Moon Crater Math Modeling Activity for 6th Grade

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Modeling Activity:

[LINK TO STUDENT GUIDE]

- This is a Middle School modeling activity that connects a series of math and science concepts.
- Here are all the math concepts students will be using during the lesson: gathering the following quantitative data (mass (g), height (cm), diameter (cm)), and identifying independent and dependent variables.
- Here are the Science concepts: moon craters, free fall, gathering data in three trials, and independent and dependent variables.
- Students will work in groups of three or four during this lesson.
- Before the lesson, students will watch a video of a meteoroid hitting the moon's surface then read the Galileo Telescope Story.
- They both act as an engaging hook for the lesson. At this stage, students will be asked What do you notice? What did you wonder?
- Next, we will ask: "What is the problem we are trying to solve and what information do we need?" It will be communicated to students that they are expected to use quantitative reasoning during this process.
- Eventually, we will come to agreement on the following main problem: "What is the Relationship Between the Drop Height or Mass of a Meteoroid and the Crater Diameter in Centimeters?"
- Next, the actual lesson handout will be given to students and they will be given directions. The handout is attached above, and students' evidence is shown in the Evidence section of this document.
- The following classroom materials will be used to construct the cake pan that mimics a real-life meteoroid hitting the Lunar surface: cake pan, flour, cake sprinkles, cocoa, sifter, paper towels, three small rocks of different sizes and shapes to represent the asteroids, and a marble or rock depending on the group. The Cake Pans will be all set up for the student groups.
- The Cake Pan will represent the Lunar Surface and its layers, and the marble or rock represents the meteoroid.
- Once each group's cake pans have those three layers, the groups will receive their handouts and roles.
- The roles are as follows: half of them will measure the mass of the three rocks. The other half will measure the drop height for three trials with the same marble.
- Regardless of role, students have to fill in their hypothesis, write down all the materials they are using during the experiment, write down the step-by-step procedures, conduct

the data recording part of the experiment (with three trials), answer questions, and then complete an analysis portion.

- Towards the end, each member of the groups will write a conclusion, five or more complete sentences, of the entire experiment.
- The groups will then come together and explore different trends in data and search for relationships between Drop Height and Diameter of the Crater as well as Mass and Diameter of a Crater.
- To extend the lesson, the students can complete the following:
- Students will first measure the mass and volume for each of the three rocks.
- There will be three sections in this activity, and there is an estimation period at each section.
- Each section then has students fill in data tables, and then answer a series of thought-provoking questions towards the end.
- In the first section, there is a well-structured data table already provided for students so that they have an idea of what they are supposed to look like before constructing their own tables for sections two and three.
- The first data table has students record the estimated mass, actual mass, and qualitative observations for each of the three rocks.
- The students maintain the same exact structure when constructing the second and third data tables.
- The second data table pertains to the volume of the three rocks, and students will find the volume using the displacement method.
- The third data table pertains to the density of the three rocks.
- Then, they will drop the three rocks onto the cook pan and record data on a fourth data table.
- The fourth data table first has students put all the information from the first three tables together. Then, they measure the estimated volume of the crater on their cook pan.
- Lastly, students will also draw and/or list out qualitative data that they have observed after dropping the three rocks from the same height.

Engaging Context:
We will begin the lesson by showing students this intriguing video:
https://youtube.com/shorts/KDUX73ZAATw?feature=share

- This video is a Youtube Short that shows a real-life asteroid hitting the moon and what the impact looks like.
- Most students not only do not have an idea of what an asteroid impact looks like, but also how often the moon gets impacted by these asteroids.
- We can have a casual discussion about asteroids and how often the moon gets asteroid impacts.

