What's the Matter With Teaching Children About Matter?

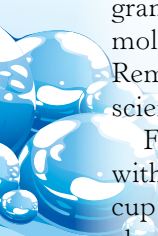
Using children's ideas about matter to inform instructional planning

By Amy Palmeri, Amanda Cole, Sarah DeLisle, Stacey Erickson, and Jennifer Janes

When it comes to learning about solids, liquids, and gases, children often bring interesting yet inaccurate ideas to the topic. When children's ideas conflict with the concepts we seek to teach, they interfere with learning. Therefore we must consider ways to elicit children's thinking and match instruction and learning experiences to the knowledge, skills, and ideas learners bring with them. We present strategies for tapping into children's ideas about matter and using them to inform instructional planning. The strategies were helpful with our third-grade students, and we encourage you to try them with your students as well.

What Children Know

We begin these experiences with the initial goal of finding out what students think about different types of matter—what they notice about different substances; how they use this information to sort substances into solids, liquids, or gases; and how they define each state of matter. The selection of substances is critical—it is important to select typical solids, liquids, or gases as well as substances that are more difficult to classify. We suggest using six to eight carefully chosen substances, such as: a pebble, rock salt, water, air (an empty cup), granular sugar or salt, chocolate syrup, cornstarch, molasses, flour, shampoo, or powdered sugar. Remind students that tasting is not allowed in science class.



For a preassessment activity, we present students with six cups with the following substance in each cup: (1) granular sugar, (2) water, (3) unifix cubes, (4) chocolate syrup, (5) cornstarch, and (6) air (empty). After observing the items, students record descriptions of the items in each cup; which cups held solids, liquids, or gases; and written definitions. We also used open-ended questions to prompt students to elaborate on their written work (e.g., What do you notice about this substance? Why do you think this is a solid [liquid or gas]? Which substances were the easiest/most difficult to put into categories? Why?).

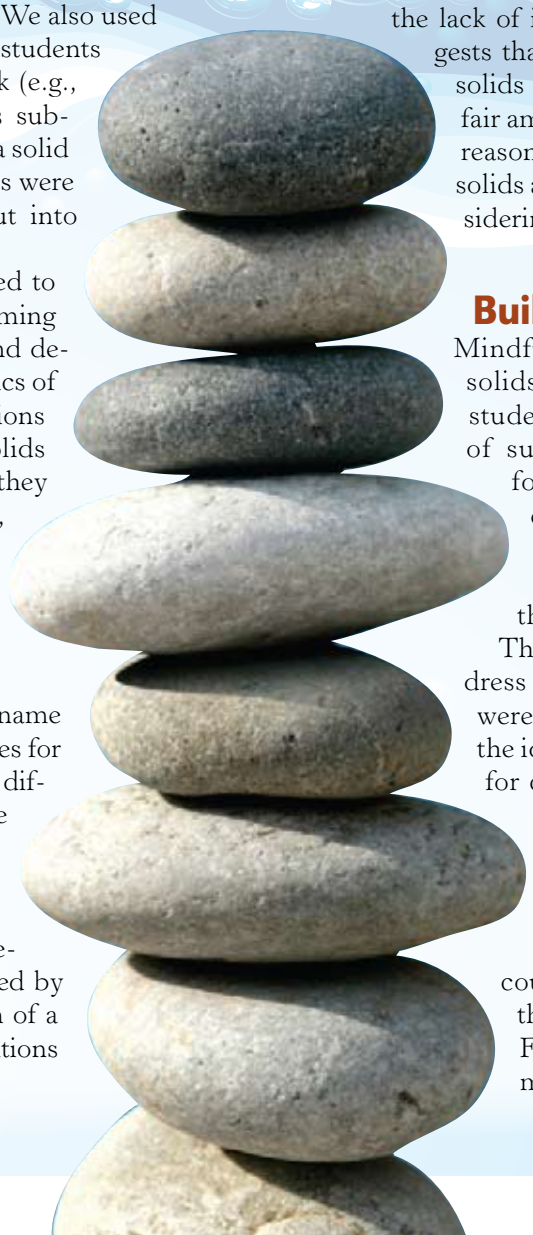
We found that students tended to define a solid, liquid, or gas by naming an example (rock, water, etc.) and describing the physical characteristics of that substance. Common definitions included language such as "Solids are hard, you can't break them, they are thick; Liquids are like water, they can be consumed, they are something you drink, they are wet; Gases smell bad, you put it in your car, it makes fire, air, etc."

