ACTIVITY 1

Introducing Inquiry and the Nature of Science

This activity introduces basic procedures involved in inquiry and concepts describing the nature of science. In the first portion of the activity the teacher uses a numbered cube to involve students in asking a question—what is on the bottom?— and the students propose an explanation based on their observations. Then the teacher presents the students with a second cube and asks them to use the available evidence to propose an explanation for what is on the bottom of this cube. Finally, students design a cube that they exchange and use for an evaluation. This activity provides students with opportunities to learn the abilities and understandings aligned with science as inquiry and the nature of science as described in the *National Science Education Standards.* Designed for grades 5 through 12, the activity requires a total of four class periods to complete. Lower grade levels might only complete the first cube and the evaluation where students design a problem based on the cube activity.

Standards-Based Outcomes

This activity provides all students with opportunities to develop abilities of scientific inquiry as described in the *National Science Education Standards*. Specifically, it enables them to:

- identify questions that can be answered through scientific investigations,
- design and conduct a scientific investigation,
- use appropriate tools and techniques to gather, analyze, and interpret data,
- develop descriptions, explanations, predictions, and models using evidence,
- think critically and logically to make relationships between evidence and explanations,
- recognize and analyze alternative explanations and predictions, and
- communicate scientific procedures and explanations.

This activity also provides all students opportunities to develop understanding about inquiry and the nature of science as described in the *National Science Education Standards*. Specifically, it introduces the following concepts:

- Different kinds of questions suggest different kinds of scientific investigations.
- Current scientific knowledge and understanding guide scientific investigations.
- Technology used to gather data enhances accuracy and allows scientists to analyze and quantify results of investigations.
- Scientific explanations emphasize evidence, have logically consistent arguments, and use scientific principles, models, and theories.
- Science distinguishes itself from other ways of knowing and from other bodies of knowledge through the use of empirical standards, logical arguments, and skepticism, as scientists strive for the best possible explanations about the natural world.

Science Background for Teachers

The pursuit of scientific explanations often begins with a question about a natural phenomenon. Science is a way of developing answers, or improving explanations, for observations or events in the natural world. The scientific question can emerge from a child's curiosity about where the dinosaurs went or why the sky is blue. Or the question can extend scientists' inquiries into the process of extinction or the chemistry of ozone depletion.

Once the question is asked, a process of scientific inquiry begins, and there eventually may be an answer or a proposed explanation. Critical aspects of science include curiosity and the freedom to pursue that curiosity. Other attitudes and habits of mind that characterize scientific inquiry and the activities of scientists include intelligence, honesty, skepticism, tolerance for ambiguity, openness to

new knowledge, and the willingness to share knowledge publicly.

Scientific inquiry includes systematic approaches to observing, collecting information, identifying significant variables, formulating and testing hypotheses, and taking precise, accurate, and reliable measurements. Understanding and designing experiments are also part of the inquiry process.

Scientific explanations are more than the results of collecting and organizing data. Scientists also engage in important processes such as constructing laws, elaborating models, and developing hypotheses based on data. These processes extend, clarify, and unite the observations and data and, very importantly, develop deeper and broader explanations. Examples include the taxonomy of organisms, the periodic table of the elements, and theories of common descent and natural selection.

One characteristic of science is that many explanations continually change. Two types of changes occur in scientific explanations: new explanations are developed, and old explanations are modified.

Just because someone asks a question about an object, organism, or event in nature does not necessarily mean that person is pursuing a scientific explanation. Among the conditions that must be met to make explanations scientific are the following:

• *Scientific explanations are based on empirical observations or experiments*. The appeal to authority as a valid explanation does not meet the requirements of science. Observations are based on sense experiences or on an extension of the senses through technology.

• *Scientific explanations are made public.* Scientists make presentations at scientific meetings or publish in professional journals, making knowledge public and available to other scientists.

• *Scientific explanations are tentative.* Explanations can and do change. There are no scientific truths in an absolute sense.

• *Scientific explanations are historical.* Past explanations are the basis for contemporary explanations, and those, in turn, are the basis for future explanations.

