteristics of predetermined, measured heights, several drops from each height, measures crater features and records and displays results through charts or graphs. 2. Show transparency of Model Impact Craters sheet and discuss suggested drop heights and how to go about recording data in their science notebooks using this as a guide. 3. Demonstrate how to use a pencil compass as a divider to measure the length of crater rays.
Day 2 20 min	**Activity:** 1. The getter from each small group gathers materials. 2. Groups investigate on their own while the teacher roams around and asks assessment questions to help them work efficiently.
Day 2 10 min	**Summary and Wrap-up:** 1. Ask students to finish the drop they are working on and to organize their materials and return them. **2.** Have students take the last 5 minutes to start to graph their results on graph paper handed out by the teacher. Finish for homework.

Assessment

	Method	Novice	Competent	Expert
Science Concept: Meteor speed impacts crater size, depth and ray length.	Observe during classroom investigations and group experiment designs.	Unable to conclude that altering the height from which the ball drops has an impact on the crater formed in the basin.	Can explain that crater size, depth and ray length changes with the height of ball dropped.	Can explain that the dept and diameter of the crater changes with the height of the dropped ball because of speed. Used multiple tests in experiment design.
Process Skill: Collect, organize and graph data	Homework	Graph does not accurately represent the relationship between the variables. Data is not organized and the graph is labeled incorrectly.	Graph is correctly labeled. Points on graph represent the correct relationship between the variables.	Data is neatly organized in a table and graph is correctly labeled. The graph accurately represents correct data.
Habit of Mind: Respect for evidence	Observe during classroom discussion and small group discussions	Will not be open to reliable evidence given during group or class discussions.	Will be generally willing to discuss the possibilities of the two sides of the crater controversy with group members.	Will suggest and accept others ideas and evidence given during group and class discussions.

Activity 3
Variable Mass Impact Simulations

Relationship of this Lesson to the unit: This is the third lesson in a series of lessons focusing on lunar craters. During this activity students will conduct experiments to determine the effects of meteoroid size and the characteristics of the craters they produce. They will write a position paper discussing the credibility of the theory that lunar craters were formed by impacts.

Massachusetts Frameworks Strand and Learning Standard:
- ***Earth Science*** 8. Gravity plays a major role in the formation of the planets, stars and solar system and in determining their motions.
- ***Earth Science*** 10. Compare and contrast properties and conditions of objects in the solar system to those of the Earth.

Science Concepts:
- Building upon previous experience with meteoroids and lunar craters, students further investigate craters by examining how the size of meteoroids impacts crater size, depth and ray length. Students will describe the processes that produce craters.

Science Processes:
- Interpreting data
- Communicating

Science Habit of Mind:
- Keep records of investigations and observations
- Offer reasons for findings

English Objectives:
- Produce writing sample with clear thesis statement and supporting details.

Activity 3 Materials for Class:
- 4 cocoa shakers
- rocks of 5 sizes
- 5 ½ liter containers
- 2 balances or scales
- newspaper
- overhead projector
- transparencies model impact craters and crater diameter and ray length graphs

Activity 3 Materials for each Group:
- 1 basin of sand
- 1 piece of 10cm x 20cm cardboard
- 1 plastic cup
- 1 meter stick
- pencil compass

Session Length: Two 45-minute sessions.

TIME	PROCEDURE
Prep	• Check materials from Activity 2 • Attach an assessment chart to a clipboard to keep during the activity.
Day 1 10 min	**Review:** 1. Discuss results from Activity 2. Have students stand up and show their graphs. Compare and contrast results between groups. Is there any pattern or relationship consistent throughout all data?
Day 1 15 min	**Discussion:** 1. Discuss real vs. simulated craters as a class. Ask, how are the craters made with marbles the same as those on the moon? How are they different? Brainstorm a list on the board. 2. Tell students that objects that hit the moon are probably not all the same size as the marbles were in Activity 2. Today we will try making craters with impact objects of different sizes, rocks. 3. Show transparency of Investigating Meteoroid Size and explain how to create a chart similar to this in their notebooks.
Day 1 20 min	**Summary and Wrap-up:** 1. Ask student to meet in their small groups for the remainder of class to define and plan an experiment. They must list and identify the experimental variables and think about which ones they will control. They then need to make their data chart and get approval from the teacher before beginning the experiment.
Day 2 35 min	**Activity:** 1. As soon as students come to class, have them get started on their experiments. 2. The getter from each group gathers materials needed. 3. Point out that balances and scales are available if needed. 4. Teacher should roam around class and observe group dynamics and ask integrating questions to help students stay focused on inquiry. • Why should you do more than one test for each rock? • Why drop all rocks from same height? • Which rock do you think will make the biggest crater? Why? • Which crater dimension will you compare to the mass of the rocks?
Day 2 10 min	**Summary and Wrap-up:** 1. Ask students to clean up their area and to organize their materials and return them. **2.** Have students take the last 5 minutes to organize their data in their notebooks. **3.** Homework: Write a 1-2 page position paper supporting Shoemaker's idea that impacts created the craters on the Moon. Use information from the reading and results from Activities 2 and 3 as evidence for Shoemaker's position.

