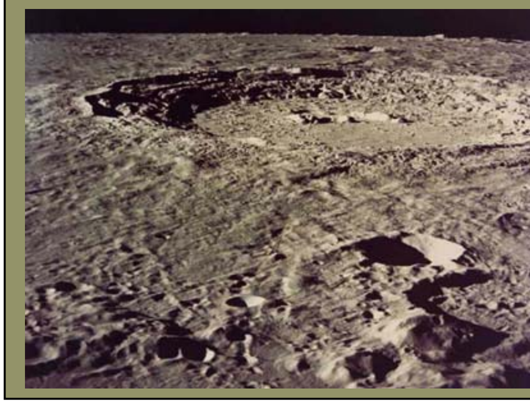
Designing Craters:
Creating a Deep Impact

What Factors Influence Crater Size?

TEACHER GUIDE

BACKGROUND INFORMATION



In this activity, your students will be exploring their ideas about what factors influence cratering. Your main task is to guide them as they design a formal test of a particular factor and look for patterns in their results. Your focus should be on the explanations of the results that your students are getting rather than on "right" answers that you expect them to get.

Appendix B: "Current Scientific Thinking About Cratering" will give you a summary of what we understand about cratering today and the differences between high energy cratering events, like those that take place on a Solar System scale, and low energy cratering events like those your students are creating in the classroom.

This information can be useful to you as you are interpreting your students' results for yourself and asking students questions, but should not be seen as the collection of answers where you intend your students to arrive after completing their experiment. Remember that the main goal here is for students to work on experimental design skills and explore their own thinking about cratering.

NATIONAL SCIENCE EDUCATION STANDARDS ADDRESSED

(View a full text of the National Science Education Standards.)

Grades 5-8

Science as Inquiry

Abilities necessary to do scientific inquiry

- Design and conduct a scientific investigation
- Communicate scientific procedures and explanations.

Physical Science

Properties and changes of properties in matter

- A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample.

Motion and Forces

- The motion of an object can be described by its position, direction of motion, and speed. That motion can be measured and represented on a graph.

Grades 9-12

Science as Inquiry

Abilities necessary to do scientific inquiry

- Design and conduct scientific investigations.
- Communicate and defend a scientific argument.

MATERIALS

Visit http://csss.enc.org/safety.htm to print "Science and Safety, Making the Connection."

Since your students will be designing their own experiments in this activity, they should be encouraged not to limit themselves to materials provided and to bring in other everyday, common household materials that might be useful as needed. However, having the basic supplies used in the last activity and listed in the "Module Overview" section can save time and serve as inspiration.

For each student:

- Guidelines for Good Experiments
- Journal Assignment #3 – found in Appendix D
- Poster Presentation Guidelines
- Graphing Your Data
- Journal Assignment #4 – found in Appendix D
- Class Results: Factors that Influence Cratering – Duplicate enough of this summary sheet so that each student has the same number of boxes as there are class presentations.
- Journal Assignment #5 – found in Appendix D
- Graph paper or graphing software

For the teacher:

- Teacher Guide Supplement, "Poster Presentation of Experiment and Results"
- Digital video camera (optional)
- Image analysis software (optional)

PROCEDURE

Day 1

1. Distribute the "Guidelines for Good Experiments" handout and discuss with your students. Explain that their group will be meeting with another group later in the period to compare ideas and check those ideas against the guidelines.

2. Allow students to work in groups of 3-4 participants. Ask each group to choose (or you may assign) one specific cratering factor, from the list generated by the class in the "Exploring Cratering" activity, that they will investigate further in a formal experiment. The following factors may be considered (* Recommended for each class):

   * Mass
   * Velocity
   * Density
   • Diameter
   • Acceleration
   • Impactor elasticity
   • Connectivity of surface material

3. Give the students a limited time frame for experimental design that will allow you 20 minutes at the end of class for peer review groups to meet. Most groups will be able to finish within 20 minutes or less.

4. As groups finish, pair the groups together and give each group a "Peer Review" handout. Instruct students to turn in Peer Review sheets when finished.