- A lot of key questions can arise and students can begin thinking about specific pieces of quantitative data.
- This data can include: velocity of asteroid with depth of impact, mass of asteroid with depth of impact, angle of impact with depth of impact, etc.
- Students can begin developing an idea of the problem we are trying to potentially solve or mimic.
- We can also talk about the surface of the moon and the layers right underneath the surface.
- Have a brief discussion on how these layers are influenced by the asteroids.
- This is a great leeway to the actual activity.
- Then the students will read the following Galileo Telescope story: “In the early 17th century, Galileo trained his simple telescope on the Moon. He described a barren, chaotic, landscape, including vast, dark plains and rugged mountain ranges. The most prominent features found everywhere on the Moon's surface in varying sizes and concentrations were the circular structures we recognize today as craters. As the power of telescopes advanced, the craters could be examined with increasing magnification and resolution, giving rise to a scientific controversy regarding their origin. The discussion around how the craters might have formed became intense in the 1950s and continued into the 1960s: Were craters the result of volcanism or impact? Jack Green supported the hot-Moon theory, proposing that 95% of the major lunar surface features were volcanic in origin. Gene Shoemaker supported the cold-Moon theory, claiming that the craters originated as a result of impact events-high-speed solid objects moving through space and crashing into the Moon.”

Measurable Objectives:
Students will be able to:
- select appropriate tools to measure mass, height, and diameter.
- represent data in an organized manner for analysis.
- create a data table from measured values.
- create a two coordinate graph
- evaluate data to draw conclusions about a given phenomenon..
- construct a scientific explanation using direct evidence to explain a given phenomenon.

Standards:
- NGSS SEP: Develop a model to predict and/or describe phenomena.
- NGSS SEP: Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.
- NGSS SEP: Use mathematical representations to describe and/or support scientific conclusions and design solutions.

- NGSS SEP: Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems.
- CCMS SMP: Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems.
- CCMS SMP: Model with mathematics.
- CCMS SMP: Use appropriate tools strategically.
- CCMS Measurement: Understand measurable attributes of objects and the units, systems, and processes of measurement.
- CCMS Measurement: Apply appropriate techniques, tools, and formulas to determine measurements.

Evidence:

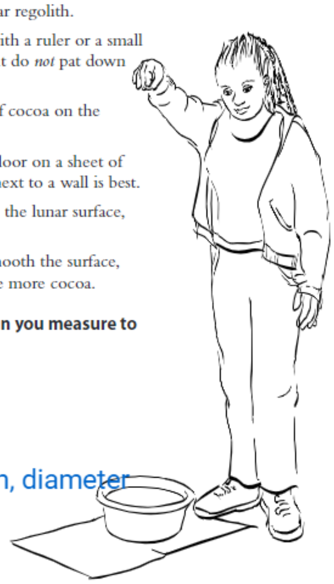
The start of the Modeling Impact Craters activity is where I introduced the simulated lunar surface and projectile. Flour acted as the moon's dusty regolith surface, hot cocoa mix acted as the maria for contrast, and the bowl represented the shape of the moon. The projectile was a small, smooth marble that acted as a meteoroid in space waiting for an impact. After carefully reviewing lab safety directions, specifically, not throwing marbles down into the lunar surface, students were free to explore and discover what crater features can be measured to compare craters. Students could just simply let go of their marble and see what was created in the bowl.

Lunar Crater Formation

Procedure

1. Get a basin with 1.5 liters of flour. This is your small area of lunar regolith.
2. Smooth the surface with a ruler or a small piece of cardboard, but do *not* pat down the flour.
3. Sprinkle a *thin* layer of cocoa on the surface of the flour.
4. Put the basin on the floor on a sheet of newspaper. A place next to a wall is best.
5. Drop meteorites onto the lunar surface, and observe.
6. After several drops, smooth the surface, and sprinkle on a little more cocoa.

What crater features can you measure to compare craters?



Ray length, depth, diameter

NOTE: Do *not* throw the marbles into the flour—just drop them.

Some feedback that I received from students was that you could measure the amount of ejecta that flies out of the surface in the form of ray lengths, you could also measure the length across of the crater that was created, and measure the diameter. Students also observed that the marble was embedded in the surface fully, partially, or not at any depth below the surface.