While our students were able to name and describe a number of examples for each state, it appeared to be more difficult for them to give a concrete definition that could be applied across examples. Although some students mentioned air or carbon dioxide, gasoline was the most frequent example of a gas mentioned by our students, and their definition of a gas was more vague than the definitions for either solid or liquid.

When sorting substances, students had little difficulty sorting typical solids and liquids, such as water, rock salt, and a pebble. During sorting, the placement of the cup with air was the most varied across students—consistent with their vague definition of gas.

When discussing viscous liquids (e.g., molasses and shampoo), some students identified these substances as both solids and liquids. Similarly, when sorting granular or powdery solids, some identified these substances as solids, liquids, and even gases. Students correctly identifying these substances as solids focused on the properties of the individual grains, with one explaining, "The sugar might be a solid because the individual pieces are solid, even though the sugar as a whole, when in the cup appears liquidlike." Students identifying these as liquids focused on texture—the softness of the flour—or the "pourability" of the sugar.

Several students sorted the powdery solids into the gas group. The vagueness of the definition of gases and the range of samples identified incorrectly as a gas (and the lack of identification of air as a gas) suggests that students are more familiar with solids and liquids. Even so, there was a fair amount of inconsistency in students' reasoning related to some examples of solids and liquids, particularly when considering the notion of pourability.



Building on Knowledge

Mindful of the simplistic definitions of solids, liquids, and gases offered by the students and our awareness of the type of substances that caused difficulty for them, we next created learning experiences to support the refinement of students' definitions by confronting and building upon their initial ideas.

The activities described below address (1) the students' notion that solids were hard and couldn't be broken, (2) the idea that pourability was a criterion for classifying something as a liquid, and (3) their vague notion of gases. Through these activities, our students developed more accurate definitional knowledge of solids, liquids, and gases that could be applied in and support further learning.

First, we built a link from our informal explorations of solids, liquids,

and gases to more formal instructional activities by selecting one easily recognizable example each of a solid, a liquid, and a gas. We opted to use three plastic jars with lids, placing a rock in the first, water in a second, and air in the third. After allowing students to see what was in each jar, we asked them to identify what each contained. We asked if the object was a solid, liquid, or gas and placed appropriate labels on the front of each jar.

Second, we introduced formal definitions for the terms *matter, solid, liquid,* and *gas*. *Matter* was defined as anything that takes up space; *solids* as substances that have a definite shape that does not change depending on the container; *liquids* as substances that take the shape of their container; and *gases* as substances that take the form of their container and spread out to fill the container.

After each definition was introduced, we asked students to discuss each substance in the jars in relation to the definitions. Discussing one jar at a time, children were asked to justify the labels placed at each jar, drawing on details from the definitions and characteristics of the items in the jar. For example, when discussing the rock, children noted that the rock was just there sitting in the jar; in contrast, when discussing the jar with water they noted how the water was not "globbed" together but rather that it "spread out to the edges of the container."

