Formative Assessment Probes
A look at how probes uncover conceptual connections

By Francis Eberle and Page Keeley

Students come into our classrooms with preconceived ideas. The formative assessment probes described here are questions informed by standards (AAAS 1993; NRC 1996) and research on student learning (Driver et al. 1994) that uncover students’ ideas and ways of reasoning about common science topics. These probes can be effective tools to help teachers build a bridge between students’ initial ideas and scientific ones. In this article, we describe how using two formative assessment probes can help teachers determine the extent to which students make similar connections between developing a concept of matter and a concept of rocks. Both probes require students to consider the properties of size, weight, shape, texture, or form in developing a concept of “matter” or “rock.”

The information uncovered through use of the probes informs instruction and can promote deeper conceptual understanding by helping students solidify an understanding of rocks and matter. These probes used together can help teachers learn whether their students connect the idea that matter comes in different sizes, shapes, textures, and forms and can have different properties while still being considered “matter” with the similar idea that rocks can come in different sizes, shapes, and forms and have different properties while still being considered a “rock.” Both “rocks” and “matter” are not defined by size, shape, texture, or form.

The following classroom snapshots show how these two probes helped a fifth-grade teacher uncover a similar conceptual rule students were using to form initial ideas about rocks as well as matter. Data from the students’ ideas were used to design lessons from two different curricular units and help students make similar conceptual connections between physical properties in an Earth science context and physical properties in a physical science (matter) context.

Probing Students’ Conceptions: Rock
Students worked through a lesson on rocks and minerals in which they examined rocks with magnifiers and performed various tests to observe their physical properties. The students recorded rock data, such as color, size, weight, hardness, texture, and form. The purpose of this lesson was to develop their measurement and observation skills as they apply to describing physical properties of rocks. The students shared their observations and compared different rock samples. Toward the end of the lesson, the teacher asked “What is a rock?” Students provided their own definitions: “hard, rough things found on the ground,” “heavy things that make up the Earth” and “large chunks made up of minerals.” The teacher mentally noted the responses that mentioned weight, size, shape, and texture. She realized that in order for students to use their observations about the
physical properties of rocks for further lessons that were planned, they needed to develop a common understanding of what determines whether “rocklike material” is considered to be a rock. Before ending the day’s lesson, she decided to use the probe, “Is It a Rock?, Version 1” (Keeley, Eberle, and Tugel 2007; see Figure 1) to examine students’ ideas further.

This particular probe is designed to elicit students’ ideas about what determines whether something is called a rock. The probe does not seek a technical definition but rather is purposefully designed to reveal whether students believe rock material must be a certain size, shape, or texture to be considered a rock. Rocks come in many sizes, shapes, and textures, ranging from huge boulders to microscopic specks; to rough jagged rocks to smooth, round stones. Rocks can be described by their size and shape, and words like boulder, cobble, gravel, sand, silt, and clay have specific meanings related to the average size of rock fragments.

The teacher concluded the lesson and collected the students’ responses to the probes, explaining that tomorrow they would further explore the idea of “what is a rock?” She was surprised to find that most students’ conception of a rock depended on the size, shape, and texture of the rock. For example; many students responded that a piece of sand and the dust from rubbing two stones together were not rocks because they were too small. Some students said a rock had to be jagged. If it was smooth, then it was a stone.

In examining the teacher notes that accompanied the probe, the teacher found that the research summaries on student learning supported what she was finding in her students’ ideas, such as “younger students often intuitively identify “rocks” through their weight, hardness, color, and jaggedness (Driver et al. 1994). Therefore, some students believe that rocks are larger, heavier, and jagged whereas smaller fragments are called stones instead of rocks” and “Students have difficulty with the idea of rock types being a range of sizes such as boulder, gravel, sand, clay. They use these words in ways related to where they are found, rather than seeing them as rocks of different sizes” (Keeley, Eberle, and Tugel 2007).

The next day, the teacher posted a list of the tallies of the items on the probe students considered to be “rocks.” She asked the students to discuss in small groups their ideas about what determines whether the items on the list are rocks. Following the small group discussion, the class now agreed that all of the items on the list, except for the piece of sand and dust from rubbing two stones together, could be considered rocks. They now decided that rocks could not be smaller than a piece of gravel and changed some of their ideas to agree they could be different shapes and textures.

The teacher decided to further confront students’ ideas with a demonstration involving actual rocks. She picked up a rock the size of a walnut and asked the students if it was a rock. All of the students agreed it was a rock. She asked them if it would still be a rock if she broke it into smaller pieces. The students replied that it would depend on how big the pieces were. The teacher then wrapped the rock in a towel and pounded it with a hammer. When she opened the towel, the rock was broken into smaller pieces. The students examined the pieces and agreed they were all still rocks. The teacher picked up a small piece smaller than a pea and asked students if it would still be a rock if she broke this small piece into smaller pieces. The students began to reconsider their ideas and agreed it would be a rock, even if it got down to the size of a piece of sand. However, the students were still undecided about the dust from rubbing stones together. So, the
teacher gave groups of students two stones and asked them to rub them together over a piece of white paper. The students observed the dust with magnifiers and discussed whether the dust was still “rock.” Some students said it was no longer a rock because it was a powder. Other students argued that it was “rock powder” so it must still be a rock but in powder form. Many of the students changed their initial ideas after now realizing that rocks can be broken down into smaller and smaller pieces and still be rocks because they were made of the same material. They now agreed that size does not matter whether something is a rock. It’s what a rock is made up of that matters.