Next, we had a class discussion about performing a controlled experiment on the simulated lunar surface to see how meteoroid drop height or meteoroid mass affects the crater diameter. Students were placed in groups of four because there is a lot of responsibility that goes into this activity. Someone has to prepare the lunar surface between trials. Someone has to record the measurements of the crater diameters. Someone has to drop the meteoroid, marble, very steady to reach inside the bowl. And finally, someone has to keep track and retrieve the meteoroid from the bowl. There is a lot of room for error and not controlling all the necessary variables could affect the results. It was important to spend time reviewing the concept of a controlled experiment. Here is an example of a student's work for reviewing the steps of the controlled experiment.

Crater Investigation Planning

1. What variable will you investigate?

   drop height/ speed

2. What procedure will you use?

   Gather materials, prepare the surface, put basin on floor

3. What will you measure?

   crater diameter in centimeters

4. How will you record your data? How many trials? (Set up a table.)

   i would record myt information on a data table. I will complete three trials for each increment and take an averag

5. How will you display your results? (Design a graph on the next page in your notebook.)

   I will display my results on a 2-coordinate graph

After assigning groups a specific variable to investigate, students had to make a prediction about what they thought would happen in the experiment. Here are the predictions from two different variable groups:

Hypothesis: Pre-Lab Question: (answer in complete sentences)

1. **If** I increase the _______height__________ **then**... the crater size will be larger.

Hypothesis: Pre-Lab Question: (answer in complete sentences)

1. **If** I increase the mass of the meteoroid **then** the diameter of the crater will increase.

Students collected evidence of modeling impact craters by measuring crater diameters created by dropping meteoroids, marbles, at different heights or by dropping different size meteoroids from the same height. Groups of four students were assigned a different independent variable, meteoroid drop height or meteoroid mass, to determine the size of the crater diameter created during impact. Students used electronic balances to measure the mass of the different sized meteoroids and to confirm that the same-size marbles were of equal mass. Crater diameter measurements were measured with a centimeter ruler and recorded in a chart. Three trials were recorded for each increment and an average crater diameter was determined. Here are some pictures of students collecting data for the modeling impact crater activity.

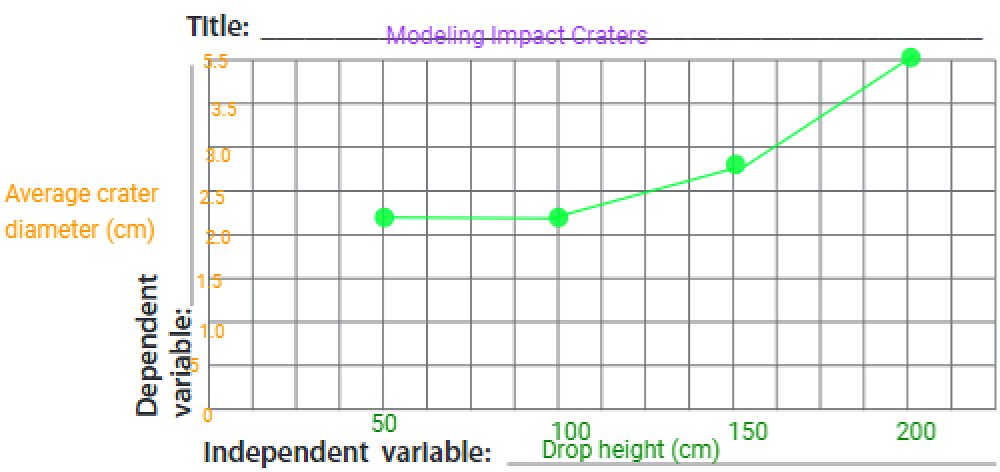

Modeling

Here is an example of a chart that a student recorded their data for drop height, speed, of the meteoroid.

