but not good enough to get a decent main sequence? Also, you mentioned that once they get data, they're set for 3–4 nights inside reducing their data. There is still a problem: you have to decide five minutes before lab starts whether the weather is OK.

D.B. Caton: Out of 15 lab nights per semester, we will have perhaps five that are photometric and two or three more that are good enough for visual or photographic work. The problem with last-minute weather changes *is* indeed still a problem since it takes about 30 minutes to set up the telescopes. We always have both an indoor and outdoor lab exercise ready each lab night.

H.S. Gurm: *How about using a 6" or 8" Cassegrain with a larger f-ratio instead of a Celestron, particularly when doing photometry?*

D.B. Caton: I see no problem with using a six- or eight-inch Cassegrain to do photometry. Our Celestrons were chosen for their reliability, availability at competitive prices, and wide range of accessories available from both Celestron and second-source manufacturers.

L.A. Marschall: *1) How many labs does this exercise take; 2) and how many students do the lab each semester?*

D.B. Caton: 1) One lab indoors and one lab outdoors. Good students get about 20 Pleiades stars in two hours. Average students get about half that number. 2) About 75 students per semester, in three groups of 24. The students work in pairs.

CRATERING IN THE CLASSROOM

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The SEMS Project (Science Education in Middle School) in Michigan is a cooperative science education improvement effort by several universities, hundreds of school districts, and the state department of education. Upper elementary and middle/junior high school teachers have been targeted for improvement of science instruction. Although the initial area of focus included teachers of grades five through nine, the project has been successfully extended to early elementary grades. While there are many excellent teachers at these grade levels, research findings indicate that 49 per cent of all middle school science teachers are teaching without a major or minor in science! The situation is even more critical at the upper elementary levels.

In an effort to improve science teaching at the upper elementary and middle/junior high school levels, over 300 well-qualified teachers were selected to be

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trained as resource leaders for their respective school buildings and districts. Upon completion of their training in 1986, these teacher/leaders returned to their home school districts and made efforts to assist out-of-field and inadequately-prepared science teachers in their schools.

This technique of using local teachers as resource leaders afforded the greatest capability to reach the largest number of teachers possible. A resource training manual and model lesson plans were developed for the resource team training and utilized the goals and results of several sources for the improvement of science education for all students: 1) develop scientific and technological process and inquiry skills; 2) provide scientific and technological knowledge; 3) use the skills and knowledge of science and technology as they apply to personal and social decisions; 4) enhance the development of attitudes, values, and appreciations of science and technology; and 5) study the interactions among science-technology-society in the context of science-related issues; (National Science Teachers Association, *Science-Technology-Society: Science Education For The 1980's*, 1982).

Over seventy "ideal or model" lessons were developed and field-tested in classrooms to assist in the training of resource leaders and for utilization with their out-of-date/field teaching colleagues. One very popular lesson is Appendix 1. This activity proved to be one of the most successful for all teachers regardless of academic background. It is called "Formation of Impact Craters" and is found in the Space/Astronomy section of the *SEMS Resource and Training Manual.* The SEMS lessons contain specific sections on motivators, processes, teaching strategies, careers, extensions, and resources in addition to the usual science activity sections.

This experiment basically has the student teams investigate the relationship between the height of a dropped marble and the corresponding crater width in a box of sand. Impact craters are a significant part of our science in astronomy, planetary geology, and the evolution of life. Correct experimental techniques, the transformation of one form of energy to another, and the relationship between drop height and crater size are emphasized in this activity.

After initial introduction and motivation with visuals, the student teams, composed of three students, plan the experiment with the available materials and conditions. The experimental procedure is to first brainstorm (*i.e.*, think freely and wide-rangingly) about the possible variables and then to design the experiment to control the variables as the team tries to gather the relevant data. A marble is dropped into a sandbox from successive heights in 10 centimeter increments starting from an initial height of 10 centimeters up to as high as possible — perhaps several meters. The crater position in the sandbox should be the same location and the identical techniques/measurer should be used for each drop. Different masses and types/depths of sand may be used.

Analysis of the data via careful plotting of the height *versus* the crater width should follow the experiment. A smooth relationship is rare because of sound reflections off the container sides. This will form the basis for more experimentation by the teams. Extensions of this simple activity extend to astronomy, dinosaur extinctions, volcanic eruptions, and nuclear winter.

Formation of Impact Craters

Lesson 33 Space Astronomy

Overview:
Impact craters caused by meteorites are believed to be related to lunar craters and possibly to the extinction of dinosaurs. The transformation of kinetic energy of motion of a meteorite into heat, sound, displacement of materials, and the relationship of crater size to velocity at impact are emphasized in this activity.

Objective:
After completing this activity, students should be able to:
1. Describe the transformation of energy that takes place during the formation of an impact crater.
2. Describe the technique of investigating the relation between crater size and impact velocity at impact of a meteorite.
3. Infer how craters on the moon may have been formed.

