Talk Science

Professional Development

Transcript for Grade 5 Scientist Case: The Water to Ice Investigations

1. The Water to Ice Investigations Through the Eyes of a Scientist

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We met Dr. Hugh Gallagher in his office at Tufts University. Dr. Gallagher is an Associate Professor in the Physics Department and does research on subatomic particles of matter called neutrinos. We asked him to do some of the very same investigations your students do in the *Water to Ice* section of the 5^{th} grade Inquiry Project curriculum.

In these investigations, your students take a close look at two familiar materials: ice and water. Familiar as ice and water are, they raise some interesting questions:

- Are the solid and the liquid different materials, or the same?
- Are there properties, such as weight or volume, that *don't* change when the material melts or freezes?

This case focuses on the core science concept *matter.* Scientists use two different perspectives or scales to think about matter: the *macroscopic* and the *microscopic*. The *macroscopic* scale is the scale that is visible to the naked eye. Properties such as weight, volume, and temperature are known as "macroscopic" properties. On a microscopic scale, matter appears very different. On this scale, **matter is composed of discrete particles that are too small to see**. Scientists use the *microscopic* perspective to understand what we observe from a *macroscopic* perspective.

In their investigations, your students use a simulation we call the "particle magnifier" to zoom in and compare ice and water on a microscopic level. This is a new and very different perspective for your students. In these video clips, you'll see Dr. Gallagher describe what he observes when he looks at ice and water using the same particle magnifier that your students use, and how he uses this perspective to explain how water and ice are similar and are different. Knowing how a scientist thinks about the water to ice investigations on both a microscopic and a macroscopic scale will help you to listen to your students' ideas and support their learning.

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2. How Does a Scientist Compare Water and Ice?

Notice what Hugh observes that's different about ice and water and what he observes that's the same.

Sara: I made these two samples of water the ice. This is the same thing that the students do in the curriculum. I made two samples that have the same weight of water. And I put one in the freezer. And I'm wondering if you could tell me what's the same and what's different about them.

Hugh: Okay. Can I play with them a little bit?

Sara: Yeah.

Hugh: OK. The first thing that you notice – or that I notice – when you pick them up is that they don't feel very different. That's what you said: the weights were the same of the two when you prepared them. But this one definitely feels different. It's cold to the touch and this one isn't.

And it's a little bit harder to kind of tell but there is a volume difference between the two as well. When this water over here froze, it kind of changed its shape a little bit and now occupies more space than the one we have over here. And if you could look at these up close you can kind of see that that's the difference. And in particular there is a big block of ice inside here that is sticking up over the top that is taking up more space than just the water itself in this one over here.

Part of the question sometimes you ask is: Are water – liquid water – and ice different? For a scientist, they are not different; it's the same fundamental thing. It's water molecules in both cases, but they are arranged differently. In one case they are arranged in the liquid phase, liquid form, and in the other case they are arranged in a solid form, but it's the same kind of fundamental piece – building block – in both cases.

As a scientist when we look at objects like this, what we are talking about here are, sometimes we use the terms *macroscopic*. They are big things, they are things that you can see, that you can lift up in your hands. And the kinds of ways in which we would describe it and the ways in which we would measure its properties are things like the volume, the weight, and the temperature. So those were the three kinds of pieces that came into the story there in a couple of different places.

<u>Notice How</u>

- *Hugh uses **macroscopic** properties of volume, weight, and temperature to compare samples of water and ice.*
- *Freezing and melting change the form of matter from liquid to solid and back again, but they do not change the material.*

3. How Does a Scientist Interpret a Particle Model of Ice?

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Notice the difference between the properties that Hugh observes from the particle (microscopic) perspective and what he observes from the desktop (macroscopic) perspective.

Sara: This particle magnifier is set at minus 15 degrees Celsius, which is about the temperature of my freezer, and here we have a block of ice. And I'm wondering if you would click on the magnifying glass and zoom in and tell us what you see?

Hugh: Okay. All right, well what I see here are a simulation of the motion of the individual water molecules which is pretty cool, I think. And as a scientist this is a natural thing to look at because in the back of our minds when we are thinking about or talking about water or air, or almost anything, we can very easily switch into this picture as a mental model even if we are not explicitly talking about it or working with it.

Sara: So right now when I look at those I see red circles that are about a quarter of an inch in diameter and I'm wondering are ice particles red, are they circular, are they quarter of an inch in diameter?

Hugh: No, no they are not.

Sara: And I'm also wondering are they cold, are they hard, are they wet, are they slippery?

Hugh: Yeah. They are not. The terms that you just described -- used to describe a sensation or an observation of the *macroscopic* object -- aren't going to hold when we're working with the fundamental particles. Okay.

Again, they all have the same size. The sort of the physiological terms you're using -- slippery, wet, cold -- those aren't true at the microscopic level. The only thing that we could [say] --if we were going to try point to a particular molecule and say, "Okay, what is it that we could really say about that particular molecule that might be different from some of the others?"— would be: How is that molecule moving? What is its velocity at a particular point in time? But that's really the only thing that would differentiate it from any of the other molecules.

Sara: What about its weight? Do those particles have weight?

Hugh: They do, they all have weight and the weights are identical.

Sara: What is in between the particles?