Model Impact Craters—Speed

1. In your group, prepare the lunar surface.
2. Set up your station to measure the heights from which you will drop the four objects. (Remember, higher drop heights = faster impact speed.) Speed is your **independent variable** because you are changing it.
3. Record your **dependent variable** in the table below: diameter, depth, or ray length.
4. Drop objects, record data, calculate averages, and produce a graph of the results.

Drop height (cm)	Dependent variable: Crater Diameter			
	Trial 1	Trial 2	Trial 3	Average
50	2	2.5	2.5	2.3
100	2.3	1.5	3	2.3
150	4	1.5	3	2.8
200	5	5	6.5	5.5



This particular group that investigated the drop height, speed, of the meteoroid performed three trials for a height of 50 cm, 100 cm, 150 cm, and 200 cm off the lunar surface to measure the crater diameter. An average of the three trials was taken for each drop height and recorded in the chart. To make sure students were on track and understood what they were measuring in the experiment the teacher gave a quick formative assessment on identifying the variables and control. Here is an example of student work:

Identify the Variable

Directions: In a different color text answer the following questions about your crater experiment.

1. Independent variable:
   (What did you change in intervals for your crater experiment?) The independent variable in the experiment was the drop height. It changed from 50cm, 100cm and 150cm.

2. Control:
   (What stayed the same during your crater experiment? Name at least 2 factors that stayed the same.) The control variable in the experiment was the mass, the surface, and the ball. They all stayed the same in each trial.

3. Dependent variable:
   (What did you measure in your crater experiment?) The dependent variable of the experiment was the diameter of the crater.

Here is an example of a chart that a student recorded their data for the mass of the meteoroid.

Model Impact Craters—Mass

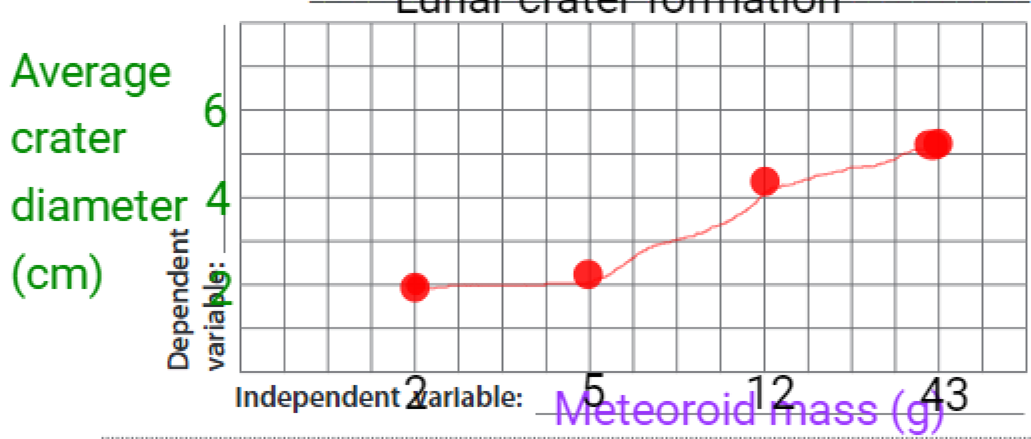
1. In your group, prepare the lunar surface.
2. Determine the mass of your four objects. Mass is your **independent variable** because you are changing it.
3. Set up your station to measure the height from which you will drop the four objects. (150 cm is a good height.)
4. Record your **dependent variable** in the table below: diameter, depth, or ray length.
5. Drop objects, record data, calculate averages, and produce a graph of the results.

independent variable

Control: 100cm drop height

Object mass (g)	Dependent variable: Crater diameter cm			
	Trial 1	Trial 2	Trial 3	Average
2	2	1.5	2.5	2
5	2.2	2	2.8	2.3
12	5	4	4.5	4.5
43	6	6	3.5	5.2

Title: Lunar crater formation



This particular group investigated the mass of the meteoroid and performed three trials at a mass of 2 grams, 5 grams, 12 grams, and 43 grams. They controlled the 100 cm height at which they dropped the meteoroid off the lunar surface to measure the crater diameter. An average of the three trials was taken for each meteoroid mass and recorded in the chart. To make sure students were on track and understood what they were measuring in the experiment the teacher gave a quick formative assessment on identifying the variables and control. Here is an example of student work:

Identify the Variable

Directions: In a different color text answer the following questions about your crater experiment.

