IMPACT!

Photo courtesy of NASA; Graphic Work by Joe Taylor

IMPROVING STUDENT LEARNING THROUGH AN INQUIRY CRATER INVESTIGATION

Blake J. Williams and Derek J. Hollingshead

ABSTRACT: The fight against student compartmentalization of science concepts is an ongoing battle for all science educators. When an inquiry-based investigation of natural phenomena, like that presented here, is integrated into curricula new links between science concepts are created. These new connections promote a deep and robust understanding of science content. This cratering activity has students applying prior knowledge of gravitational forces, momentum, conservation of energy, and density while exploring the intricate relationships between these fundamental concepts. This activity also provides abundant opportunities for explicit connections to the nature of science. Impact cratering is a phenomena which can be easily modeled within a classroom, and deeply understanding it requires application of several fundamental science concepts. *This article addresses National Science Education Standards A, B, D, and G and Iowa Teaching Standards 1, 2, 3, 4, and 5.*

This activity is designed for use within a high school physics course but can easily be modified for use in astronomy, earth science, or physical science courses. Prior to implementing this activity, students should have demonstrated a basic understanding of gravitational forces, momentum, conservation of energy, and density. The goal for the investigation of impact cratering is to understand an interesting and easily observed natural phenomenon, reinforce student knowledge of fundamental concepts, and promote more cross-concept connections in a manner that more accurately reflects the nature of science.

Posing the Problem & Understanding Student Thoughts

If your school has a decent telescope, prior to beginning this activity, have students observe the moon through the telescope and note the many craters that may be observed. Having students do this is not essential for the activity, but does provide a more authentic context for what is to come. You might even note the scandal that resulted when Galileo first pointed a telescope to the moon and noted the rugged surface of the moon did not fit with prevailing thought that the Moon, being a heavenly body, would be perfectly smooth.

When back in the classroom, begin the activity by showing students a more highly magnified view of moon craters (See for example Figure 1) to establish the phenomena to be investigated in this activity. When students first observe the craters we ask

- “What differences do you notice between the craters?”

Students often make reference to the size, depth and shape of the craters, but teachers should use wait-time and encouraging non-verbal behaviors to draw out additional ideas. Once students' ideas have been exhausted, we then ask

- “What factors might account for those differences?”

Students already know craters are formed when an object collides with another object. However, students do not have an accurate understanding of how different impact craters are formed. Students commonly suggest the distance an object falls, size, weight, mass, angle of impact, and speed affect the size and shape of impact craters. We record all student suggestions on the whiteboard for future reference.

Investigation

Once students have finished brainstorming their initial ideas regarding what factors affect the size and shape of impact craters, we ask guiding questions to first have students develop a model for testing their ideas and then making explicit the connection between in-class modeling and the nature of science. Some example questions are

- "How could we test your ideas?"
- "What would be the benefit of using models to test your ideas?"
- "What supplies would you need to model impact cratering?"
- "How is this similar to or different from what scientists do?"
- "Why might scientists use models?"

Typically students will suggest they model impact craters by dropping items into a material such as sand. We supply students with a container and sand, flour, or dirt to drop items into. Common household items are great for modeling impact craters. The specific items dropped do not matter, but we provided items of various shape, size, mass, and density as shown in Figure 2. Drop cloths placed under and around the containers are recommended for cleanliness.

Students are first directed to make qualitative observations and determine which factors affect the size and shape of impact craters. Little direction is required during the initial phase of the investigation because we have previously extensively taught, modeled and enforced proper lab and safety habits. That said, before we release students to begin their work, we do ask students to tell us what safety precautions they must take when conducting their tests. As students work, our role is to walk amongst the groups carefully observing what they do and listening to their dialogue. We ask questions which encourage students to think critically about the way they set-up the experiment. Example questions include

FIGURE 1
Sample image of moon craters.

http://www.nasaimages.org/luna/servlet/detail/NVA2~4~4~4929~105455:Lunar-Farside-from-Apollo-11

- "Why did you choose this particular set-up?"
- "How might you improve your set-up?"
- "What are the pros and cons of such a set-up?"
- “What have you noticed thus far? Why might that be the case?”

FIGURE 2
Objects that students typically use to model craters

- Golf Balls
- Marbles
- Ping-Pong Balls
- Rocks
- Styrofoam Balls

Students often use washbins or shallow cakepans to hold the soil material. Some students do not create deep enough layers of soil material or do not account for accurately measuring drop heights. To address these issues, we ask the students how they might accurately measure the drop height or what problems might arise if their objects bottom out of the soil material.