Assessment

	Method	Novice	Competent	Expert
Science Concept: Describe the processes that produce craters with variable characteristics and of various sizes	Position paper homework	Provides information relevant to the paper, but information is incorrect and is not connected to the position being argued.	Defends Shoemaker with logical arguments and provides evidence from the reading and investigation.	Defends Shoemaker with logical arguments and evidence from the reading and investigation. Refutes some of Green's evidence. Or, agrees with Green and provides strong evidence.
Process Skill: Interpret and communicate data	Position paper homework	Information provided is incorrect and is not connected to the position being argued. Student lacks evidence from reading or own personal investigation.	Provides evidence from the reading and investigation in a meaningful way.	Provides logical arguments and evidence from the reading and investigation. Uses information and data to refute the opposing side.
Habit of Mind: Keep records of all observations	Observe during classroom discussion and small group discussions	Unable to keep accurate note of observations during investigation.	Able to list and identify the experimental variables and those needed to be controlled. Data was organized in chart form.	Able to list and identify the experimental variables and all those that needed to be controlled. Data was neatly organized in chart form.

Activity 4
Crater Analysis and Classification

Relationship of this Lesson to the unit: This is the fourth lesson in a series of lessons focusing on lunar craters. During this activity students will use multimedia to observe the creation of different crater forms: simple, complex and basin. .

Massachusetts Frameworks Strand and Learning Standard:

- ***Earth Science*** 8. Gravity plays a major role in the formation of the planets, stars and solar system and in determining their motions.
- ***Earth Science*** 10. Compare and contrast properties and conditions of objects in the solar system to those of the Earth.

Science Concepts:

- Building upon previous experience with meteoroids and lunar craters, students further investigate craters by classifying craters by forms. They will reconstruct the history of impact craters that resulted in the present appearance of the Moon.

Science Processes:

- Graphing

Science Habit of Mind:

- Be careful and accurate in observations

Math Objectives:

- Using data to make line graphs

Activity 4 Materials for Class:

- Map of Moon poster
- Smartboard
- CD-ROM

Activity 4 Materials for each Group:

- 8 moon photos
- Handouts

Session Length: Two 45-minute sessions.

TIME	PROCEDURE
Prep	• Preview multimedia • Make copies of organizing Lunar Craters worksheet for each student.
Day 1 20 min	**Review:** 1. Ask for student volunteers to share their homework position papers to the class. Encourage students to engage in constructive criticism. 2. Collect all homework. 3. Ask students to take out their mass and crater data from Activity 3 and have them graph their results individually. 4. Use student examples to show whole class what the data should look like on the graph. 5. Ask students: • Can craters form as a result of objects smashing into a surface? • How does size of incoming object affect size of crater? • The length of ray? 6. Summarize results and findings from Activities 1,2,3 for students. Experiments similar to the ones each group just did show that large meteoroids could produce large craters. One thing we were not able to reproduce in the classroom is the speed at which objects fly through space. Meteoroids travel so fast that when they hit the Moon, an explosion occurs, releasing energy.
Day 1 25 min	**View Multimedia:** 1. While seated at their desks, students will view the multimedia on the smartboard located in front of the classroom. 2. In the formation chapter, open Simple and Complex Craters. Have a student volunteer read text aloud. 3. Go to Crater Formation Animation. Play the 3 simulations at least twice. Open links to see examples of the kinds of craters shown in the simulations. 4. As review, ask students to answer a few of the questions on the images pages if there is time.
Day 2 20 min	**Moon Photo Activity:** 1. Ask students to get in their small groups and spread out throughout the room. 2. The getter must gather 8 close-up photos of the moon. 3. Each student in the group is to choose a different photo to work on. 4. On the board, list the characteristics hey must find: • The largest crater • The smallest crater • The longest rays • A central peak • A different kind of crater **5.** After each student has studied and observed 2 photos, the group will discuss what was found.

