[MUSIC PLAYING]

SPEAKER: In this video, we show the practices that support ongoing changes in student thinking. The first of the practices is introducing ideas that students can use to reason with in the upcoming activity. This is an interactive form of direct instruction.

The second is engaging students with an activity that generates observations or data. The second practice requires that students use the introduced ideas from the previous practice to reason with. The third practice is using this new knowledge to revise models and explanations for the angering event. This set of practices would be used four or five times throughout the middle of a unit to help students make cumulative sense of activities, investigations, and readings.

We'll draw examples from a high-school class studying ecosystems, a middle-school class examining the energy story behind phase change, an upper-elementary class constructing explanations for how sound works, and a teacher education class investigating the gas laws.

One goal of this set of practices is to help all students elaborate on and revise their thinking about a natural phenomenon. To do this, students need investigative experiences, the infusion of new science ideas, and opportunities to talk out how these concepts and experiences might inform their current explanations.

Another goal is to involve all students in scientific practices. We want to help them develop questions and investigations that would lead to conversations about claims, evidence, and how a community of thinkers learns to argue together as some ideas gain credibility, and others are left unsupported.

Students can only go so far in theorizing about a phenomenon without having new science ideas introduced by the teacher. They can see patterns and relationships. But they cannot invent what is unobservable.

Teachers can provide access to new ideas, like sound compression waves or carrying capacity in ecosystems, by presenting these orally, by showing video, by having students read, or most often, a combination of these. In a moment, we'll show you different ways that teachers combine the introduction of new ideas with science activity.

SPEAKER: What do you guys thing about that?

SPEAKER: We want to acknowledge here that the research is inconclusive about whether the introduction of new ideas should always precede investigative activity. The most productive teaching we've seen allows students to initially engage with materials and activity, puzzle about what they're observing, then be presented with a new science idea. This concept allows students to then return to the activity, design new kinds of investigations, and reason in new ways about the outcomes. The new ideas are not presented simply to be confirmed by the activity.

Before we show examples of teachers involved in the practices of introducing an idea and engaging students with data, we'll describe a wider range of work that students could participate in. There are many things in a classroom that could be classified as an activity. Only a subset of these are actual investigations that could be designed by students with data collection and analysis to follow.

Nonetheless, we list here all different kinds of engagements with materials and ideas that could happen and have the potential to stimulate learning. Perhaps the richest opportunity to engage in several scientific practices is to support students in designing investigations where they collect and analyze their own data.

Students can also work with secondhand data-- in this case, the population fluctuations of different animal species that inhabit the Antarctic. Students can also do paper-and-pencil tasks that simulate real data collection-- in this case, using cups of beans that represent energy and how it gets passed from one trophic level to another in an ecosystem.

Students could use a computer simulation to generate data that could otherwise not be collected-- in this case, the gravitational attraction of stars, planets, and moons. Proof of concept demonstrations can be used to show some relationship or fact-- in this case, a representation of buoyant forces.

Students can use paper-and-pencil activities also to develop conceptual understandings-- in this case, how a watershed is determined by the topography of the land. And finally, students can act out science concepts with their bodies and interactions-- in this case, how sound energy is passed through air molecules.

In Carolyn's fifth-grade unit on sound, she introduces the idea that air is made of particles and that sound is roughly the bumping of these particles together.

CAROLYN: At least one thing that you just learned about air.

[CHATTER]

One thing. Yeah?

SPEAKER: They're always moving.

CAROLYN: They're always moving. Do you guys agree with that?

SPEAKER: Yes.

SPEAKER: She then takes her students to the playground to measure, with decibel meters, the loudness of an air horn at different distances and different directions.

CAROLYN: Are you ready?

ALL: Yes.

SPEAKER: I'm not saying that you got it.

[AIR HORN BLOWING]

SPEAKER: Students consolidate this data. And Carolyn realizes that the data in table form is not helping students visualize and communicate about the results. She creates a representation that does prompt sensemaking talk by students. One group of students theorizes that sound must travel like ripples in a pond. The next day, the teacher returns to the playground. And students record the sound behind the air horn. Carolyn and some visiting educators press students to make sense of the findings and to decide which of their initial models this new data supports.

This is Anna's seventh-grade classroom the day after they had created a consensus model of the soft-drink distillation. She spells out explicitly what scientific modeling is to her students. She expresses that ideas in her classroom are expected to be shared, critiqued, and revised over the duration of the unit.

ANNA: So we're going to try and come up with a bunch of different reasons why this stuff is happening. We're going to post it in the room. And as we learn more about what's going on, we might say, oh, that wasn't true. We're going to take that Post-it off. Or we might put a big star on Post-its that have ideas on them that we've verified with labs and readings and stuff. Or we might add more information or add Post-its even. So this is going to be something that's up in our class this entire unit.