After groups have completed their initial investigations they are brought back into a large group for a quick discussion. We ask students to share their initial procedures and observations as well as any problems or issues with their set-ups. After addressing any concerns the students have or any issues we noticed we prepare students for collecting quantitative data by asking questions such as

- "How can we quantify our investigation of the craters?"
- "What characteristics of craters can we measure?"

Students often want to measure diameter or depth of craters. These dimensions are fine, but we also push students to consider how they might measure the distance objects are ejected during crater formation.

After discussing how to quantify crater data, the students are sent back to the investigations to gather quantitative data and determine which factors have the greatest affect on the size and shape of the craters. Since all students will not work at the same rate we must continue to carefully monitor the entire class. If some students appear to complete their testing early they are asked to go one step further and use their data to rate the factors they tested in order from most effect to least effect on impact craters. Students might also be pushed further by investigating a different independent variable such as angle of impact.

Performing experiments in the classroom necessarily limits the possible ranges for tests of each factor. Some tests may introduce unique safety concerns which must be considered before they can be implemented. Students will often want to drop objects with a much greater mass than typically available or drop an object from a window or balcony. Other possible tests can include the use of a sling-shot to propel an object toward the ground. Performing these tests as demonstrations addresses possible safety concerns by removing students from any dangerous situations. These demonstrations are beyond the scope of this activity, but are extremely useful methods for introducing or expanding upon the knowledge base established in this activity.

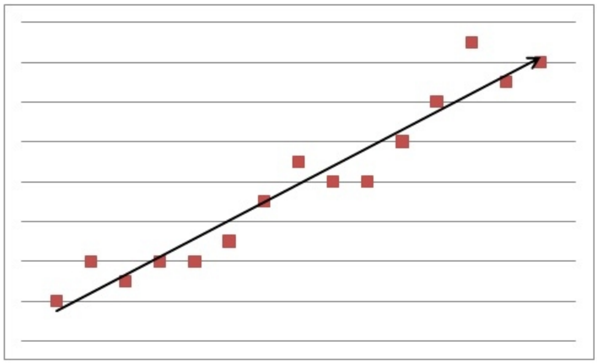
Data Analysis

When students have completed their data collection they must analyze the data. We ask questions which reinforce the nature of science concept that data requires interpretation while also guiding students toward data organization and interpretation. The following questions are used to help guide students:

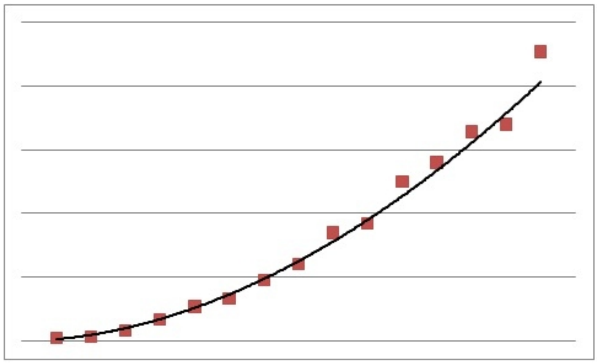
- "How can we organize our data to help us make sense of the results?"
- "How might we visualize our data to more easily interpret the results?"
- "Why might you get rid of some data?"
- "How could we gain confidence in our interpretations?"
- "Why might some groups have differing interpretations?"
- "How is this similar or different from what scientists do?"

After this discussion, students create graphical representations of their data. When students suggest graphing we encourage them to carefully consider the pros and cons of using specific types of graphs. Usually students decide to create line graphs representing how the size of the impact crater changes with relation to each variable tested. Example qualitative graphs can be found in Figure 3. The specific relationship students come to is not of great importance and will be different for different variables or may depend on quality of student data. We are most concerned with how students explain the data and work to help students connect their explanations to other content.

FIGURE 3
Examples of qualitative graphs resulting from investigations.



Linear relationship between two variables.



Parabolic relationship between two variables.

Connecting Activity and Content

Students will often come to different conclusions regarding which factor plays the greatest role in the creation of craters. Since this is an exploratory activity we have students discuss this issue and decide what factor is most important. Students are expected to provide a sound rationale for their conclusions along with evidence to support their claims. Our role during this discussion is to act as a facilitator while students share their ideas. That is, students work with their group to create explanations while we check in with each group to pose questions to help students clarify their thinking. During these group discussions, students are provided hand-held whiteboards to use as visual aids when presenting their conclusions. When students present their ideas, we expect other groups to question the students and also ask questions ourselves to help students connect their ideas to their observations and evience.