5. Assign "Journal Assignment #3" in Appendix D for homework.

Technology Tip

You may want to encourage the use of technology as students conduct their experiments. Digital photography or video could be used to record impacts. Students could then use image analysis software to interpret their results. Image J is a downloadable tool that can be used for this.

http://rsb.info.nih.gov/ij/

Day 2

6. Let the students know that each person in the group will need to have a copy of the group's data (e.g., data chart) for tonight's homework.

7. Students conduct experiments as planned and reviewed during Day 1.

8. Assign "Graphing Your Data" as homework.

Teacher Tip

It may be necessary to spend some time explaining how to graph experiment results. Remind students of the format for plotting both independent and dependent variables:

1) The independent variable or factor being tested (e.g., mass of impactor) should be plotted on the horizontal or x-axis.

2) The dependent variable or the effect (e.g., crater size) is plotted on the vertical or y-axis.

Day 3

9. Ask the students to share what they see in their graphs so far. Talk about reasons why the students might want to conduct more trials today, such as getting more data points for the chart, reducing error by repeating the experiment through multiple trials and averaging the results, exploring surprises in the data, etc.

10. Students return to their experiments.

11. If groups finish early, distribute "Poster Presentation Guidelines." Tell students to read the background information and follow the directions to begin creating a poster for the “Deep Impact Cratering Symposium.”

12. Assign "Journal Assignment #4" in Appendix D.

Day 4

13. Meet with class to discuss reporting experiment results. Go over "Poster Presentation Guidelines.”
Note: Express to students the importance of including clear experiment procedures on the poster as other groups will refer to the poster when replicating the experiment. You also need to instruct the students that their data charts and graphs need to be turned in to you in a form that will be easy to photocopy and distribute for the next activity. Suggest they use the same format as "Graphing Your Data" for their data charts, but be sure that they add any new data collected on the second day of experiments.

14. Students work on presentation of data and results.

Day 5

15. Groups present their posters to the class.

16. Students fill out the summary sheet, "Class Results: Factors that Influence Cratering," during presentations.

17. Have a summary discussion with your students about what factors seemed to have an effect on crater depth, diameter, and shape.

18. Assign “Journal Assignment #5” found in Appendix D.

Student Anticipations

In this activity, students design experiments to specifically test the effect of one factor on crater depth, diameter, and shape. If possible, every student group should work on a different factor. The factors marked with * are the ones to be sure are included. You should also include one or two more from the general "What is the surface like?" category. The chart in the previous activity also includes some ways in which these factors might be tested, although these are by no means the only ways.

Student Anticipations - Continued

Experiment Design

Your key role will be to encourage your students to devise ways of quantifying their results and of keeping all of the variables the same except the one being tested. Most groups will realize the need to quantify the crater diameter and depth. Some discussion of how they are choosing to measure those values might prove interesting. Your students will probably measure the crater from rim to rim for diameter and from rim to base for depth. Scientists actually measure in reference to the original surface of the planet instead. It is **not** necessary to have your students change how they are making their measurements, but having them articulate what they mean by "diameter" and "depth" could be useful.

More groups may need to be encouraged to quantify the variable they chose to change in their experiments. For example, in the pilot test, a group varied the mass of the impactor, recorded quantitative data for the diameter and depth of the crater, but recorded only a qualitative label for each impactor (softball, golf ball, wiffle ball, etc.). This seemed acceptable to the group at the time, but when asked to make predictions about masses they had not specifically measured, they found that their data did not allow them to easily interpolate for other masses. This group went back and measured the mass of their objects when it was time to make predictions.