SPEAKER: Several days later, one of her students tells her about a phase change occurrence that related to the unit on distillation. Anna shifted her instruction to center on this girl's experience.

ANNA: OK. So Kayce asked this question the other day. She went to Starbucks. This is real. This is not made up. She went to Starbucks. She got an iced drink because she's lucky.

She set it down on the table. And a few minutes later, she realized that the outside of the cup had water on it and that there was a puddle forming on the table. So her question was, where did that water come from? And how did it get there? So what is that little puddle that forms?

SPEAKER: Anna realizes that if her students don't grasp that water molecules are in the air and normally moving too fast to aggregate into visible droplets that they will not be able to reason productively about the distillation. She decides to show a video on condensation but only after she engages her students in a brief activity. Before the activity, she asks her students to take a stand on two questions.

SPEAKER: [INAUDIBLE]?

ANNA: Say yes or no. Henry is going to make a guess. And he's going to say inside or outside. Inside or outside.

SPEAKER: Anna then provides students with a sealed jar of water with red food dye and ice cubes and asks them to talk about what happens over the next few minutes. In this teaching practice, one critical routine is to circulate among groups of students and draw their attention to things that they may have overlooked, to get them to talk to one another about their emerging ideas, or to challenge their thinking. Anna demonstrates how this is done with a group of students who are puzzled about where the water on the outside of the jar is coming from.

ANNA: Is this water on the outside that I feel because it feels wet? Is that coming from inside the jar?

SPEAKER: No. It's coming from outside of the jar.

ANNA: How do you know that [INAUDIBLE]?

SPEAKER: Because you said if it comes from the inside of the jar--

SPEAKER: Don't do that. Don't say it out loud.

SPEAKER: So [INAUDIBLE] said, if [INAUDIBLE].

ANNA: OK. Hannah, what do you think?

SPEAKER: It is.

ANNA: It is what?

SPEAKER: Inside.

ANNA: So how can you explain that it's not red if it's coming from the inside and the water inside is red?

ANNA: Because the water on the outside is clear.

SPEAKER: Exactly. It's coming from the outside. It's not red.

SPEAKER: [INAUDIBLE] which is coming from the inside.

SPEAKER: It's clear. It can't come from the inside unless it'd be red.

SPEAKER: No, but it's cold. And then it's--

SPEAKER: It's cold on the outside.

SPEAKER: The coldness makes it like--

SPEAKER: It's from the inside, but the ice is melting it. It makes it white on the outside. So when the ice melts, it'll make the water different. If it's with food coloring, and the ice will melt. And from the outside, it'll be a different color.

ANNA: What do you mean?

SPEAKER: If that ice melts, I think that-- if that melts-- it's melting. So that's why the color is that. It's clear.

ANNA: So are you suggesting that this ice when it melts gets collected down there?

SPEAKER: Yeah.

ANNA: So how is it getting there?

SPEAKER: But there's no hole or anything at the bottom, even if it was like collecting it.

ANNA: Do you remember the experiment you're talking about that we did? Can you explain what we did in that experiment?

SPEAKER: We heated it up. Inside was soda in there. And it was a solid.

SPEAKER: After the activity, students are given blue sticky notes and asked to vote a second time for where they think water from Kayce's Starbucks cup came from. Their sticky notes have to provide reasoning and evidence for the choice they've made.

In my secondary science methods class, we are studying the gas laws. I show another way that new science ideas can be introduced through readings and, in this case, a set of jigsaw readings about unobservable features of gases. I then demonstrate how a metal bottle can implode, just like the railroad tanker car, under certain conditions.

Following this, we wonder together if there are conditions that we can test that might tell us more about the tanker. I remind my students that what makes science modeling so powerful is that models help you see gaps in your understanding and to pose testable questions. My novices are, in fact, required to tell me how their investigation is motivated by an uncertainty with part of their model. Only then do I give the go-ahead for the investigation.

So you're all trying to come up with testable questions. Testable questions in authentic science come from models that scientists have. And the models like you have on your table are examples of those. And I want you to think about, what kind of question can you develop that's going to help you understand this model? And make revisions to that model, or add something to that model.

You've got a test that will help inform what you're thinking about here in the model. So tell me about that.

SPEAKER: Well, we were thinking if we fill one bottle up with some water and heat it up and do the test like you described it, when we heat it up and put the top on it, put it in the cold water, and then heat up another bottle that doesn't have any water in it, and do the same thing.

SPEAKER: Because then we can look at the steam inside. And that'll help clarify that there is steam inside and the role that steam plays in the tanker crushing.

SPEAKER: Yeah, but look. See how far in that is? That wasn't that far in.

SPEAKER: And that's the one that had water in it?

SPEAKER: And that's the one that had water in it.

SPEAKER: During and after the investigation, I circulate and use some back-pocket questions to probe their thinking.

[CHATTER]

Jesse, you want to show me-- you can use any one of the three pictures here. Do you want to show me what about this is something like the bottle in the experiment you want to run?