1. Independent variable:
   (What did you change in intervals for your crater experiment?) Mass

2. Control:
   (What stayed the same during your crater experiment? Name at least 2 factors that stayed the same.) We controlled the height at 100 cm.

3. Dependent variable:
   (What did you measure in your crater experiment?)
   Crater diameter

After reviewing both sets of formative assessment it was clear that students in both groups understood what variables they were measuring and controlling.

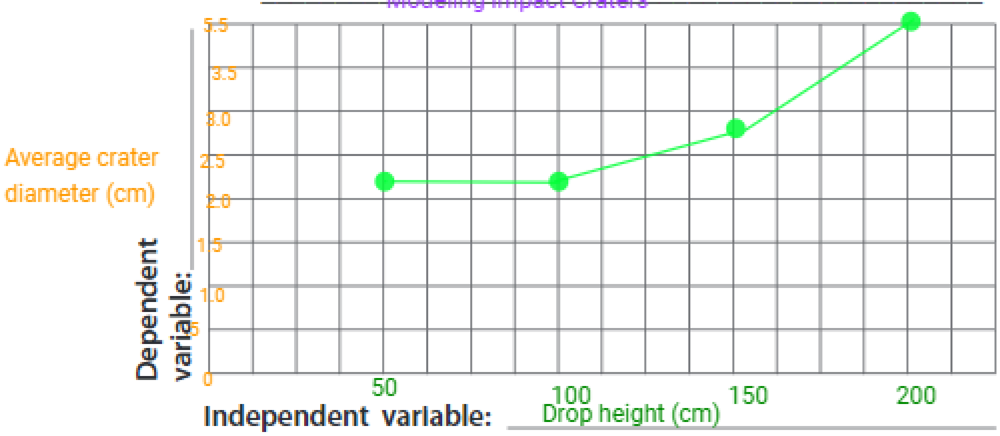
Once all students modeled the experiment and obtained their data it was time to create a two-coordinate graph to analyze their results. As a class, we reviewed the origin, x-axis, and y-axis of a two-coordinate graph. We had a class discussion on where the independent variable and dependent variable are placed on the graph. We also went over increments and how to spread out the graph on both axes. Points on the graph were connected to see if there was a relationship between drop height, speed, and average crater diameter. Here are the graphs that pertain to the group's data from above:

Model Impact Craters—Speed

1. In your group, prepare the lunar surface.
2. Set up your station to measure the heights from which you will drop the four objects. (Remember, higher drop heights = faster impact speed.) Speed is your **independent variable** because you are changing it.
3. Record your **dependent variable** in the table below: diameter, depth, or ray length.
4. Drop objects, record data, calculate averages, and produce a graph of the results.

Drop height (cm)	Dependent variable: Crater Diameter			
	Trial 1	Trial 2	Trial 3	Average
50	2	2.5	2.5	2.3
100	2.3	1.5	3	2.3
150	4	1.5	3	2.8
200	5	5	6.5	5.5