Varying the speed of impact can create some quantification difficulties as well. The easiest way to vary the speed of impact is to drop the object from different heights. However, making the connection between different heights and different impact velocities due to gravitational acceleration is difficult for students to make in detail. Instinctively, many of the students in the pilot recognized that dropping from different heights would produce different impact velocity. They measured and recorded the height. As they got further from the actual experiment, they moved away from their understanding that it was the impact velocity they were varying and began to think of it solely as the distance from the impacting surface. Several students were asked initially, "Why did you choose to vary the height?" To this they responded, "To change the speed of impact - a higher drop gives you a greater velocity." Later these same students asked, "Well, how far away are you sending the impactor from?" This question shows they had focused on the distance as the important factor rather than the velocity of impact. Continually asking your students to explain the connection between height and velocity throughout the process may help alleviate some of these difficulties.

Experiments that involve the nature of the target surface will be both harder to quantify and harder to keep to just one variable. However, these experiments are also the ones that allow for more creative thinking by your students. Several groups who tested different materials during the pilot test simply recorded the diameter and depth of the crater and a description of the target material (rocks, sand, rock and sand mix, etc). These groups ran into the same difficulties in the next activity as the group that recorded only a descriptor for the impactor. One of the groups that used different target materials went back and calculated the density of the surface material by determining the mass of a specific volume. Another estimated the average particle size. Yet another group varied the surface by adding different quantities of water to sand. They kept track of the volume of water added.

Another difficulty that arose in quantification involved measuring those factors that were kept constant as a reference point. For example, students who vary the mass of the impactor very carefully dropped the impactors from the same height every time, but did not record that height. That was not crucial to their own data the first day, but both repeating the experiment the next day and comparing results to the results of others in the class were more difficult without that information.

While you may need to push your students to work on methods to quantify their experiments, you do want the experiments to be their own design as much as possible. Moving between the groups while they are working on the design process and listening to their ideas can help you strike this balance.

Student Anticipations - Continued

Graphing your data
The students are asked to graph their data on the first night of testing as homework. The format of the graph is left up to the students. Having students graph as homework is done in order to give them (and you!) a quick check as to whether or not they have done enough trials in their experiment to truly see a pattern yet and to begin thinking about anomalous data. It forces the students to think about what information they are recording and how to display that information. Interesting things seen in the graph in the first night can be further explored in the second day of experimentation. It also gives you as a teacher a look at what further direction they may need about displaying and recording their data. How much support and additional direction your students need in order to graph their data can vary widely depending upon how much graphing experience they have. Some students in the pilot testing groups struggled with labeling the numbers of the graph with even spacing. Others created graphs that showed depth and diameter numbers for craters, but simply labeled the varying factor. Still other groups easily created a variety of graphs and charts using spreadsheet software.

End results
The basic trends you should expect to see in student data are:

1) Greater masses make deeper craters. Crater diameter is a little more questionable - at these low speeds, the diameter of the crater is more a reflection of the diameter of the object. **NOTE:** *This is only true at low speeds, not in Solar System scale cratering. This will be discussed in a subsequent activity, "Cratering in the Classroom, the Lab, and the Solar System."*
2) Greater velocity will give you greater depth and diameter. Once again, the diameter is somewhat dependant on what you drop. You should get increasing diameter if you used something like a ball, because an increasingly large cross-section will sink into the surface.
3) The smaller the angle of impact, the shallower the crater. However, the diameter will tend to increase in one direction, making an elliptical crater. **NOTE:** *This is again an effect of low speeds. This will be discussed later in "Cratering in the Classroom, the Lab, and the Solar System."*
4) The more a surface is compacted, the smaller and shallower the crater will be.

TEACHER RESOURCES

Web Sites
http://deepimpact.jpl.nasa.gov/high_power/pdf/STCommQuesListen.pdf
This text provides strategies that students can use to effectively prepare for communicating, questioning, and listening.

http://genesismission.jpl.nasa.gov/educate/scimodule/Launch_Propulsion.html
Launch and Propulsion, a science module developed by NASA's Genesis mission, provides informational texts and engaging hands-on activities to develop students' understanding of manipulating and controlling variables in experiments.

http://www.genesismission.org/educate/scimodule/PlanetaryDiversity/plandiv_pdf/OuchThatHurtsST.pdf
Impact Cratering student text from the Genesis *Cosmic Chemistry: Planetary Diversity* module.