NINE

CORE PRACTICE SET #3

Supporting Ongoing Changes in Thinking: Activity and Sense Making

SCIENCE ACTIVITIES ARE a blessing and a curse for learning. On the positive side, students love to work with materials and to socialize with each other in the process. They see abstract ideas come to life through lab work, satisfying the basic human instinct to "try stuff out." On the negative side, some activities can be tedious exercises that amount to little more than filling out work sheets. They may have nothing to do with what students are currently learning, or can be so scripted that no decision making or critical thinking is required.

In this chapter we describe what meaningful activity looks and sounds like, by sharing strategies and tools that deepen students' understanding of science ideas while involving them in authentic disciplinary work. The teaching practice, aptly named, is *engaging students in activity and sense making*. We begin by naming different types of student activity that support learning. Our collection is not exhaustive, but it may help you identify which of these you use often in your own classroom, reflect on what each type of activity is good for, and perhaps expand your repertoire.

In the previous chapter we described how to introduce new science ideas and/or language that would be used by students during activity. But we want to remind you that learning research indicates that, in some cases, it may be best to let students noodle around a bit, puzzle, and explore with materials *before* you formally present new science concepts. Following this brief, perhaps loosely structured encounter with materials or data, students can be introduced to the focal science idea, then use it to view the prior activity through new lenses and employ more precise academic language with peers to make sense of what they're seeing. In this way, students can feel a need for the new idea—the presentation is "just in time" to support their sense making. So, you'll have to use judgment about what comes first: the telling or a brief exposure to the activity.

WHAT COUNTS AS AN ACTIVITY?

We use the word *activity* carefully because the teaching community does not agree on its defining characteristics in the classroom. Activities can include labs, investigations, or just plain hands-on work, and even these mean different things to different teachers. Activities can include everything from doing library research to sorting rocks, from investigating pollution in the creek behind the school building to prepping for the annual science fair. And we have not yet figured out how "engagement with scientific practices" fits in with this assortment. Teachers mix and match these experiences depending on their own backgrounds or on the curriculum they're using.

We cannot resolve these issues in this book, but we can provide names for activity types that place distinctly different demands on students and result in different kinds of learning. At the same time, we make the case that whatever work you ask students to do in groups, you can significantly influence the learning outcomes by attending to a common set of teaching moves.

As you can see in figure 9.1, activities suit different goals. If you want students to develop basic science concepts and abilities, you can have them do proof-of-concept work (#1), develop routine skills by following procedures (#2), use a paper-and-pencil activity (#3), do jigsaw readings (#5), or stage a round of Science Theater (#6). If you want students to engage in authentic scientific work, you might have them design studies (#4) or use simulations to produce analyzable data (#7). If you want them to do authentic work *and* connect science with social issues, you can have students use secondhand data to make and argue claims (#8), or enact a debate that focuses on community issues (health, ethics, economics) related to science (#9).

For activities in any of these categories, you can make *adjustments in the intellectual demand* for students. If you want to provide more support, you can

FIGURE 9.1 **Types of learning activity in science classrooms**

1. Students do "**proof of concept**" work, manipulating materials to confirm a principle or réproduce an expected result. **Example:** Students in chemistry class demonstrate a double replacement reaction by mixing solutions that produce a yellow precipitate of insoluble salts.	2. Students **develop routine skills** by following procedures and practicing. **Example:** Ninth graders learn to balance chemical equations, graph data, use distillation equipment, etc.	3. Students in groups do a **paper-and pencil activity** to make meaning of a concept or system. **Example:** Middle school students use a topographic map to understand what a watershed is and its relationship to distributions of flora and fauna.
4. Students **design their own study** (often within limits set by teacher), collect data, and analyze it. **Example:** Fourth graders use decibel meters to test whether sound moves in all directions from its source.	5. Students work in **jigsaw groups with readings** to identify and share key ideas in texts. **Example:** Sixth graders analyze different web pages for information about forces in sports, sharing the "big ideas" with one another.	6. Students act out "**Science Theater**"—physically representing a science idea with their bodies. **Example:** Seventh-graders take on the roles of blood cells, staging a performance of how blood moves through chambers of an amphibian heart.
7. Students use **computer simulations** to produce observations and data that could not otherwise be collected. **Example:** Physics students create a planetary system to generate data about relationships between mass and gravitational attraction of bodies in space.	8. Students **analyze secondhand data** to identify trends or use as evidence for claims. **Example:** Biology students use data from state health departments to test relationships between reported cases of asthma and family income.	9. Student groups **plan and enact a debate** about science-in-society issues or about what is causing a phenomenon. **Example:** AP environmental studies students participate in structured argument about costs/benefits of converting the country entirely to "clean" energy.