Hugh: Nothing. Ice is made up of water molecules and nothingness: vacuum. So if we talk about the vacuum it's

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really hard to imagine, it's hard to kind of get our heads around, because it's not what we're... we don't physically experience it when we look at a particular object. It seems to have some kind of uniform density; the matter seems to be sort of equally distributed throughout whatever region of it that we look at.

But when we look at the microscopic level it is totally, totally different; the mass, the weight, the stuff. And we could, if we could break the molecules down even further, those molecules are made of atoms, atoms are made of other things, all of these little pieces are concentrated at very specific locations and space that are really physically quite small. And the space between the molecules is completely empty of any matter, any substance, anything.

Summary

- *Ice is composed of discrete, identical particles that have weight, are in motion, and are too small to see.*
- *The particles that make up an object do not have the same properties that we observe at a macroscopic scale.*
- *There is nothing between the particles.*

4. What Does a Scientist Notice When He Uses the Particle Magnifier?

Notice the changes that Hugh observes as he increases the temperature in the particle magnifier.

Sara: Would you start at absolute zero and work your way up, looking at the ice and then the water, and just talk about what you notice at each temperature?

Hugh: Okay. Well you picked a particular temperature here to start that if you look at it seems kind of arbitrary: minus 273 degrees Centigrade. Like, why that number? That's a really special temperature and the thermometer over here is labeled perfectly; it's absolute zero. And the thing that is really incredible about absolute zero is that it's the lowest possible temperature, it's the temperature at which all the motion at the microscopic level stops or is at its absolute minimum.

We go up [to -89 degrees C], we put energy in, they're moving it's still a solid but they're moving around a little bit. Up to minus 15 degrees C, more motion, more velocity on average for the molecules but still a solid.

So we go now above the freezing point, and now we're looking at something which is fundamentally different. There is a huge difference, the difference between -- we can even make this minus 2 -- the difference between

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what we're seeing between minus 2 and plus 2 is a world away from what we saw even going from minus 273 up to minus 2. Okay, and here the main difference is now our molecules they're not stuck to that same spot. They can move all around. If we follow one of these molecules, it's having collisions. I'm just trying to track this little one here; it just went off the screen. We can follow any one of them and eventually it's going to go, wander, all over the place here.

This is a fundamentally different kind of microscopic motion than what we had seen in all those other temperatures and that fundamental difference in behavior is what we call phase transition or phase transformation. So now we are looking at a different form of matter all together, and so we have gone from a solid to a liquid. And that aspect of it, that the molecules are no longer locked at sort of one location relative to their neighbors, is what characterizes the primary difference between a liquid and a solid.

Sara: Now are these particles the same as the ice particles? Are they the same weight, the same -- take up the same amount of space, the same spacing? Are there the same number of particles there?

Hugh: Yeah, so let me be totally clear on this aspect of it. When we talk about our particle model here, the particles themselves are never going to change no matter what we do to the temperature in these simulations. We can go from absolute zero, the solid form, above the melting point into a liquid form, increase the temperature more to the gas -- you know, to evaporation, the vaporization -- up into gas molecules, and at the molecular level nothing is changing.

Yeah, so as long as we're staying liquid now, as we're going up in temperature we're saying that, that's going to be just putting more energy in, it's just going to increase the energy that the molecules have. That's just going to make them move faster, and that's what we're going to see. We go up to 20 degrees C -- faster kind of motion of the molecules-- and then even more, up to 50 degrees C. And then that's where this particular simulation ends.

<u>Summary</u>

- *As the temperature increases, the average speed of the particles increases.*
- *When the material changes phase from solid to liquid, the particles remain the same but their position relative to their neighbors changes.*

5. How Does a Scientist Think About the Differences Between Ice and Water?

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Listen to how Hugh uses the particle magnifier to explain both how water is the same as ice and how water differs from ice.

Sara: So how does this particle magnifier help us explain the similarities between ice and water and the differences between ice and water that we see at a macroscopic level?

High: Yeah, the similarity is that both cases we have molecules and the molecules here they are not changing. They are all round red blobs. And that's representing the fact that our water molecules are the same in both cases: solid and liquid. The thing that does change is how they're – where they are relative to their neighbors in the motion they have. In the solid they have some motion but they are fixed, in fixed locations. And in the liquid they can move past their neighbors, they can move around in whatever volume the liquid as a whole occupies. So that's the main difference between the solid and the liquid and that's what we're seeing in the simulation.

Sara: Does it explain why the water and the ice weigh the same even though they seem like such different things?

Hugh: It does, it does because in both cases we are looking at the same number of red dots, the same number of molecules. And all the mass is in the molecules and they all have the same mass.

So, the really fun part as a scientist is understanding how this picture, how this world, relates to this world. How things that we can observe and measure about macroscopic objects allow us to infer things or to learn things or to build or discard models of the microscopic phenomena, and how having a model, a picture for the microscopic phenomena, maybe developing some theoretical tools or models or equations to describe it, how that might lead us to new predictions about what we might see for macroscopic phenomena.

<u>Summary</u>

- *The particle model allows scientists to understand macroscopic phenomena.*
- *Water and ice are composed of the same particles, so weight is conserved during freezing and melting.*
- *In liquids the particles can move past their neighbors, so liquids can flow while solids cannot.*