Chapter 3

I've Got a Theory About That

How do scientists explain observations?

In this section, you will come to see how

- scientists create different kinds of knowledge, and
- theories and laws serve different purposes.

You will be able to help your students

- make and test predictions,
- recognize data are different from their explanation, and
- plan science fair investigations.

In the last chapter, I discussed models—intuitive mental models students bring to the classroom and also models scientists use to explain observations. More than once I referred to the NGSS Appendix H understanding "Science models, laws, mechanisms, and theories explain natural phenomena." We often discuss these words as if they mean more or less the same thing. In everyday life, for example, we talk about a "theory" as an educated guess, perhaps a lightly tested idea that has not yet garnered enough support to be classified as a "law." It's as if there's nothing particularly different about a theory and a law, one just has more support than the other. With enough evidence, any theory could someday be called a law.

This always bothers those of us who study what science is and how science works. We recognize that science and scientists create fundamentally different kinds of knowledge. This means also that scientists—and students doing investigation activities—must also be using varied kinds of methods and skills. Science is not about a step-by-step linear method. No, science is more open-ended than that—more creative and more fun!

OBSERVING DIFFERS FROM EXPLAINING

To show you what I mean about different kinds of knowledge, consider this example. In 2012, *Harvard Magazine* reported on a study where researchers looked at data about violent behavior among high school students (Gudrais, 2012). The study's raw data were a survey completed by about 1,900 students. By itself, the information is just lines in a spreadsheet. But creative researchers recognized a pattern in the data, a correlation.

Key Takeaway

Finding patterns in raw data is a creative activity.

Students drinking a lot of sugary soda each week seemed to be more violent than those who did not. They were more likely to have behaved violently toward peers, another child in their families, and someone they were dating.

Our first thought is always to wonder why—why would kids drinking sugary beverages be violent? I can think of multiple ways to explain the pattern.

- Maybe all that sugar changes kids' behaviors; they get hyperactive, attention spans decrease, and impulsive behavior increases.
- Or maybe it's not that sugar leads to violence, maybe the violent tendencies came first—violent kids love sugar.
- Or maybe an environment that fosters violent behavior just happens to also be one discouraging healthy eating habits. Left unsupervised, children choose sweet sugary beverages and learn to resolve problems through violence.

The same generalization can be explained multiple ways. We cannot yet say one of the explanations is right and the other two are wrong. We have at least three explanations for the same data. The recognition of a link, or correlation, between sugary drinks and violence does not mean the drinks *caused* the violent behavior.

The raw *data* (survey responses), *generalization* that came from the data (sugar is linked with violence), and *explanations* for the generalization are *separate* things. They were created by different people, using different thought processes, and their validities would be tested different ways. Figuring out a procedure to test a question, interpreting the resulting data, and explaining any patterns observed, are different kinds of mental activities. You, your students, and individual scientists may very well be more skilled at one mental activity than another.

Testing whether the correlation is more generally true—remember, science strives for more general and universal ideas—would involve repeating the survey in other places. Testing whether soda *causes* violent behavior would need a different kind of study, perhaps testing the prediction that making non-soda-drinking children consume large quantities of soda pop would make them more violent than they were before drinking the soda, although that's so unethical and unlikely that scientists would ultimately need some other investigation to test the potential causal relationship.

Let's see how these same differences are illustrated during an investigation activity.

ACTIVITY 3

Melting Ice

Overview: Students are surprised to observe ice melting faster on metal than on wood or plastic. They go on to investigate how fast ice melts on other substances, looking for patterns.

Grades: Elementary students can focus on investigating the operational questions in Steps 1–5 if the abstract scientific explanation is omitted. Middle school students can benefit from the entire activity.

Time needed: 40–60 minutes. If time is constrained, students can observe Steps 1–3 or 4 one day and complete the activity the next day.

