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Comparing Crystals

Janet Sharp
Montana State University-Bozeman

Karen Hoiberg
Fellows Elementary School

Scott Chumbley
Iowa State University, chumbley@iastate.edu

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Abstract
Most upper elementary science curricula contain some sort of lesson in which students identify and compare the visual structure of table salt and table sugar. So, when we set out to conduct this rather standard lesson with our fifth-grade students, we expected them to learn how to use some of their senses to identify salt and sugar granules and to be able to describe some of the differences between them. Instead, we found students' curiosity propelled the lesson forward, and they began asking good questions themselves.

Disciplines
Elementary Education | Materials Science and Engineering

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A standard lesson on identifying salt and sugar crystals expands into an opportunity for students to develop deeper questions.

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By Janet Sharp, Karen Hoiberg, and Scott Chumbley

Beginning Our Lesson

We opened the lesson by reading *Two Bad Ants* (Van Allsburg 1988). This book refers to sugar granules as "crystals." In an effort to connect the lesson to the story, we continued to use the word *crystal,* but also often interchanged "crystal" with "granule."

Starting the lesson with a literature connection certainly grabbed students' attention. Students were excited to listen to the story of two ants trekking across dangerous terrain to bring sugar crystals back to their queen. As we read the book, we asked students to describe the illustrations of the sugar crystals in the book. Students commented, "They look rounded, kind of like soccer balls" and "They look like gems in a ring."

The book's illustrations show the sugar crystals looking fairly uniform in shape and size. This is not unreasonable because to the naked eye, sugar granules appear to be consistent and to the touch, the granules all feel gritty in the same way. However, this can lead students to conclude that *all* sugar granules are essentially identical, which is not the case.

Moreover, many students mistakenly believe that *any* matter is simply made up of a collection of smaller versions of the matter. Knowing this, we anticipated our students might imagine that sugar granules all look the same under a microscope or that a sugar cube is composed of a whole bunch of smaller sugar cubes somehow adhered together.

Such ideas can confound students' understandings of the basic nature of molecular structure and the resulting geometric shape of the matter. (In this article, we are


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Students observe models of sugar's structure.

using *geometric shape* to mean the clearly identifiable overall shape of the matter visible at low magnifications, whereas *molecular structure* is a scientist's technical view and is not visible to the naked eye.)

We wanted students to be able to recognize the patterns of salt's geometric shape and to discuss the uniqueness of sugar's geometric shape. In order for students to develop an initial understanding of the idea of crystal structures, we knew it was important to compare sugar to something that *did* form a geometric structure (i.e., salt), so we followed the reading of *Two Bad Ants* with a hands-on experience comparing salt and sugar.

Background Science: Salt v. Sugar

The molecular structure of matter is determined by the chemical bonds between the atoms that make up the matter. Table sugar's molecular structure is more complex than table salt's structure. In sugar, bonds form in a variety of locations in a variety of protrusions, which makes irregular shapes. Sugar's bonds form chains between atoms, then the chains bond in geometrically irregular ways, making the shape of the structure unfamiliar and not as readily identifiable (geometrically) as the shape of salt's structure. This makes it difficult to predict the physical appearance of any given sample of table sugar.

Fracturing (breaking along nonflat surfaces) and conglomerating (adhering in clusters) tend to further obscure a familiar, predictable geometric shape. (Sugar's seeming irregularities *can* be predicted at a molecular level, giving sugar a predictable crystalline characteristic at that level.) When matter composed of a crystalline structure is broken apart, it often breaks in ways that produce similar-looking geometric shapes—as in table salt, but not always—as in table sugar.

Table salt's visual appearance is much more readily predictable because of its molecular structure. Its chemical bonds are structured so that each piece of salt "looks" the same no matter where you look—like a cubic rectangular prism. As a result, salt's geometric shape is truly indicative of the crystal structure, since the cubes we see are composed of repetitions of the same general cubic crystal structure that fit together like a mosaic.

Table sugar granules tend to be smaller than table salt granules. Even through a magnifying lens, sugar granules can be seen to have a less recognizable shape than salt. Table salt and sugar are good examples to compare because salt's visual structure forms a nice neat visible cube and, although sugar does possess a crystal shape, the specifics are not typically visible at low magnifications or without knowledge of molecular structures.