Title: Modeling Impact Craters



Model Impact Craters—Mass

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independent variable

Control: 100cm drop height

Object mass (g)	Dependent variable: Crater diameter cm			
	Trial 1	Trial 2	Trial 3	Average
2	2	1.5	2.5	2
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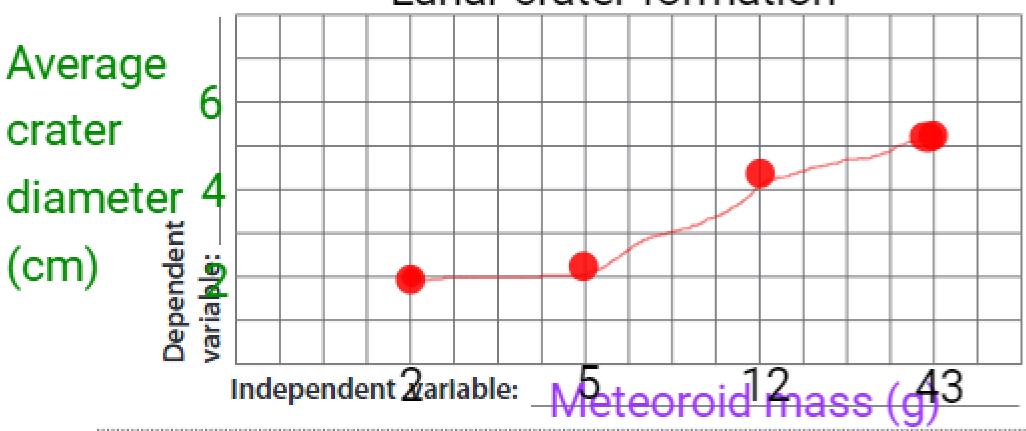
Title: Lunar crater formation



I walked around the room helping out individual group members that would go back and review creating the two-coordinate graph with the remainder of students. I checked for understanding frequently by looking over graphs and conferencing with students individually.

After creating the two-coordinate graph students could answer the following results and analysis questions. Here is an example of their work from the meteoroid height:

Results: **Answer the following questions below. See attached graph**

Independent variable: (Which variable changed? Can be found on the X-axis)-

The height at which we dropped the marble.

Dependent variable: (Which variable you measured. Can be found on the Y-axis)-

The crater size.

Title: (X-axis vs. Y-axis)

Meteoroid speed vs Average crater diameter

Analysis: **Answer only questions that pertain to your experiment in complete sentences.**

1. Some groups investigated the **variable of meteoroid speed**. How did you test that variable?

We tested the meteoroid speed by dropping the marble from four different heights.

2. If you increase the drop height of the impacting object (marble), what happens to the crater size?

If you increase the drop height, then the crater size will get larger.

Here is an example of their work from the meteoroid mass:

Results: **Answer the following questions below. See attached graph**

Independent variable: (Which variable changed? Can be found on the X-axis)-

Mass

Dependent variable: (Which variable you measured. Can be found on the Y-axis)-

Crater diameter

Title: (X-axis vs. Y-axis)

Lunar crater formation

3. Some groups investigated the **variable of meteoroid size**. How did you test that variable?

We measured four different size rocks and did three trials for each rock.

4. If you increase the mass of the impacting object (rock), what happens to the crater size?

The crater size increased.

Reviewing these answers showed that students understood how the graph was created and the trend of the graphs as they pertain to their variables.

Collection of the data for both meteoroid height, speed, and meteoroid mass for measuring average crater diameter most definitely enhanced the understanding of a controlled experiment. By controlling the meteoroid mass and changing the height from which the meteoroid was dropped showed an increase in average crater diameter. By controlling the height from which the meteoroid was dropped and varying the mass also showed an increase in average crater diameter. Mass and speed affect the size of the lunar crater created. The data obtained from these two group's experiments shows how these variables relate to each other and that students controlled the proper variables to have these results.

To sum up this experiment, students were assessed by completing a Model Impact Craters Lab write-up. Here is the template Model Impact Craters Lab Write-up and a sample of student work from the meteoroid height, speed, assessment.
Copy of Madelyn White - Model Impact Craters Lab Write-up

Here is a rubric for assessing the crater lab write-up.
Rubric: Model Impact Craters Lab Write-up

Collaboration:

- All team members contributed equally with strong communication and commitment. Our group met multiple times for collaboration virtually as well as assigning tasks to work on using shared documents.

References

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