do things like physically model parts of the activity before students try it (how to use lab equipment, for example). You can also model your thinking for students, talking out loud as you search out key ideas from a jigsaw reading and making marginal notes for later reference. Reasoning aloud can also be used to make your thought processes evident to students about designing an investigation, developing a claim, or getting started on any other type of cognitive or procedural task. Support can also take the form of prescribing steps students should follow during an activity, rather than having them make choices of what to do next (this approach can be too prescriptive, so use it with caution). You can provide writing scaffolds, such as sentence frames for parts of the activity, or give students ready-made tools (empty tables for recording observations, or an x-y coordinate plane to plot data points). If students are likely to get lost with a multipart activity, you can require that they ask for a "check-in" conversation with you after completing the early phases and before proceeding further. All of these ways of structuring the student experience allow even the youngest of learners to engage in meaningful and sophisticated work. The supports, of course, are not meant to be permanent—over the school year you would systematically withdraw them and give your students more responsibility to make decisions about how to proceed, create their own tools, and even set their own goals.

There are some types of activity, scaffolded or not, that we should steer clear of. Common "cookbook" investigations, for example, are unhelpful for learning. In these, students mindlessly follow procedures and never get to the sense making required of real science. We also recommend against the investigation of arbitrary questions, even if students are in charge of the design. Science does not involve questions such as "Will my plants grow faster if they are doused with water or with soda?" A question like this, although testable, has little to do with the development of any coherent understanding of underlying causes. In other words, the results do not help develop any serious explanation about plant growth. This applies to first graders as much as to upper-level high school students. Similarly, we advise against investigations outside the bounds of the natural world. The sciences do not investigate questions such as "How many of our students walk to school versus take the bus?" or "Does our cafeteria recycle more than 50 percent of its food waste?" Although these can be motivational hooks for students, they are essentially inquiries without science content.

During activities, it can be tempting to become overly focused on "variables" talk, procedure writing, error analysis, formulaic lab report writing, and the like. These priorities have been an accepted and routine part of school science for decades, but an exclusive focus on them can trivialize what science is. Lab work is most beneficial when it immerses students in authentic disciplinary practices like modeling, designing investigations, analyzing and displaying data, seeking out relevant information for a project, and representing ideas and findings for an audience. Science is more than identifying the variables and writing conclusions.

Regardless of which type of activity is used with students, it should always support some part of an explanation for the unit's anchoring event. Conversely, for every part of that underlying explanation, you should devote at least one learning activity and the sense-making conversations that go with it. Whatever activity you select, it should provide a shared experience for students, around which a common language and set of ideas can be developed.

SENSE MAKING IN ACTIVITY

As much as teachers and students enjoy activities, research on instruction shows that activity, by itself, does not reliably influence learning. What is usually missing is the sense-making talk. Sense making means that students gain insight into some relationship between ideas, representations of those ideas, and experiences they have, but getting this to happen by design in classrooms is difficult. Lots of responses by students can give the mistaken impression that they've made sense of ideas, representations, or explanations; such false indicators can include using technical vocabulary, completing procedural labs, and using formulas in prescribed ways to come up with answers. Sense making is not as simple as this, and it takes time. It is about making connections and recognizing particular kinds of relationships or patterns.

While there are an infinite number of ideas in the world, there is a smaller set of ways that the human mind seeks out links or storylines to make new information meaningful. These more elemental targets of sense making are handy because they can be used in different circumstances to help students learn about a wide range of topics. Some of these targets include *comprehending a conceptual category* and *why something fits in that category* (such as why whales belong to the category of mammals, or why combustion is an example of an exothermic reaction), *recognizing distinctions among things that appear closely related* (e.g., alleles versus genes), and *understanding why things in the same class can be similar or distinct* from one another (e.g., how copper wire, water, and the human body can all be conductors of electricity). In other cases students can *learn how parts of a representation symbolize something in the real world* (for example, how peaks and troughs in a sound wave correspond to places where air molecules are compressed against one another or pulled apart). Students can *recognize how parts make wholes that have unique characteristics* (e.g., cells making up tissues, which make up organs and organ systems, which in turn make up organisms), or *grasp how a new idea can be used to explain an everyday event* (such as buoyant forces helping explain why ice cubes float in water) or *why a set of events or conditions causes something to happen* (e.g., the gravitational tug of the moon causing the earth's tides). These are just a few general categories for how learners process new information and, in some cases, reorganize what they believe.

Sense making is both about understanding an idea (such as mitosis in cells) and using that idea to explain events in the world (why out-of-control mitosis allows some cancers to spread more rapidly than others). We don't want students to come away with only academic understandings of concepts (such as their definitions and examples); we also want students to try to solve authentic problems, *using the ideas as tools*. Even better, we want students to recognize which ideas are relevant as resources when doing intellectual work, without being prompted by the teacher. Great teachers set up conversations that lead students to make these connections for themselves. When students are always told what the relationships are, they are "borrowing" the sense that someone else had made, and consequently their learning is both fragile and temporary.

