Designing Craters: Creating a Deep Impact

Cratering in the Classroom, the Lab, and the Solar System

TEACHER GUIDE

BACKGROUND INFORMATION

Using analogy and modeling are common and effective instructional approaches to helping students understand complex or abstract ideas. However, research shows that students often transfer all attributes of the model to the phenomenon itself, not just those attributes that are appropriate. This can be reduced if we help students to think about models and analogies as representations or descriptions of the phenomenon, rather than the phenomenon itself.

This lesson steps back from the modeling of cratering in the experiments just conducted in the classroom and encourages students to recognize that there are differences between what they did in the classroom and cratering events at Solar System scales. The lesson also shows that while scientists often have better equipment and more knowledge on which to base their lab experiments, those experiments have limitations as well. Finally, the students think about why we do such modeling in science if it is not an *exact* representation of what is going on.

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

- Develop descriptions, explanations, predictions, and models using evidence.

Physical Science

Transfer of energy

- Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways. Energy is transferred in many ways.

Grades 9-12

Science as Inquiry

Abilities necessary to do scientific inquiry

- Formulate and revise scientific explanations and models using logic and evidence.

MATERIALS

- "Cratering in the Solar System: Images" from Appendix A (Print the number of copies needed for student groups)
- "Cratering in the Solar System" Student Handout
- "Deep Impact Cratering Research: Scientific Modeling in Action" Student Handout from Appendix C
- "Thinking about Scientific Modeling" Student Handout

PROCEDURE

1. Have the students look back at their notes about crater shape from "Exploring Cratering" and "Comet Research" handouts. Have them share anything they noticed about crater shape. What factors seem to influence crater shape?

2. Now, using an overhead or projected computer screen, display an image of craters on Mercury, the Moon, or any one of the images included with this module in Appendix A that shows a large number of very circular craters. Point out that craters in the Solar System are mostly circular.

3. Have students compare the craters they created in the classroom with the displayed crater images from Appendix A and to identify any differences. Ask students for initial ideas about what might explain the differences.

4. Explain to the students that they have noticed a difference between craters on a Solar System scale and craters they created in the classroom. Tell them that today they will be looking for more possible differences between what goes on in the larger scale Solar System and what happened in their experiments.

5. Divide students into groups. Provide each group with "Cratering in the Solar System: Images" from Appendix A of this module and each student with the handout "Cratering in the Solar System." In this activity students will compare their cratering experiments with the images from Appendix A, the diagrams on the student activity sheet, as well as with the "Pumice Impact Test Animation" available at (http://deepimpact.jpl.nasa.gov/gallery/mpeg4.html This exercise helps students understand how classroom models are inadequate to fully understand how cratering happens in the Solar System.

Caption Comments

On the next page there are captions and comments for the teacher about the diagrams on the handout "Cratering in the Solar System." Copy the next page for students who would benefit from captions.

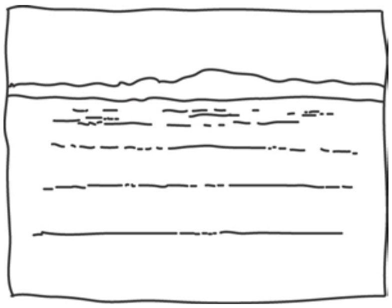
The following statements correspond with the illustrations/captions from the handout "Cratering in the Solar System" and compare what students can see in the handout with what they may have observed during their group experiments.

1. Students will see this.
2. Students will not see this.
3. Students will still not see this image, because the residual trail made by a **hypervelocity** impactor is shown and their projectile is not moving at hypervelocity.

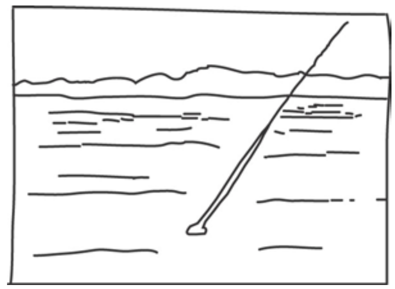
4 – 6. The students should be able to see an **ejecta curtain**, but probably won't be able to break it down into the stages illustrated on the handout.

7. Students may or may not see a circular crater. If the impact were **hypervelocity**, it would be circular.

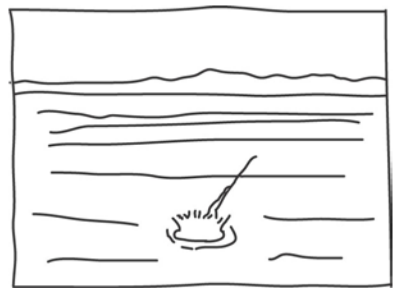
Note: **Definition of hypervelocity** – *a velocity many times the speed of sound.*
Definition of ejecta curtain – *A thin, funnel-shaped sheet of material/debris that has projected upward from a point of impact.*



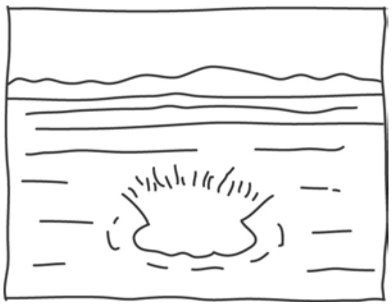
1. Pre-impact – everything is calm and static.