• *Scientific explanations are probabilistic*. The statistical view of nature is evident implicitly or explicitly when stating scientific predictions of phenomena or explaining the likelihood of events in actual situations.

• *Scientific explanations assume cause-effect relationships*. Much of science is directed toward determining causal relationships and developing explanations for interactions and linkages between objects, organisms, and events. Distinctions among causality, correlation, coincidence, and contingency separate science from pseudoscience.

• *Scientific explanations are limited*. Scientific explanations sometimes are limited by technology, for example, the resolving power of microscopes and telescopes. New technologies can result in new fields of inquiry or extend current areas of study. The interactions between technology and advances in molecular biology and the role of technology in planetary explorations serve as examples.

Science cannot answer all questions. Some questions are simply beyond the parameters of science. Many questions involving the meaning of life, ethics, and theology are examples of questions that science cannot answer. Refer to the *National Science Education Standards* for Science as Inquiry (pages 145-148 for grades 5-8 and pages 175-176 for grades 9-12), History and Nature of Science Standards (pages 170-171 for grades 5-8 and pages 200-204 for grades 9-12), and Unifying Concepts and Processes (pages 116-118). Chapter 3 of this document also contains a discussion of the nature of science.

Materials and Equipment

• 1 cube for each group of four students (black-line masters are provided).

(Note: you may wish to complete the first portion of the activity as a demonstration for the class. If so, construct one large cube using a cardboard box. The sides should have the same numbers and markings as the black-line master.)

• 10 small probes such as tongue depressors or pencils.

• 10 small pocket mirrors.

Instructional Strategy

Engage Begin by asking the class to tell you what they know about how scientists do their work. How would they describe a scientific investigation? Get students thinking about the process of scientific

inquiry and the nature of science. This is also an opportunity for you to assess their current understanding of science. Accept student answers and record key ideas on the overhead or chalkboard.

Explore (The first cube activity can be done as a demonstration if you construct a large cube and place it in the center of the room.) First, have the students form groups of three or four. Place the cubes in the center of the table where the students are working. The students should not touch, turn, lift, or open the cube. Tell the students they have to identify a question associated with the cube. Allow the students to state their questions. Likely questions include:

- What is in the cube?
- What is on the bottom of the cube?
- What number is on the bottom?

You should direct students to the general question, *what is on the bottom of the cube*? Tell the students that they will have to answer the question by proposing an explanation, and that they will have to convince you and other students that their answer is *based on evidence*. (Evidence refers to observations the group can make about the visible sides of the cube.) Allow the students time to explore the cube and to develop answers to their question. Some observations or statements of fact that the students may make include:

- The cube has six sides.
- The cube has five exposed sides.
- The numbers and dots are black.
- The exposed sides have numbers 1, 3, 4, 5, and 6.
- The opposite sides add up to seven.
- The even-numbered sides are shaded.
- The odd-numbered sides are white.

Ask the students to use their observations (the data) to propose an answer to the question: *What is on the bottom of the cube*? The student groups should be able to make a statement such as: *We conclude there is a 2 on the bottom*. Students should present their reasoning for this conclusion. For example, they might base their conclusion on the observation that the exposed sides are 1, 3, 4, 5, and 6, and because 2 is missing from the sequence, they conclude it is on the bottom.

Use this opportunity to have the students develop the idea that combining two different but logically related observations creates a stronger explanation. For example, 2 is missing in the sequence (that is, 1, _, 3, 4, 5, 6) and that opposite sides add up to 7 (that is, 1—6; 3—4; _—5) and because 5 is on top, and 5 and 2 equal 7, 2 could be on the bottom.

If done as a demonstration, you might put the cube away without showing the bottom or allowing students to dismantle it. Explain that scientists often are uncertain about their proposed answers, and often have no way of knowing the absolute answer to a scientific question. Examples such as the exact ages of stars and the reasons for the extinction of prehistoric organisms will support the point.

Explain Begin the class period with an explanation of how the activity simulates scientific inquiry and provides a model for science. Structure the discussion so students make the connections between their experiences with the cube and the key points (understandings) you wish to develop.