MATERIALS

- Small blocks of metal, wood, plastic, and any other insulators or conductors on which ice cubes can be placed in Step 5 (commercially made materials are available, but just about any pieces of metal, wood, or plastic will work OK)
- Ice cubes, bowls for holding the cubes
- Paper towels
- Scales or balances to ensure ice pieces are similar masses (optional)
- Infrared thermometer to confirm metal and plastic/wood are same temperature (optional)

INSTRUCTIONS

1. Show students blocks of metal and either wood or plastic. If it's at all possible, let the students touch the materials, too.
2. Pull out a bowl of ice cubes and ask students what they think would happen if an ice cube was put on each block. Ask the students whether they think (a) the ice on the metal would melt fastest, (b) the ice on the wood or plastic would melt fastest, or (c) the two cubes would melt at the same rate? Follow up by asking, "Why do you think so?"
3. Having solicited predictions, ideas, and explanations, it's time to find out what actually happens! Whether as a teacher demonstration or students trying on their own, put ice on metal and wood, observe, and have students make notes on observations. (Perhaps first reminding students science is about finding answers via investigations.)
4. Discuss with students what they observed and what they think is going on.

5. Provide students with ice, metal, and wood (or plastic). Beside metal and wood or plastic (for example you can use metal pots and plastic cutting boards), give them other materials onto which they can put an ice cube, such as a variety of metals (conductors) and materials like plastic, glass, and/or ceramics (insulators). Task students with figuring out which materials melt ice quickly and which do not.
6. Group student observations and findings to introduce the concepts of conductors and insulators. Older students can also be introduced to the scientific explanation.

What's Happening? Heat is conducted more efficiently to the ice from conductors, like metals, than insulators, like wood, plastic, and glass.

NGSS Connections: Performance Expectation MS-PS3-4 says students who demonstrate understanding can plan an investigation to determine the relationships among the energy transferred, the type of matter, the mass, and the change in the average kinetic energy of the particles as measured by the temperature of the sample.

TRY IT!

Although technically not a 5E or learning cycle, this lesson incorporates elements of the model. When students observe the unexpected differences in how ice melts on metal and wood or plastic (Step 3), they're *engaged* in the lesson. They continue on to *explore* ideas for themselves (Step 5). The teacher then gathers students' observations and ideas and *introduces new concepts* (conductors and insulators for younger students; energy transfer, as well, for older students) that students have experienced for themselves (Step 6). I don't discuss it here, but to make this activity a full-fledged 5E or learning-cycle lessons, students would go on to use their learning in a new context, which could range from answering application questions to solving problems or even another hands-on activity about heat conduction.

TEACHING TIPS

Step 1: See if students notice that the metal block feels colder than the plastic one. It's unintuitive that the two items will actually both be at room temperature (an observation confirmable, eventually, via an optional infrared thermometer). There is no need to share temperature info with students yet, though.

Step 2: This step (combined with the previous) is ultimately about getting students to think about and commit to a prediction, based on their ideas about what will happen. Some teachers like to solicit verbal responses from individual students, some prefer students write their predictions, and some prefer students discuss their thinking in pairs or small groups before committing to an outcome. Whichever method is used, however, I suggest

- soliciting responses from multiple students, and
- following up by asking "Why do you think so?"

These are ways to increase participation and better understand student thinking. Understanding students' preconceived ideas is the starting point for conceptual change.

Steps 3: As with any demonstration or investigation activity, you should have already tried this for yourself. Most of us would predict we would see two ice cubes slowly melting. Because the metal feels colder to the touch than plastic, wood, or ceramic, we might predict ice would melt a bit slower on the cool feeling metal.

Key Takeaway

Try investigation activities on your own before teaching them to students for the first time.

Quickly, however, it's clear the ice is melting faster on the metal than the plastic or wood. Science educators call demonstrations where results fly in the face of expectations based on common sense ***discrepant events***. Common sense often predicts something different than what's observed. Seeing such a marked difference in the rate ice melts is, for most of us, a discrepant event. (Watching milk swirl in the Milk Fireworks activity is also a discrepant event.)

A discrepant event is a demonstration that produces an unexpected outcome, something differing from what students' previous experiences would lead them to believe was true.

Step 5: Students now go on to do their own investigation activities, examining how ice melts when put on top of various materials, after trying the demo out on metal and plastic or wood, replicating what the teacher did. Trying out the procedure the way the teacher did, and getting similar results, serves as a kind of check for understanding that students understand the procedure you'd like them to follow. Students might even test the possibility of a sneaky teacher trick by moving the unmelted cube on the wood over to the metal—only to find the cube now starts melting faster than it was on wood. After observing cubes on metal and wood or plastic, however, they take over and try the procedure out on new materials.

This would be a good activity for pairs or, possibly, groups of three students. Larger groups might go off task as too many students don't really have anything to do.