Looking Through the Lens

To begin the investigation, we asked students whether or not different pieces of sugar and/or salt would look the same if we could get an up-close view. They responded, "Well, I know they look the same when I just see them," and "I think they will look different, but I don't know how."

Next, we prepared several samples of sugar and salt so students could conduct a more in-depth hands-on exploration themselves. Prior to the class period, we gathered the necessary materials and prepared them so the student groups of four could function with few directions. Each student group needed:

- One sheet of black construction paper;
- Two paper cups (3 oz), one labeled *Cup 1* and containing about 120 mL of sugar, and the other labeled *Cup 2* and containing about 120 mL of salt;
- One paper towel, cut into four squares;
- A plastic garbage bag to cover each student's desk;
- Four paper clips (one for each paper towel piece);
- A pencil and paper; and
- Two clear-plastic cups (8 oz—the short, squatty ones work well), one containing about 200 mL of cold water and the other containing about 200 mL of hot water.

When the materials were ready, one student from each group collected the materials and each group began the activity. First, students divided the construction paper in half, pouring 100 mL of the substance from Cup 1 on one half and 100 mL of the substance from Cup 2 on the other half, so they had 20 mL of each substance left to examine in the next exploration. Each group observed the samples, recording on the paper any differences and similarities they observed.

Students' observations included "white," "rough," and "piles up." Students then used magnifying glasses to examine the samples more closely. Students were surprised to see the differences in the salt and sugar samples under a magnifying glass. The physical appearance of different groups' sugar varied, whereas everyone's salt was a cube. Their comments included:

- "One shape is like a cube (it has good corners), the other is bumpy (with lots of points.)"
- "They're both white."
- "Pieces seem to be about the same size."

Students recorded these observations on their paper.

Water Interactions

Next, we asked students to make four "sample" pouches—two sugar and two salts—of the substances. To make the pouch, students put about 10 mL of salt or sugar in the center of the square of paper towel, gathered the four corners together, connected the corners with a paper clip, and attached the paper clip to a pencil. This created a small pouch of the substance that students could control with the pencil (see Figure 1).

Students tested both salt and sugar's reactions to hot and cold water. To do this, students suspended a pouch of salt or sugar across the rim of a plastic cup of hot water, making sure the base of the towel touched the water. Next, they created a second pouch (of the same substance) and suspended it across the rim of a plastic cup of cold water, again making sure the base of the towel touched the water. By the end of the lab, students had tested salt and sugar in both hot and cold water.

Students observed what happened as the water began to seep through the towel and affect the granules. Because students were familiar with making powdered drinks they were not surprised that sugar dissolved in both hot and cold water or that sugar dissolved most quickly in hot water. Students also observed that salt dissolved in both hot and cold water, but not as quickly.

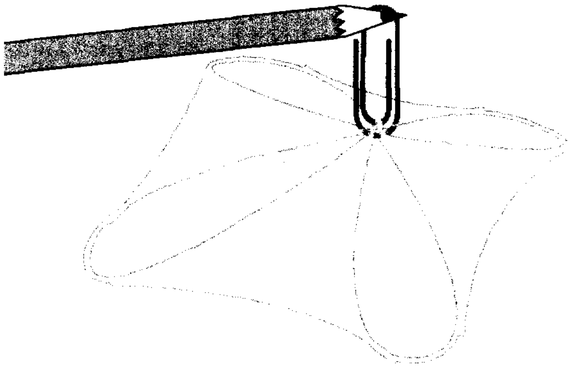
Students commented about their experiences. For example, one student said, "Mom puts sugar in her hot tea and Dad puts it in his iced tea. Mom's sugar always dissolves faster. I used to think that happened because of how she stirred it!" Another student was fascinated watching the sugar react to the hot water: "Neat, it looks like heat rising on a hot day!"

Modeling Salt and Sugar

After observing the granules' behavior in water, we had students return to their observations about the dry granules. They drew and built models of what they saw

Figure 1.

Sample pouch for salt and sugar investigation.



when they looked through the magnifying lens earlier. They built one salt model and one sugar model—using hollow coffee-stirrers and pipe cleaners (Geddes 1992). Students' drawings and models were based on the images they saw with the magnifying glasses.