Next, we presented a new collection of materials for students to sort. It is critical to select items that challenge the ideas articulated in the students' initial definitions. For example, to challenge the idea that solids are hard, you might include a cotton ball or piece of cloth. We used the following: an orange, a bag of sugar, a container of hand sanitizer, 10 unifix cubes (or similar math manipulatives) snapped together, a small inflated helium balloon, juice in a clear plastic bottle, a cotton ball, a pencil, and an empty lunch bag (air). In this context, we recommend a full class activity where students can pull items from a large bag and be asked to identify, with justification, the item as a solid, liquid, or gas (for the liquids and gases students should be directed to consider what is inside the container). The whole-class format allows for debate and discussion and provides opportunities for the teacher to reinforce ideas that confront, challenge, and extend the students' initial ideas to align with more accurate understandings.

For example, to address the idea that solids can't break, the teacher could break apart the strip of 10 unifix cubes and ask students to explain whether or not the unifix cubes are still solid. To illustrate the idea that liquids but not solids take the shape of their container, the teacher could pour liquids and pourable solids into a shallow container enabling students to see the difference between liquids that flow and granular or powdery solids that heap. The students concluded that some substances will take the

shape of some but not all containers. When they noticed the granular and powdery solids heaping rather than flowing, this prompted a closer look at the substances, with children beginning to note that the small pieces (or grains) individually retained their shape.

To help our students begin to understand the distinction between gases that spread out to fill their containers and liquids that take the shape of their containers, we focused on the small helium balloon and the paper lunch bag (that was expanded with the open part folded down to close the bag). With the helium balloon, students were asked to tilt the balloon from side to side and to describe what, if anything, they felt or heard moving inside the balloon. We contrasted this with what they felt and heard when they did the same thing to the bottle of juice. Students noted the substances inside the two containers behaved differently. With the paper lunch bag, students were asked if they thought the air in the bag was resting at the bottom of the bag or if they thought the air filled the entire bag. Students acknowledged that the air in the bag was not likely to be resting at the bottom of the bag.

To draw closure to these activities, we presented students with some of the same substances that caused confusion during the initial informal sorting activity. After sorting, students should be asked to explain why all of the items in each category belong and to articulate a definition in their own words, for each state of matter. When our students informally offered new definitions for solids, liquids, and gases as part of a group discussion, there were notable differences between these definitions and those offered during the formative assessment activity. Students were now likely to pick up the language from the simple definitions given: "retaining shape," "taking shape of container," and "filling the container" to distinguish between solids, liquids, and gases. Some of the everyday tangible ideas that characterized their initial definitions were maintained and other aspects were dropped. We heard comments like, "solids tend to be hard, but they're not always hard," "liquids are not just broken solids," "The difference between pourable liquids and pourable solids is that solids heap and liquids spread out." Students stopped describing liquids as something you drink, and fewer students described gases as smelly. In general we would characterize their new definitions as less tied to specific well-known examples and more consistent with scientific definitions. Students' performance on this sorting task and their justifications and definitions helped us evaluate to what extent they were developing more robust understanding of solids, liquids, and gases and to make informed instructional decisions about experiences that should follow. With a firm understanding of solids, liquids, and gases in place, next instructional steps could take a number of directions. Students could begin to examine (1) properties of materials (e.g., hardness, flexibility, strength, brittleness, and density, etc.), (2) what happens when substances are mixed (e.g., physical changes, chemical change, dissolving, mixtures, solutions, etc.), and (3) change of state (melting/freezing and boiling/condensing, etc.).

A Real Learning Experience

As a result of these learning experiences, we saw changes in the way our students talked about solids, liquids, and gases. Their internalization and flexible use of definitional knowledge served as a foundation for later learning about matter. However, it wasn't just our students who learned. We learned the value (and challenge) of grounding our instructional planning in detailed knowledge of our students' thinking. ■

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Connecting to the Standards

This article relates to the following *National Science Education Standards* (NRC 1996):

Teaching Standards

Standard B

Teachers of science guide and facilitate learning.

Standard C

Teachers of science engage in ongoing assessment of their teaching and of student learning

Content Standards

Grades K–4

Standard B: Physical Science

- Properties of objects and materials

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academy Press.