One of the things you can do during the activity is provide guidance by discussing with students what they would need to do to assure their test was "fair," like making sure to choose two ice cubes that seem identical. Indeed, students might have other ideas they would like to test.

Throughout the investigations, the teacher's role (beyond managing the classroom) involves

- asking students about what they're doing ("Tell me about what you're doing"),
- accepting their responses ("OK"), and
- following up by asking students to explain their procedures ("Why did you decide to do that?" or "What were you trying to find out?"), which spurs further conversation.
- The teacher also can provide subtle hints to help increase the chances investigations are fruitful. Often this involves asking students to make predictions. ("Suppose you were to do ___. What do you think would happen? . . . How can you find out?").
- Interacting with students also allows the teacher to tell students explicitly how their actions parallel those of other scientists (pointing out when students are engaged in science practices), teaching students lessons about what science is and how science works.

Key Takeaway

These teacher behaviors are useful and suggested for just about all investigation activities.

Students will presumably come to accept—as a conclusion to their experiments—the general pattern or description that ice melts faster sitting on metallic materials than plastic, wood, ceramic, or glass materials.

WHAT'S GOING ON IN THE SCIENCE?

Disciplinary Core Ideas PS3A and PS3B are about energy and its movement from place to place. MS-PS3-4's clarification statement mentions experiments with ice melting and the cooling or heating of various materials:

> Examples of experiments could include comparing final water temperatures after different masses of ice melted in the same volume of water with the same initial temperature, the temperature change of samples of different materials with the same mass as they cool or heat in the environment, or the same material with different masses when a specific amount of energy is added.

At the end of the activity, we are all still left wondering *why* ice melted faster on metal than on wood or plastic. The generalization about materials on which ice melts faster or slower is a different type of knowledge than the accepted explanation underlying the observations. It's an explanation that cannot be directly developed via hands-on classroom activities. As with many scientific explanations or models, things quickly get abstract.

Many other observations and generalizations have led scientists to accept an overarching explanation—a scientific theory, actually. It starts with a model in which everything is made of invisibly tiny particles constantly moving around (molecules, atoms, etc.). It's part of the same model we used to explain what was happening with voltage and current in electrical circuits.

The explanation includes the idea that energy is being transferred from the metal or plastic to the ice. The way it's modeled, when objects hold a lot of (heat) energy—when they are warmer—the particles making up the objects are moving or vibrating more than those making up objects holding less (heat) energy (National Research Council, 2012, p. 120).

When molecules collide, they transfer energy; when a fast particle hits a slow particle, the fast particle ends up moving a little more slowly and the slow particle ends up moving a little faster. In the case of our ice, the chunks of metal and plastic are warmer—their molecules, on average, are moving around faster—than those of the ice. When the faster moving particles meet the slower moving particles, the resulting collisions leave ice particles moving a little faster (the ice warms) and the metal and wood particles moving a little slower (the metal and wood cool). Scientists call the process (heat) *conduction*.

The same explanation predicts and explains why conduction depends on temperature differences, how large the items are and how much of them are in contact with one another, what else is in the surroundings, and—last but not least—properties of the materials themselves. Some objects are really good at transferring heat energy—they are good heat conductors—others are not. Metals, as it turns out, are good heat conductors; plastic and wood are not.

As one might predict (and test) from this model, if few particles are bouncing around, a substance would be a poor heat conductor. Vacuums don't conduct heat at all, and gases (with many fewer particles per unit area than liquids or solids) are usually poor conductors. Double-pained windows with little or no air in between the panes are very poor conductors—that means they do a great job at making sure heat energy does not leave your home. Similarly, fur, feathers, and "puffy" fibers trap air, and air is a poor conductor, so these materials do a good job keeping warmth from escaping on a cold day!

CONNECTIONS TO THE NATURE OF SCIENCE

Watching the ice melt, we all ask the same questions, whether scientists or children: "Why?" "What's going on?" We observe something unexpected, cool, or otherwise personally intriguing (a pattern, generalization, or similar description), and we wonder why (i.e., search for an explanation). We wonder why the ice melted faster on the metal, why soda pop consumption is linked to violent behavior, and why the milk swirled (Chapter 1). In each case, we try to explain what we observed. And just like recognizing a pattern amongst soda pop drinkers is different than explaining the why behind the pattern, recognizing ice melts faster on metal than wood, or milk swirls faster when it's warm, is different than explaining the why behind the pattern.