To prepare for the model building, we clipped several pipe cleaners into approximately 7 cm segments. Students made the models by inserting the pipe cleaners into the ends of the hollow coffee-stirrers and bending the covered wire to connect them and form "corners." (Alternatively, students may use gumdrops, clay, or peas to connect the corners. Or, if working with older children, spherical beads can be connected at the vertices to model atoms.)

To follow up, we asked questions and discussed the model building experience:

- What do you notice about the two structures you built? *("The salt is easy to build. It always makes boxes. The sugar is hard to build. And each piece isn't always the same.")*
- What do you notice about the physical appearances of the models in each group? *("Everyone's salt is basically the same and everyone's sugar is different!" "At first I thought salt and all granule-type stuff were all the same shape and size. But I learned that they are not.")*
- What differences do you notice between the two samples? *("It surprised me that the salt made a box. It doesn't feel like a box when it's between my fingers." "I thought all granules would look the same, even pepper!" "Smaller pieces of sugar don't look like I thought they would look, even though they feel sort of pointy and look pointy under the magnifying lens.")*
- How could you tell salt from sugar? *("Put them under a magnifying lens! You can identify salt right away!")*

Through building the models of the geometric shapes, students were able to analyze the images they had seen through the magnifying glass because they had built larger objects they could physically manipulate. These structures also communicated their images to us, their teachers, thus allowing us to informally assess students' visualizations of the three-dimensional nature of the two samples of granules.

Expanding Questions

We were pleased with students' progress in the investigation. Then, we noticed several students' hands in the air. What happened next surprised and elated us. Our students had generated a list of better questions than we ourselves had prepared! They wondered:

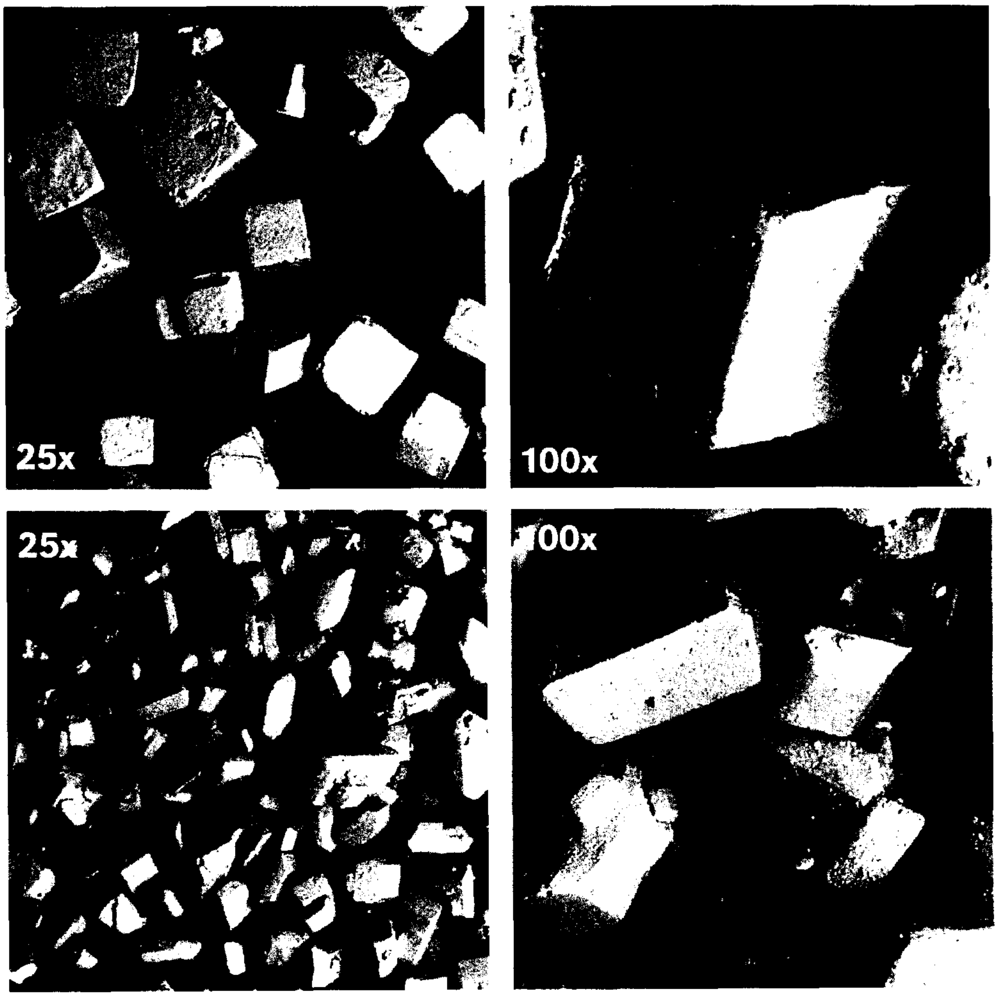
- Why don't all granules (sugar, corn starch, baking soda, flour, salt, pepper, etc.) look basically the same under the lens?
- Why don't all pieces of sugar look the same? Shouldn't they look the same? Aren't they the same thing?
- Why is salt smooth looking with corners?
- Why does sugar look bumpy?
- Why don't sugar and salt look exactly alike? If we magnified each far enough wouldn't they eventually all look the same?