One lap around the room by me is used to ask them to reason about the activity itself. The second lap I make around the room is to look for two or three interesting theories that I want to make public during the subsequent whole-class discussion.

The third practice in this set is using new knowledge to make revisions to students' models and explanations. From the images we've shown so far, it is likely very clear that modeling and constructing causal explanations are the two scientific practices at the heart of ambitious science teaching. The lessons we've shown here often last two or three days.

At the end of that time, students are asked to document what they think they now know and how it might influence their thinking about the anchoring event. One tool we use for every unit is the summary table. This is Anna's version of it. Each row represents an activity or investigation.

On the left side of each row is a simple description of the activity. The next column is a brief statement about what patterns or trends emerged from the activity. The third column is an attempt to explain why the investigation turned out the way it did. And the fourth column asks students to link the activity with the larger anchoring event.

Here, Anna describes her own color coding of these columns. She wants students to do this work. She refers here to an activity her class had just done on thermal conductivity and how heat traveling down a metal rod had caused wax to melt on the far end of it.

ANNA: So we're going to start our summary table for the activity we've spent the past few days on. So if you choose to do a green paper, green is making a model. So you're drawing and labeling a picture of the toothpick and candle activity. And you need to draw zoom-ins of the metal. So you want to draw a zoom-in of the metal as it's heated and a zoom-in of the metal on the opposite end from the flame.

If you choose pink, you are writing down your observation that you had during that activity. So what did you see happen to the toothpicks when we heated the metal? Just straight up what you saw. No explanation yet.

If you choose yellow, now you're explaining. So you're explaining why the toothpick closest to the candle fell first. You have to use the word "molecules" in this answer and this ongoing list of words that all my classes have been making. Heat is transferred just like dominoes. We've got fifth period saying it's like zombie tag. I want you to use those ideas to explain why that first toothpick fell.

And then last is purple, making that connection back to our Coke and 7up lab. So if our heat source is the flame heating the metal, we can compare that to the hot plate heating the flask and the frozen soda.

SPEAKER: Another of our teachers, Bethany, uses a variation of the summary table with her high-school class. In the final two columns, students are asked to record whether the activity or investigation provided supportive evidence for their hypothesis of the anchoring event or whether evidence supported other hypotheses their peers had developed.

Carolyn knows that elementary-aged students might be overwhelmed with a summary table that contains such density of information. As her students share what they've learned that day, Carolyn records information similar to that in Bethany and Anna's classrooms but on separate pages a poster paper.

CAROLYN: Like, the air molecules bumping is something that we learned. This idea of a strong bump maybe being a louder sound, and a soft bump being a quieter sound, I think is important to remember.

SPEAKER: In my methods class at the university, I use the summary table but then also use another strategy for directly revising models. This strategy you see here was invented by one of our novices several years ago and has proven very successful with students from elementary through high school.

You have models in front of you that you created a few days ago. And so the reason you produced the models was just so that you can make your thinking visible to yourself, to your partner, to me as a teacher. But now since you've created those models, we're going to do what scientists often do when they learn more information, when they test ideas. They want to go back and change different parts of their models.

And so we're going to change these models in systematic ways, not just redraw all over them. So we have four choices for how we're going to redo our models. If you want to pick a green sticky here, you can choose to revise a part of your model.

If you want to use that sentence frame, you can. We think some things supports part of our model, but we would like to change, and then you fill in the blank in order to make our model more accurate. You can use that sentence frame if you want. If you want to do that, you pick a green sticky.

If you want to use an orange sticky, that is adding an idea. If you want to pick a blue sticky, that is you want to remove some idea you have there. You don't have to cross it out. You can just put the sticky on and say, take this away. And then the purple one is we have a new question that we didn't have before.

Which one did you think is key? That you may have overlooked something or you didn't put two and two together.

SPEAKER: The tanker is closed.

SPEAKER: We talked about forces inside and outside the tanker. But we didn't-- and we kind of vaguely tried to talk about pressure. But we didn't really talk about where there's low pressure and where there's high pressure. And so that's what these two are adding, that there's low pressure inside as it's starting to crush [INAUDIBLE] outside. And then it's equal here. And then we're not quite sure up here if there's higher pressure inside than outside or if they are equal.

SPEAKER: In this video, we've seen the three practices that support ongoing sensemaking by students around an anchoring event. The variations in how the practices play out in different classrooms is noticeable. But having a practice-based vision of ambitious science teaching means there are important similarities.

In each of the classrooms we visited, students understand that every activity they do is intentional. It's designed to support their understanding of big ideas. Teachers in these classrooms treat students' ideas as legitimate science and, at the same time, reinforce that ideas in science always change in response to new evidence.

Every student is helped to participate. And tools used by the teacher that make thinking visible make participation easier for a wider variety of students.

[MUSIC PLAYING]