It may seem seamless, but three separate mental processes are actually going on here. Watching the ice melt is collecting data, noticing differences in how it melts on different surfaces is analyzing and interpreting data, and trying to explain the mechanism behind what's going on is another kind of interpretation.

NGSS Connection:
SEP4 Analyzing and interpreting data

When scientists wonder why, and think about explanations, they must ultimately go a step further and test their explanations. Thinking about what's happening leads to other investigations. In school, science investigation activities end cleanly. Exigencies of schooling regularly prohibit anything else, but this is one way school science often differs from the activities of scientists.

For scientists, data from one investigation often lead to another question for another investigation. If students move from observing a demonstration to planning and carrying out their own investigations, they are more accurately acting like professional scientists than typically seen in school science experiences. In the case of our ice melting investigation activity, when students consider what they think will happen when they put ice on different materials—when they make predictions, in other words—and then create tests to find out whether observations support their ideas, they are mimicking scientists, while learning themselves. If results testing one question lead them to try something else, that's even better!

Key Takeaway

Investigations often lead scientists to new questions and investigations.

PRACTICES IN PRACTICE

Although student investigations *always* involve multiple SEPs, the performance expectation I mentioned in connection with this activity (MS-PS3-4) begins with "Students who demonstrate understanding can plan an investigation to determine the relationships among. . . . " This is a reference to SEP3 *planning and carrying out investigations*. Students working on investigations where they are trying to learn more about how or why ice melts at different rates on different materials are asking investigable questions, planning and carrying out investigations, and—when they see what happens—analyzing and interpreting their data.

NGSS Connection: SEP3 Planning and carrying out investigations

In general, students will be more successful planning and carrying out investigations if the data they collect involve something both tangible and familiar. Everything students use in this investigation activity (as well as others in this book) should be familiar to most students. That said, NGSS's Appendix F provides additional clues about differing expectations for students in Grades 3–5 vs. 6–8 regarding this practice:

- **In the 3–5 classroom:** Generally speaking, younger students will need more teacher structuring than older students. They can understand, plan, and carry out investigations involving fair testing, which means at some level they can understand the concepts of controlled variables and the need to consider how many times a test has been repeated. They can also make predictions about what they believe would happen if a variable was changed, and then carry out investigations to test their thinking. (In this activity, comparing equal sized pieces of ice would be an example of a controlled variable that makes tests more "fair.")

- **In the 6–8 classroom:** All else being equal, older and more capable students can plan and carry out investigations at a slightly more sophisticated level and with less teacher structuring than their younger counterparts. Instead of talking only about fair testing, Grade 6–8 teachers can discuss independent and dependent variables, as well as controlled variables. The ***independent variable*** is the thing you are testing or changing, and the ***dependent variable*** is the thing you are measuring or observing as a result of changing the independent variable. In this investigation, the wood, metal, plastic, etc. is the independent variable, and ice-melting speed is the dependent variable. ***Controlled variables*** are the things you consciously keep the same to make your tests fairer. Older students are also more capable of evaluating different ways of collecting data.

Independent variable is the factor the experimenter is consciously changing or testing; it's the thing he or she is trying to find out about.

Dependent variable is the measurement or observation being recorded as a result of changing the independent variable; it's the experiment's outcome data.

Controlled variables are factors in an experiment the experimenter consciously keeps the same to assure a fair test; ideally, the independent variable is the only difference between groups being tested.

ADDENDA: THEORIES, LAWS, AND HYPOTHESES

As a Grade 3–8 teacher, it probably meets expectations if your students leave school recognizing the difference between observing, seeing potential patterns or generalizations, explaining what was observed, and recognizing that continued curiosity spurs further investigation. This differs from a caricature of science where scientists always follow a rigid multistep method, get a result, create conclusions . . . and call it a day. That's an unfair exaggeration, but it's one my colleagues and I often hear.

As a teacher, however, you need deeper understanding than your students. You'll feel more comfortable, more confident, more able to pay attention to your students' needs if unconcerned with your own understanding of what you are teaching.