Motivator:
Show students photographs of planets and moons and have them observe the range of sizes and similarities among the craters. Also examine space photographs of the Earth and view the NASA film *Exploration of A Planet.*

Materials: (Per small group)
Marbles of various diameters
Meterstick or metertape
Laboratory book for recording data
Graph paper
Shoebox or foil pan or similar container filled with wet sand, or soft plaster of Paris.

Procedure:
Instruct students to drop the marble into the sandbox or wet plaster from increasing heights, beginning at a height of 10 centimeters, and continuing in increments of 10 cm, up to a height of several meters if possible. Each time they should measure the height from which the marble was dropped, as well as the depth and width of the crater. Emphasize that good inquiry habits and laboratory procedures require accurate measuring techniques.

Subject:
Earth and Space Science: Solar System, Galaxies, Universe

Group Size:
Small groups (3–5)

Time:
150 Minutes

Teaching Strategies:
Guided Discovery
Inquiry
Simulation
Discussion

Concept:
A meteorite that rushes toward another celestial body, such as the moon, has potential energy by virtue of gravitational attraction between it and the body, and kinetic energy by virtue of its movement. Craters thus produced result from both the potential and kinetic energy of the meteorite.

Processes:
Observing
Measuring
Predicting
Interpreting Data
Controlling Variables
Formulating Models

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Formation of Impact Craters (continued)

Ask students to identify the sources of energy in the act of raising the marble, releasing it, and the subsequent impact crater in the sand or plaster. (This will involve *chemical energy* and *metabolism* in your body; *gravitational potential energy* (GPE = mgh) that is directly proportional to the height of the drop disregarding *air frictional energy*; *kinetic energy* (KE = 0.5 mv^2) of the marble that increases to a maximum as it hits the sand; *mechanical energy, frictional energy,*and *sound energy* as the impact crater is formed.) Have students summarize the data in a table.

Suggest that students plot a graph, showing crater diameters versus drop heights. Ask: *What general relationship did you discover? How does this activity demonstrate conservation of energy?*

As a group, discuss the variables in this experiment that might affect the size or shape of the crater. (Examples might include marble characteristics, sand or plaster characteristics, angle of approach, and similar factors.

Extension/Follow-up Activities:

You might wish to have students drop stones of various sizes into a large tray of wet plaster of Paris. After a crater has formed, have them carefully remove the stones and allow the plaster to harden. Compare this with pictures of the moon's surface.

Have interested students read and report on the possible event 65 million years ago in which it is suggested that dinosaurs became extinct.

Applications:

Remind students about those "falling stars" that they used to wish upon. Explain that they weren't "stars" at all, but were really small bits of rock left over from the formation of our solar system. Also, fossil records confirm that many life forms periodically become extinct and the evolution of life to its present state may be drastically affected by large impacts from space every few million years. In fact, the government has now started Operation Sky Watch to monitor asteroids that pass close to the Earth.

However, an even more immediate concern comes from the possible results of a limited nuclear war. It has been estimated that crater dust, debris, and smoke from a nuclear explosion might block enough sunlight so that a significant cooling of the Earth might take place suddenly. It is suggested that temperatures might drop to -40° C. Ask: *Could humans survive?*

Careers:

Astronomer
Aerospace Engineer
Geologist
Satellite Specialist

Resources:

The Solar System and Beyond, 4 color filmstrips, 55 frames each, and 4 cassettes, National Geographic Society, Educational Services, 17th & M Sts., N.W., Washington, D.C., 20036, 1985.

Discussion

L. Gouguenheim: *I wish also to comment that a similar lab was successfully given by L. Celnikier during a summer school for teachers. The report was published in the proceedings of the TARBES Summer School (1978, L. Celnikier, Editor, Publication de l'Observatoire de Paris).*

J. Fierro: *Covering the sandbox with colored powder or cornstarch will show ejecta and rays for the crater experiment you described.*

J.V. Feitzinger: *In the book* Astronomie Experimentelle (Experimental Astronomy) *by J. Meurers, about 1955, you will find detailed descriptions of experiments on cratering. The production of central bulges is described.*

W. Bisard: Yes, thank you.

J.-C. Pecker: *All these types of experiments are good inasmuch as they help students to make actual measurements, build diagrams, and understand the physical processes that may happen in the universe. But these is a danger of misconceptions: for example, some young people might think that* large *craters on the moon are created by objects that are coming from* far away, small *ones by objects that are coming from the* vicinity.... *So teachers should heavily comment about the* difficulty *of generalization, and of extrapolation of classroom experiments to the real astronomical world.*

O. Gingerich: *Can you get elliptical craters? How do you measure the sideways component?*

W. Bisard: Yes, especially with very oblique impacts. The astronomical craters are *circular* and are caused by the explosion of superheated gases at the impact site. No evidence can be found of initial sideways velocities of astronomical impacts.

LABORATORY ACTIVITIES IN THE TEACHING OF ASTRONOMY

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Astronomy is one of the most popular of the sciences. That this is so can be seen in the frequent news articles about astronomical discoveries and happenings, in the number of questions about the sky fielded by planetarium and observatory staff, and in the large turnouts for public observing sessions at observatories or astronomy

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