Probing Students’ Conceptions: Matter

These students lacked an understanding that the formation and composition of a rock is what makes a rock rather than the properties of size or texture of a rock. Several weeks later the teacher began a unit on physical changes in matter and decided to find out if students’ ideas about what materials are considered to be matter were related to their initial ideas about what materials are considered to be rocks. Because both the rock unit and the matter unit involved related ideas about the physical properties of shape, size, weight, texture, and form, the teacher decided to probe the students’ conception of matter and then try to link their ideas about matter to their prior ideas about rocks. Before beginning the unit on matter, the teacher asked students to complete the Is It Matter? probe (Keeley, Eberle, and Farrin 2005; see Figure 2). This probe is designed to elicit whether students can distinguish between things that are considered matter and things that are not.

The students shared their ideas in small groups and tallied their responses during a whole-class discussion. Again, the teacher noticed that materials on the list that were small, such as powders, or too small to even see, such as air or dissolved sugars were not considered by many students to be matter. Students used reasons such as “it has to have weight” or “you have to be able to feel or see it.” The teacher challenged students’ ideas with an observation similar to breaking the rock and involved them in a demonstration and discussion about matter using sugar cubes, sugar granules, magnifiers, a small container of water, and stir sticks. Students observed the sugar cubes and agreed they were matter because you could see and feel them. The teacher asked them to crush the cubes and examine the pieces of sugar. Were the pieces still matter? Some students answered yes, and when further probed to explain their thinking they said because “I can hold it,” “I can see it,” “it is hard,” and “it takes up space.” Others students said it wasn’t matter because “it is in pieces” or “it doesn’t hold together in one shape.” The teacher then asked if a single granule of sugar is matter. Some students said the granule is matter because “they can see it and it is part of the sugar cube, which is matter.” Others said the granule wasn’t matter because “it is too small.” Then the teacher asked students to think back to the rock unit when they decided whether small pieces of a rock were still rock. Could the rules the students use for determining whether pieces of sugar are matter be similar to the rules used to determine whether pieces of rock were still rock? Now students were beginning to argue that it didn’t matter how small something was; it is still matter, just like the small pieces of rock were still rock. It’s just their size that changed, not what they were made of.
Next, the teacher showed the students all three forms of sugar again—the cube, sugar granules, and sugar dissolved in water. She asked again if the sugar cube is matter. The students resoundingly agreed it was because “it is solid and they can see it.” The teacher asked if the sugar cube is the same thing as the sugar granules and the single granule of sugar. The students said the granules and the single granule are the same as the “clumped together” sugar cube so it’s still “sugar matter.” The teacher then asked them about the sugar dissolved in the water. Some answered it was no longer matter because you couldn’t see the sugar. Others argued that the water gets sweeter when you put sugar in it so it must still be matter because it’s there, even though you can’t see it.

At this point, the teacher noted the different ideas students had about whether something like dissolved sugar could still be matter if you couldn’t see it as well as their difficulty in accepting items on the probe like air as matter. She used this information to plan the next day’s lesson on “invisible matter,” leading students toward developing a particle conception of matter that is not defined by the senses of being able to see or feel matter.

After several more lessons observing and describing various forms of matter and their properties, noting how physical properties can change matter yet it still remains matter, the teacher brought the students back to the connection between the rock and matter unit.

She guided the students in concluding that although a rock’s physical properties (e.g., size, shape, texture, etc.) may change, it doesn’t change the rock into something else, it is still a rock. A working definition was provided for them that rocks are one or more hard materials made of a mineral or combination of minerals. They then discussed their ideas about matter, making lists of what is matter and what is not. They discussed sizes of parts of matter (e.g., molecules in air) as being matter, emphasizing that the size is not a determining characteristic. They developed a working definition of matter as “the stuff things are made of.”

**Implications for Instruction**

Understanding science requires a deeper knowledge than just knowing facts or the names of things. Instruction that focuses on just one learning goal in one context—such as rocks or matter, without connecting the two—can lead to isolated pieces of knowledge that extend similar misconceptions into other topic areas. Students need to be able to attach new ideas to a framework of science knowledge (NRC 2000). Teachers have opportunities to help students connect science topics when they are related to each other. When teachers do not provide opportunities to connect related ideas in science, it is not surprising students are unable to transfer ideas across topics.

As a result of examining students’ ideas related to rocks and matter, the following instructional suggestions emerged:

- Provide students many opportunities to collect and examine a variety of rocks and matter and describe, rather than define, them according to their observable properties.
- Be clear with students about the terms and language you use and explain why particular words are being used (e.g., sand, boulder, gravel, and rock when teaching about rocks).
- Compare a whole cookie then break it into smaller parts. Have students decide if the pieces are still “cookie.” Then try it with rocks.
- Help students to develop operational definitions of rocks/matter so when they are older they are able to bridge from
their operational definition to a scientific one.

Looking at relationships between curricular topics and learning goals can be tricky, but doing so, as appropriate, can help students learn that science is not a set of isolated ideas. Looking for commonalities in students’ ideas across contexts can help teachers make connections across curricular units like “Rocks” and “Matter” that are typically taught separately. Students’ prior ideas may not change with just one instructional experience, so persistence, clarification, and repeated emphasis of these connections across topics will provide the opportunities necessary to help students better understand scientific ideas.

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References


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