I started the chapter by mentioning the NGSS nature of science understanding that "Scientific models, laws, mechanisms, and theories explain natural phenomena." Now I can return to it and connect it with my discussion of the melting-ice activity. When we say ice melts faster on conductors than insulators, we're actually expressing a scientific law (or at least a law-like statement). And our explanation, the one with invisibly tiny particles (atoms or molecules) bumping into each other, is based on a scientific theory.

Key Takeaway

Scientific models, laws, mechanisms, and theories explain natural phenomena.
—NGSS Appendix H

Scientific theory is a broad explanation for some aspect of the natural world; strong theories are well substantiated by their abilities to explain and accurately predict a wide range of phenomena.

Scientific law is a generalization or description of repeated observations.

A ***scientific theory*** is a broad explanation encompassing lots of data, while a ***scientific law*** is a generalization or description of data. Among other things, scientific theories explain laws. They are different things.

This may be a bit confusing if you were taught that hypotheses are tentative untested ideas, theories are hypotheses that have been tested a little, and laws are hypotheses that have been tested a lot—hypotheses become theories, and theories become laws. But, really, that's just plain wrong. The words may be used that way *outside* science, but they have different meanings *inside* science.

Let me show you what I mean. Here's a list of some well-known scientific theories:

- The theory of evolution via natural selection
- The Big Bang theory
- The theory of relativity
- Quantum theory
- Plate tectonic theory
- Climate change theories
- The germ theory of disease transmission
- Cell theory
- Atomic and kinetic-molecular theories (underlying the explanations about our melting ice and electrical current)
- Gravitational theory

Key takeaway

A scientific theory is a broad explanation, while a scientific law is a generalization or description. Descriptions and explanations are different things.

What stands out in lists like this is how important the ideas are to their disciplines. Geology is almost entirely based on plate tectonic theory, chemistry on the atomic and kinetic-molecular theories, the infectious disease branch of medicine on the germ theory, etc. These are not educated guesses or lightly tested hypotheses.

Scientific theories stand at the roots of their disciplines. They are the big ideas, the broad *explanations* that withstood all sorts of testing. I used the kinetic-molecular theory when explaining both conduction and melting ice, and also electrical current. Scientific theories guide and influence how scientists understand, explain, and think about their disciplines. The best theories even allow scientists to make testable predictions about things no one has yet observed.

The *Science Framework* that guided the development of NGSS accents not only the importance of scientific theories, but also the recognition theories are broad explanations:

> The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when

> it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. (National Research Council, 2012, p. 52)

What is it these theories are explaining? They are explaining all sorts of generalizations, and the generalizations are what we mean when using the term *scientific law*.

A scientific theory can never become a scientific law, because they are different things. Generalizations ("Metals are good heat conductors, plastics are not"; "children drinking sugary beverages show violent tendencies") and explanations of the generalizations are different kinds of knowledge. So, the Theory of Evolution by Natural Selection will never be renamed the "Law of Evolution by Natural Selection" and geology's Law of Superposition was never called the "Theory of Superposition."

Key Takeaway

Scientific theories never, ever turn into scientific laws.

Like theory and law, the word ***hypothesis*** is sometimes used differently inside and outside science. Like most of my peers, I define the term hypothesis to refer to scientific claims that have not yet been put to the test. Untested theories and untested laws start as hypotheses.

Hypotheses are investigable scientific claims; they can be theory-like explanations or law-like generalizations.

Returning to Chapter 1, when students observe the Milk Fireworks demonstration they may notice what they believe are patterns in how and when the milk swirls. They are forming hypotheses. If they and their peers test and retest a hypothesis we might say it's now a scientific law (or, more accurately, a law-like statement; true laws usually cover a wider variety of observations). Gifted students who learn about surface tension, the properties of water, and explanation for the swirling behavior that involves characteristics of water molecules would be learning about the scientific theory explaining a scientific law.

ONE LAST EXAMPLE: SCIENCE FAIRS

Schools sometimes use the word *hypothesis* as if it's synonymous with *predictions*. I think this probably comes out most strongly during science fair season. For those of you helping students with science fair projects, I end the chapter by considering examples of science fair questions students could investigate, assuming the students were then instructed to record their hypotheses, procedures, and results. Remember, the ***hypothesis*** is the general or overarching scientific claim

Key Takeaway

Hypotheses, when tested, lead directly to predictions—but they are subtly different things.

being investigated. The *prediction* is what the student thinks will happen when a specific investigation procedure is followed. I googled "science fair questions," and the first hit I got included these three questions:

1. Where are the most germs in your school?
2. Which brand of paper towel is the strongest?
3. Do athletic students have better lung capacity than nonathletic students?