Day 2 20 min	**Moon Map:** 1. While students are working on their photos, post the moon map poster on the smartboard for all to see. 2. Have student volunteers point out examples of simple, complex and terraced craters on the poster. 3. Ask if they noticed any craters that didn't fit those categories. Where are they? What do they look like? What could cause them? 4. Point out Plato and Archimedes Craters as examples. These large diameter craters are flooded with lava. 5. Some students may ask about what we see as seas. Explain that theory suggests that large bodies crashed into the Moon and left gigantic crater basins that filled with lava millions of years after and formed the maria that we see today. 6. Point out locations on the moon map poster, specifically the highlands. Notice that the highlands have many more craters. When the surface is completely covered by craters, it is called saturated. Have students write down the definition of this new vocab word in their notebooks. **7.** Point out the Stofler Crater where several others overlap a large crater. Ask students how they can tell which is the oldest or youngest.
Day 2 5 min	**Wrap-Up:** 1. Homework: Students will organize their notes and observations from today's activity. An example worksheet of how to chart and make lists will be given out to use as a starting point. The craters should be listed by size and feature and include a picture.

Assessment

	Method	Novice	Competent	Expert
Science Concept: Classification of craters by form	Homework worksheet	Unable to conclude that the craters are formed in different ways and appear differently.	Can explain all or most of the ways in which craters form and label their drawings accurately.	Accurately describes al crater types and includes a detailed picture that is labeled correctly.
Process Skill: Graphing	Classwork	Graph does not accurately represent the relationship between the variables. Data is wrong and the graph is labeled incorrectly.	Graph is correctly labeled. Points on graph represent the correct relationship between the variables.	Data is neatly organized in a table and graph is correctly labeled. The graph accurately represents correct data.
Habit of Mind: Careful and accurate observations	Observe during classroom discussion and small group discussions	Does not make careful and accurate observations. Details are missed and data is not written down.	Makes detailed observations, ask questions about what is observed and shares findings with group.	Makes detailed observations, ask questions about what is observed, keeps records and shares findings with group.

Model Impact Craters Worksheet

Drop Height	Crater Diameter	Ray Lengths	Average Ray	Above, even or below

Organizing Lunar Craters Worksheet

Crater Type	Description	Picture
Basin		
Tiered		
Complex		
Simple		
Flooded		

Personal Reflection

What went well?

- Knowing the students fairly well, group dynamics went really well. In this grade, cooperative groups are used often and the students know how to work together and enjoy it. There will always be some socializing going on when middle school students are asked to work together, but I was impressed with their ability to work fairly and cooperative with each other.
- The activities were fun for the students. It kept their interest on the topic at hand. The students loved being able to design their own experiments and use sand to drop different size balls into!
- They were all able to grasp the concepts I had hoped they would. They understood the variables very well. Most groups designed experiments that did take all the variables into account before starting. Those who had missed something is their procedure soon caught on and quickly added it in. All were at the competent stage at the end, with some experts as well.

What did I learn?

- Clean up of materials always takes longer than expected. I didn't allow for enough time for materials to be put away, have the students settle back down into their seats and wrap up the lesson at the end of each class.
- Having the rubric to assess student knowledge of concept, habit of mind and process skills was not enough. I found myself getting to involved with each group and forgetting about my clipboard. I thought I would be able to remember who said what when after class, but sometimes there wasn't enough down time once one class left before the next one arrived.
- I need to do more observing and less interacting. I had a tendency to want to talk and ask what each group was doing instead of sitting back and observing their interactions and skills. Even though I had established assessment questions to ask each group, I would end up staying with groups longer after the questions had been answered.
- Students will always have lots of questions that can easily drag the lesson off topic. It is great that they are so interested in the topic at hand, but I found myself easily swaying toward discussions with them about irrelevant material to that day's lessons. I soon started to make a list of their questions to use while planning future astronomy lessons.
- That adding water to the investigations using sand basins brings a new dynamic to the experiment. Two groups actually added this into their procedure for making impact craters. They were able to see their craters better, leading to more detailed observations and more accurate measurements of crater diameter.

What would I have changed?

- The unit plan really needed more time – ideally at least 2 more 45-minute sessions. Their conversations and ideas were so rich and interesting that I think everyone would benefit from being able to continue it without time constraints.
- Starting the unit with research and dialogue given to them worked well. However, being in 6th grade, I would have liked to give them the opportunity to do some of their own research on another topic that has come under controversy. It is important for them to realize that science always changes and scientists make mistakes as well. They had a hard time believing something that a scientist thinks is right, could be proven wrong. I wanted them to feel empowered about their ability to do science experiments and make their own theories.
- My original plan contained flour basins, however, sand was readily available in the lab and ended up working better when students started to get it wet. However, those students who used damp sand could not measure ray length, but I let that slide considering they were creative with their design.
- I started of using marbles, but after the first section, I switched to balls. I gave the students the options of using marbles, ping-pong balls, lacrosse balls, baseballs, tennis balls, softballs, soccer balls and kick balls. They seemed more interested in playing with these things rather than just marbles. Also, they started thinking more about size and weight of each.