Key points from the *Standards* include the following:

- Science originates in questions about the world.
- Science uses observations to construct explanations (answers to the questions). The more observations you had that supported your proposed explanation, the stronger your explanation, even if you could not confirm the answer by examining the bottom of the cube.
- Scientists make their explanations public through presentations at professional meetings and journals.
- Scientists present their explanations and critique the explanations proposed by other scientists.

The activity does not explicitly describe "the scientific method." The students had to work to answer the question and probably did it in a less than systematic way. Identifiable elements of a method—such as observation, data, and hypotheses—were clear but not applied systematically. You can use the experiences to point out and clarify scientific uses of terms such as observation, hypotheses, and data.

For the remainder of the second class period you should introduce the "story" of an actual scientific discovery. Historic examples such as Charles Darwin would be ideal. You could also assign students to prepare brief reports that they present.

Elaborate The main purpose of the second cube is to extend the concepts and skills introduced in the earlier activities and to introduce the role of prediction, experiment, and the use of technology in scientific inquiry. The problem is the same as the first cube: *What is on the bottom of the cube?* Divide the class into groups of three and instruct them to make observations and propose an answer about the bottom of the cube. Student groups should record their factual statements about the second cube. Let students identify and organize their observations. If the students are becoming too frustrated, provide helpful suggestions. Essential data from the cube include the following (see black-line master):

- Names and numbers are in black.
- Exposed sides have either a male or female name.
- Opposing sides have a male name on one side and a female name on the other.
- Names on opposite sides begin with the same letters.
- The number in the upper-right corner of each side corresponds to the number of letters in the name on that side.
- The number in the lower-left corner of each side corresponds to the number of the first letter that the names on opposite sides have in common.
- The number of letters in the names on the five exposed sides progresses from three (Rob) to seven (Roberta).

Four names, all female, could be on the bottom of the cube: Fran, Frances, Francene, and Francine. Because there are no data to show the exact name, groups might have different hypotheses. Tell the student groups that scientists use patterns in data to make predictions and then design an experiment to assess the accuracy of their prediction. This process also produces new data.

Tell groups to use their observations (the data) to make a prediction of the number in the upper-right corner of the bottom. The predictions will most likely be 4, 7, or 8. Have the team decide which corner of the bottom they wish to inspect and why they wish to inspect it. The students might find it difficult to determine which corner they should inspect. Let them struggle with this and even make a mistake—this is part of science! Have one student obtain a utensil, such as a tweezers, probe, or tongue depressor, and a mirror. The student may lift the designated corner less than one inch and use the mirror to look under the corner. This simulates the use of technology in a scientific investigation. The groups should describe the data they gained by the "experiment." Note that the students used technology to expand their observations and understanding about the cube, even if they did not identify the corner that revealed the most productive evidence.

If students observe the corner with the most productive information, they will discover an 8 on the bottom. This observation will confirm or refute the students' working hypotheses. Francine or Francene are the two possible names on the bottom. The students propose their answer to the question and design another experiment to answer the question. Put the cube away without revealing the bottom. Have each of the student groups present brief reports on their investigation.

Evaluate The final cube is an evaluation. There are two parts to the evaluation. First, in groups of three, students must create a cube that will be used as the evaluation exercise for other groups. After a class period to develop a cube, the student groups should exchange cubes. The groups should address the same question: *What is on the bottom of the cube?* They should follow the same rules—for example, they cannot pick up the cube. The groups should prepare a written report on the cube developed by their peers. (You may have the students present oral reports using the same format.) The report should include the following:

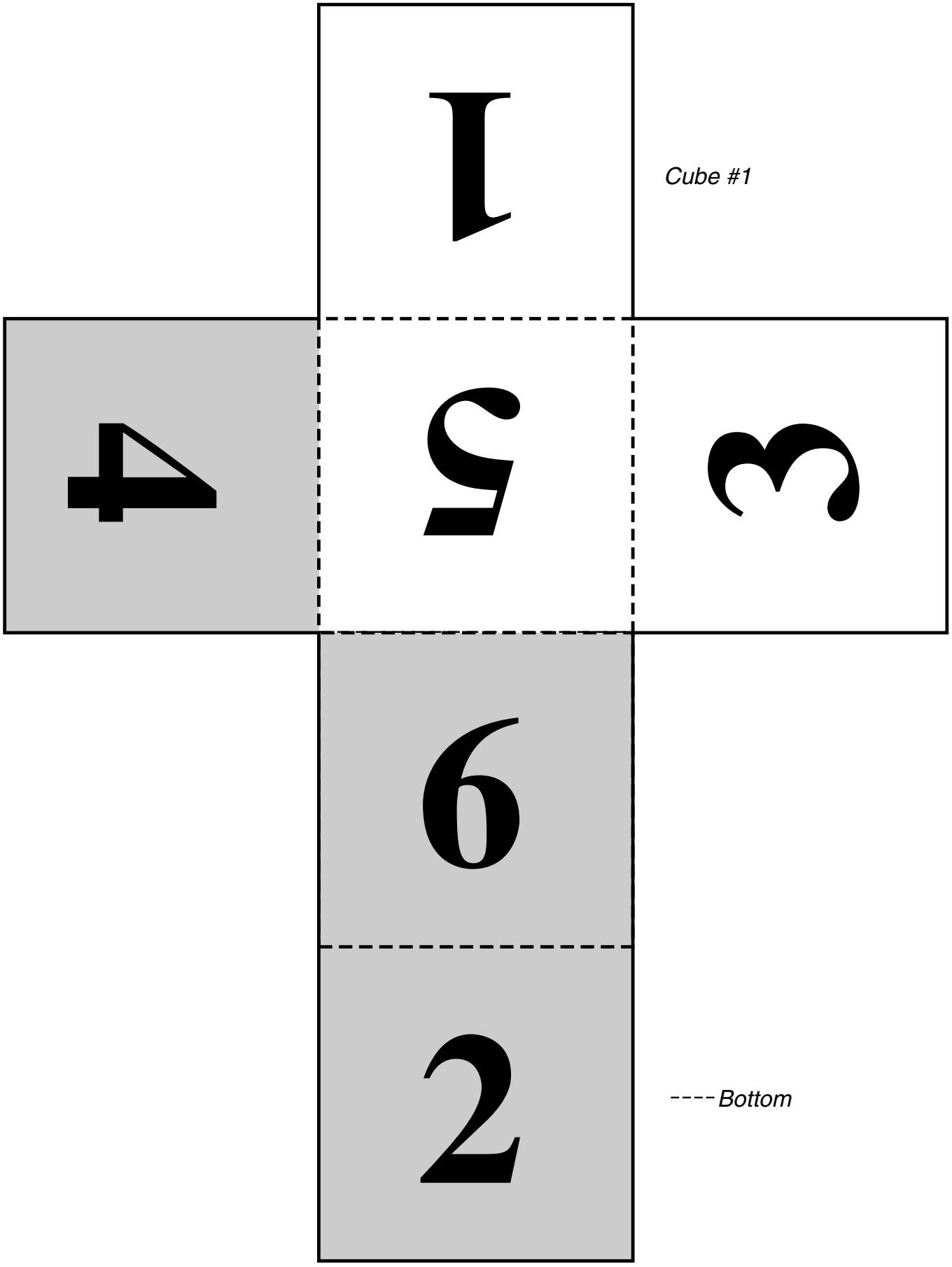
- title,
- the question they pursued,
- observation—data,
- experiment—new data,