There are lots of hypotheses and predictions you might have considered for each of these questions. Here are examples I came up with.

1. "Where are the most germs in your school?"

A student could say "I think the most germs will be in the bathrooms." This is a *prediction*.

When a student provides a prediction, asking "Why do you think so?" will often help the teacher elucidate an underlying hypothesis in the student's mind. In this case, an underlying hypothesis being tested might be that microorganisms grow most efficiently or quickly in warm, moist places. If this (law-like) hypothesis is supported, we would predict that when samples are cultured from around the school, the most germs would be found in bathrooms, kitchens, and any other comparatively warm and moist spots.

Key Takeaway

Results are not scientifically bad or wrong just because they are disappointing.

Parenthetically, to get away from the common "I was right" or "I was wrong" attitudes students often have after performing their investigations, an alternative is for students to initially consider *two* or more possible investigation outcomes and what they would mean. In the current example, one outcome from the student's investigation might be more microorganisms in the kitchen and bathroom than anywhere else, supporting the idea germs grow well under these conditions. Another outcome could be the data showing the kitchen and bathroom *not* having more microorganisms than anywhere else, seemingly supporting the idea microorganisms grow best under other conditions. Both outcomes are scientifically valid and important; both outcomes can lead to further investigations. Results other than those hoped for may sometimes be disappointing, but they are not "wrong."

2. "Which brand of paper towel is the strongest?"

Instructed to "write your hypothesis," a student jots "I think <Brand1> is the strongest." As before, this is actually a *prediction* and, as before, it's tied in with the details of the investigation procedure the student is going to use. Asked why she picked Brand1, the student might say "because it's the thickest." The student may believe thicker paper towels are stronger than thinner towels. This is the (law-like) *hypothesis* the student is testing. As in the last example, the student could begin her investigation with two or more possible outcomes in mind, considering what each would mean about paper towel strength.

3. "Do athletic students have better lung capacity than nonathletic students?"

The student wants to investigate the *hypothesis* regular athletic activity increases lung capacity. The student's procedure might be to have athletes and nonathletes blow as much as they can into bags, measuring the volume of expelled air, and the student might *predict* athletes' lung capacities would be higher than those of nonathletes.

Keep in mind, when data support a hypothesis it does not mean the hypothesis has been proven right. As in the case of the violent soda pop drinkers, *other* hypotheses could also be supported. Maybe musicians playing horns, trumpets, and other wind instruments have large lung capacities—even if they are nonathletic. The same data might be explained multiple ways, since data and its explanation are different things. The marching band playing at half-time may have stronger lungs than the football players! Of course, the only way to know for sure would be . . . another investigation.

CONCLUSION

In the previous two chapters, I've discussed how science is based on observations, empirical evidence. Our intuitive commonsense understandings of the world are also based on evidence. Science, however, differs because it's also interested in general, universal truths (laws) and broadly applicable, overarching explanations (theories).

NGSS's Appendix H says "scientific investigations use a variety of methods." This chapter helps explain why that is so. Scientific investigations use a variety of methods because science is ultimately about generating and investigating a variety of knowledge types. Each requires subtly different skills, talents, and abilities. Science is a more diverse activity than sometimes portrayed. This helps make it fun and interesting.

The next chapter continues with more discussion and detail about science's different methods, distinguishing differences in how generalizations (laws) and explanations (theories) are tested.

Key Takeaway

Scientific investigations use a variety of methods. —NGSS Appendix H

Additional Resources

To learn more about this chapter's demonstration and its scientific explanation, see the chapter "Party Meltdown," pp. 105–112, in Richard Konicek-Moran's *Everyday physical science mysteries: Stories for inquiry-based science teaching*, Arlington, VA: NSTA Press, 2013. Konicek, with Bruce Watson (1990), also wrote a wonderful article about heat, temperature, and conceptual change. The Nuffield Foundation has a nice lesson plan online at www.nuffieldfoundation.org/sites/default/files/files/Melting%20ice%20-%20merged%20PDF.pdf; note how the activity described here is slightly different from the Nuffield version.