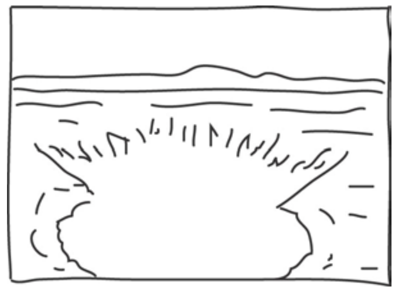
2. Impact of a hypervelocity projectile – the high speed projectile, leaves a vacuum wake or a void behind it.



3. Early excavation – the trail behind the projectile fills in, shock waves travel into the surface and rebound. Crater excavation begins.

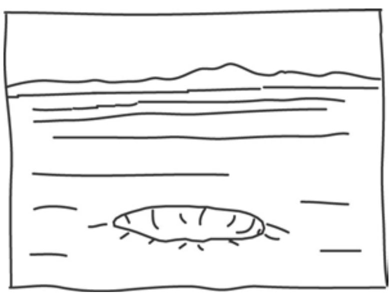


4. Beginning of an ejecta curtain.



5. The ejecta curtain expands.

6. And expands.



7. After the material falls back to the surface under the influence of gravity, a circular crater has formed.

Drawings by Nick Walker

6. Students should work on handouts in groups and be ready to return to classroom discussion in roughly 20 minutes.

7. Bring students back together. Have students share ideas about the general differences they found. Have the students discuss their ideas about why there are differences between cratering in the classroom and cratering on a Solar System scale. *See "Student Anticipation" section for suggestions on points to include in this discussion*.

8. Ask students to share what they think is the same about their cratering experiments and cratering on the Solar System scale. What did their experiments tell them that still applies?

Student Anticipations

The important thing for students to understand in this lesson is that their experiments were modeling small and slow impacts, and that this can give them a feel for the importance of particular factors in cratering - namely the effects of mass and velocity on crater size. Cratering happens in three stages (see Appendix B). Small scale modeling does a good job of modeling excavation and modification of the crater. There are also important differences between high and low energy cratering events, especially during the initial compression stages when the energy transfer to the target may involve energy losses due to heat or transformation. Differences between classroom experiments and Solar System examples of cratering include changes in crater shape as the impact angle changes and the importance of the diameter of the impactor in determining the size of the crater. Another difference between classroom experiments and cratering in the Solar System is the presence of an atmosphere in the classroom. *See "Appendix B: Current Scientific Thinking About Cratering" for more information.*

Most student interviews conducted in the initial writing of this material indicated that students believed an impactor has some quantity—momentum, force, energy—that is somehow transferred or absorbed by the target body during impact. Encourage them to share their ideas about this in your discussion. This is your chance to talk with your students about cratering as an exchange of energy.

9. Assign "Thinking about Scientific Modeling." Students should read the article "Deep Impact Cratering Research: Scientific Modeling in Action" found in Appendix C and then answer the questions. When you are reading students' written response paragraphs in "Thinking about Scientific Modeling," be looking for:
   - a recognition that there is a difference between experiments conducted in the classroom, in the lab, and actual phenomena in space;
   - a recognition that the differences are largely ones resulting from scale;
   - a recognition that smaller scale experiments are necessary to help you begin to understand what is going on in a larger scale world in which you can not control conditions as well.

IMPORTANT NOTE: How far you go in terminology (from sticking with the students' chosen and defined words at one end, all the way up to the formal kinetic energy equation on the other end) is up to you and your goals for the unit. It is important, however, if you put the equation for kinetic energy on the board, that you emphasize that this equation alone cannot explain crater size. Little undermines an inquiry experience for a student more than the perception (and in this case it would be a false one!) that the entire process they just engaged in was unnecessary because they could have been given the "right" formula at the start! Ideally, you would like your students to begin to understand that the energy of an impact's motion is transferred to the target body in the form of moving some of the target material, heating the surface, and changing the rocks themselves.

TEACHER RESOURCES

Web Sites

http://deepimpact.jpl.nasa.gov/gallery/animation.html
Click on "High-speed Pumice Impact Test" animation

http://modeling.asu.edu/modeling-HS.html
Modeling Instruction in High School Physics

http://www.mcrel.org/epo/resources/sci_modeling.asp
Scientific Modeling Text