After students have shared their conclusions we bring in the nature of science idea that science does not follow one specific method. We do this through questions such as:

- "What are the similarities and differences between each group's procedures?"
- "What accounts for these differences?"
- "How does this illustrate the idea that there is no single scientific method?"

The next understanding we focus on is the connection between gravitational forces, momentum, conservation of energy, and density. We accomplish this by making an explicit connection between the many science concepts involved. We ask specific questions targeting those connections such as the following:

- "How does gravity affect impact craters?"
- "How does an object's momentum affect impact craters?"
- "How does an object's density affect impact craters?"
- "How does the density of the soil material affect the craters?"
- "Where does a falling object get its energy?"

Students do not typically struggle with these questions, but asking these questions sets students up for the next questions that ask students to consider the interconnections of these concepts.

- "How might changing an object's density affect its momentum?"
- "How would that affect the resulting impact crater?"
- "What is the relationship between an object's momentum, its kinetic energy, and its impact crater?"

Students sometimes struggle with these questions. If students struggle we hold up impact objects of different densities and ask students how the momentum of these objects might be different even if they are traveling at the same speed. With concrete objects, students are more easily able to recognize that decrease in density will lower an object's momentum and reduce the impact effect. If students continue to struggle with these questions, we ask them to discuss the questions in small groups. At this point in the year students should have the requisite background knowledge, but may need to bounce the ideas around with peers to more easily explore the interconnections of the ideas.

These questions promote student critical thought and result in connections between concepts that would otherwise have not been made. With the conclusion of this activity students will have begun to think critically about the connections between gravitational forces, momentum, conservation of energy, and density. We use this activity to provide a concrete experience to scaffold back to in future lessons when making further connections between related science concepts.

After their investigations, we ask students to again look at the moon through a telescope or bring in pictures of craters. We choose two or three craters and ask students to apply their new understandings to explain the differences they observe in the craters.

Conclusions & Implications

Gravitational forces, momentum, conservation of energy, and density are traditionally taught as separate concepts, each with their own chapter or unit. If students are expected to develop a deep and robust understanding of science content then the connections between these fundamental concepts must be made explicit. These connections can be made by having students investigate the natural phenomena of impact cratering. Our crucial role during the activity is to scaffold students from the concrete lab experience towards the interconnected abstract concepts.

Throughout this activity we use thought-provoking and extended answer questions - encouraging students to think critically and use problem solving skills. The questions we ask are important scaffolding steps which promote student concept development. After such questions, wait-time one and two are used extensively to give students time to create understanding, meaning, and ultimately provide a response (Rowe, 1986).

This activity targets several key nature of science ideas. Research supports the idea that an understanding of the nature of science enables students to develop a better understanding of fundamental science ideas (McComas, et. al., 1998). Students first investigate the phenomena, interpret the group's data, and then explain their interpretation to the class. We also have students compare what each group did in the lab with how authentic science is conducted. Several ideas we want to draw each student's attention to include that scientific data must be interpreted, why scientists use models, and no universal scientific method exists.

Closing Remarks

This activity is designed to take three to four days. This amount of time is justified because the activity provides a valuable concrete experience which we scaffold back to multiple times in future lessons. The activity is also a valuable method for reinforcing fundamental science concepts in a way that promotes long-term understanding and application. We use impact craters as an application-phase activity for individual concepts and an exploratory-phase activity for the relationships between those concepts. This activity is designed with the intent of being used at a critical juncture in the learning cycle when students have a firm grasp of fundamental science concepts, but have not yet realized the close links between these concepts.

References

Karplus, R. (1997). Science Teaching and the Development of Reasoning. *Journal of Research in Science Teaching,* 14(2), 169-175.

McComas, W. F., Clough, M. P., & Almazroa, H. (1998). The Role and Character of the Nature of Science in Science Education. Chapter 1 in W. F. McComas (Ed.) (1998) *The Nature of Science in Science Education: Rationales and Strategies.* Kluwer Academic Publishers: Dordrecht, The Netherlands. pp 3-39.

Rowe, M. B. (1986). Wait-Time: Slowing Down may be a Way of Speeding Up. *Journal of Teacher Education,* 37(1), 43-50.

Blake J. Williams teaches physics at Ankeny High School in Ankeny, Iowa. He is an active NSTA member and teaches a physics course for the ISU OPPTAG summer program. Blake can be reached via e-mail at blakej.williams4@gmail.com. Derek J. Hollingshead teaches physics at Desert Mirage High School in Thermal, CA. He is the co-advisor for Roots and Shoots student community group and an active NSTA member. Derek can be reached via e-mail at djhollingshead@gmail.com.