What surprised us was the way children were tackling their own misconceptions. Most of their questions were "why didn't?" or "why doesn't?" something happen. They were confronting their conceptual ideas head on. And, they wanted answers!

So, what do you do when students' questions go deeper than your prepared questions?

First, we cheered because we piqued students' curiosity. Second, we scrambled to answer their main question without confusing them with too much detailed information. They knew there were differences. In essence, they wanted to know exactly how deep the differences went.

Figure 2.



SEM images of salt crystals at low and high magnification.

SEM images of sugar at low and high magnification.

Connecting to the Standards

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

Content Standards
Grades 5–8

Standard B: Physical Science
- Properties and changes of properties in matter

For us, students' questions indicated a conceptual awareness that the atomic structure of different matter can be different, even though the physical appearance may be indistinguishable. All of their questions addressed the notion that on the surface—visible with the naked eye—matter may "look" the same, but the differences in the matter making up the granules (whether they be sugar, salt, or another substance) make them noticeably different beneath the surface.

Seeking Answers Through SEM

In addressing students' questions, we determined students really wanted to know more about the two kinds of matter making up salt and sugar. So, we took advantage of a local university's Scanning Electron Microscope (SEM) to partially answer these questions. (For information on how to locate an SEM near you, see Internet under Resources)

The SEM works much like a microscope connected to a television. Instead of shining light on the sample, it shines electrons on it (light bulbs give off both light and electrons), and instead of a glass lens (as in a microscope), an SEM has a magnetic lens made from coils of copper wire. The image an SEM creates shows up on either a television screen or a computer screen in the lab. SEM images allow users to "zoom in" to get a higher magnification of the substance.

SEM images are viewed live from your classroom—they are not stored images on a website. In our classroom, we had students come to our classroom computer in pairs to view the screen where we had accessed, via the Internet, the SEM images of salt and sugar. The students controlled which sample (sugar or salt) at which the SEM was looking.

We also printed the screen images and made handouts from which groups of students could work and we created an overhead transparency of the images to use for whole-class discussion. The SEM images of salt and sugar that we used for our handouts are shown in Figure 2.

Salt's structure is readily seen at low magnifications while sugar's structure is much smaller and more irregular in size and shape. It is only at higher magnifications that some facets of sugar as a "crystal" can be discerned, revealing the shape to be more complicated when compared to the cubes of the salt. The salt's consistency in appearance at all levels of magnification was different from sugar's more random-looking appearance. Through the SEM experience, students observed that the properties of the salt and sugar matter were different and ran quite deep.

Exceeding Expectations

When we began the experiment, we only hoped students would walk away knowing that sugar and salt "crystals" were quite different in appearance—and how to distinguish between the two substances.

We were thrilled to see that some students were able to take our lesson to another level.

Through observing salt and sugar samples with magnifying glasses, manipulating three-dimensional models of their geometric shapes, and finally observing salt and sugar with the SEM, our students were not only able to compare and contrast the two substances but also make more sophisticated statements about salt and sugar, laying the groundwork for their future physical science explorations. ■

Janet Sharp (sharp@math.montana.edu) *is an associate professor of mathematics education at Montana State University in Bozeman, Montana; Karen Hoiberg* (khoiberg@ames.k12.ia.us) *is a fifth-grade teacher at Fellows Elementary School in Ames, Iowa; and Scott Chumbley* (chumbley@iastate.edu) *is a professor of Materials Science and Engineering at Iowa State University in Ames, Iowa.*

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Internet

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