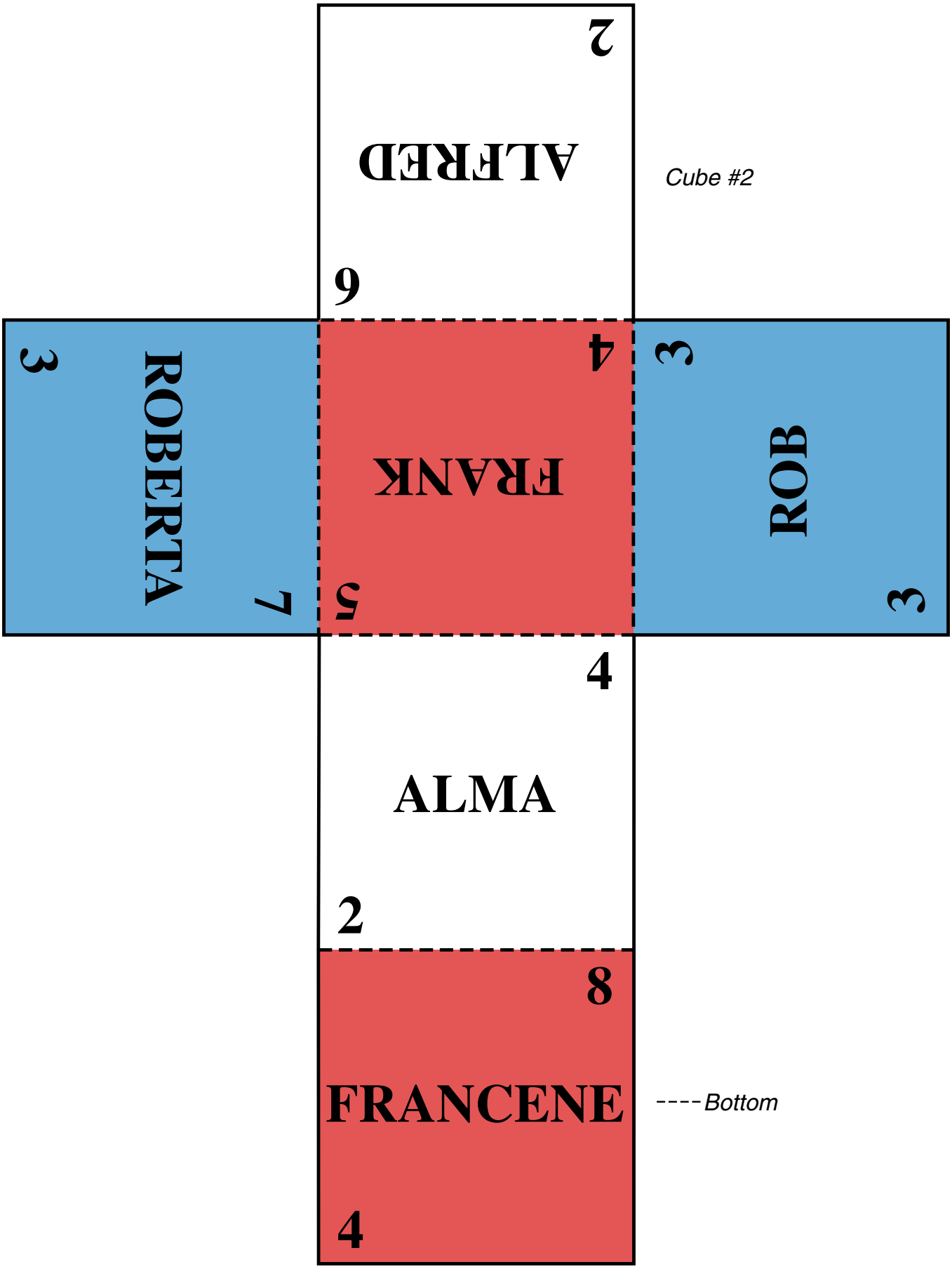
- proposed answer and supporting data,
- a diagram of the bottom of the cube, and
- suggested additional experiments.

Due to the multiple sources of data (information), this cube may be difficult for students. It may take more than one class period, and you may have to provide resources or help with some information.

Remember that this activity is an evaluation. You may give some helpful hints, especially for information, but since the evaluation is for inquiry and the nature of science you should limit the information you provide on those topics.

Student groups should complete and hand in their reports. If student groups cannot agree, you may wish to make provisions for individual or "minority reports." You may wish to have groups present oral reports (a scientific conference). You have two opportunities to evaluate students on this activity: you can evaluate their understanding of inquiry and the nature of science as they design a cube, and you can assess their abilities and understandings as they figure out the unknown cube.





Cube #2

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Cube #3