THE PARTS OF THIS PRACTICE

Sense making for students does not come as a natural by-product of activity; you have to be intentional about integrating opportunities for students to reason about ideas, representations, and experiences throughout the lesson. Here we'll focus on the moves you can make that support sense making by students. We cannot provide detailed recommendations for how to structure or scaffold all the possible types of activity that could be done in a classroom; however, we've selected an example and use it to emphasize strategic moves that make the activity meaningful for students.

Framing the Activity

The way you frame the activity shapes expectations in students for how they'll approach the task. Remember that framing is different from giving clear instructions. We recommend that your framing describe to students how the activity can help them advance their thinking about a particular puzzle or part of the eventual explanation for the unit's anchoring event. Your framing should also include a statement about how they'll use ideas—perhaps they will be making evidence-based claims as part of the activity and need a reminder that such statements use available data but also make inferences about events or relationships that go beyond the data trends. Whatever your activity, provide written and verbal guidance about how to proceed. As we mentioned earlier, you can physically model parts of the activity that could otherwise hang up students and prevent them from getting to work (you can show equipment they'll use or provide examples of completed student work).

Moving Among the Tables: Supporting Insights or Breakthroughs

After framing and directions, your students can begin to work in pairs or groups. This is a time for you to circulate, listen, and then press them to reason further about the science. The purpose of moving among the tables is not to ask students, "Have you got any questions?" or "How far along are you?" Rather, it is to find out what ideas or skills they are wrestling with and to press them to think more deeply using the resources available.[1]

Because you have to be responsive to students' thinking during your brief visits, we advise using *Back-Pocket Questions* (BPQs). These are index cards on which you write different prompts or questions to ask students as you move from table to table. On this card we recommend that you include two questions you'd ask student groups that are having trouble getting started with the task. These might be prompts for them to focus on a specific part of the task first, or to recall earlier class conversations in which a science idea, relevant to the present task, was discussed. Another two questions on the index card could be written for students who are zooming along and need more demanding questions to keep them reasoning together. Then, on the bottom of the index card, you can write generic follow-up questions to students such as "Why do you think that?" or "Do you all agree?" or "Can you unpack that idea for me?"

Having BPQs in hand may sound prescripted and not responsive to students' talk, but just the act of writing them up ahead of time helps you prethink what sticking points your students might face, or develop prompts that encourage groups to think more deeply together. It provides good questions to choose from in case some of your students need higher levels of challenge. Most of our teachers use the questions right off the BPQ card, while others improvise on the spot, using what's on their card just to spark their thinking.

Moving among the tables follows this general pattern: move to a new group of students; listen to their conversation; select a way to focus, redirect, or press on their current thinking through dialogue; make eye contact with every member of the group, asking those who have not contributed if they want to add anything; and then ask students a "leaving question" that keeps them talking after your visit is over.

Advice to novice teachers: you have about three minutes to visit each table group, so don't park yourself at a table for a lengthy conversation. When you enter a group, get down at students' eye level to talk with them rather than loom over them. Don't turn your back on the rest of the class—keep a watchful eye on the room.

The following example of moving among the tables is drawn from our eighth-grade unit on the gas laws, using the imploding railroad tanker car as the anchoring event. Students had just received interactive direct instruction (the first teaching practice in this set) about kinetic molecular motion and phase change. Following this, their teacher provided a demonstration in which he poured an inch of water into an empty soda can, then heated it to a boil on a hot plate. He inverted the can into a water bath, and it immediately collapsed with a bang. The class discussed briefly how the can was like a physical model of the tanker and also the ways that it was unlike the tanker. Then came the challenge of the day's lesson: students were asked to design their own experiment with the soda cans. They had to consider what they learned during the mini-lecture and what they had drawn on their initial models earlier in the unit. The teacher handed these models back to the students, and asked them to keep in mind that their investigations had to test some part of their theory. They would be responsible for articulating this connection to him during the table visits (see appendix F for a written guide that supports sense making during the design of investigations).

Box 9.1 shows the BPQs that the teacher drew up for this lesson. He anticipated that, despite clear instructions, some student groups would be confused about where to start or what was being asked of them. For these encounters he sketched out two questions. Below those he had written other questions for students who were moving forward on the experimental design, but needed to be pressed further about the science. Below that he placed generic follow-up questions that could apply to any group he visited (recall from the discourse chapters in this book that follow-ups are important in verbal exchanges with students). He also reserved space at the bottom of his card for names of students he would ask to share their ideas with the rest of the class later in the lesson, and a reminder about how to "prime" them to talk to their peers. We'll return to the idea of priming, which sets up whole-class discussion, in the last practice of this set.

BOX 9.1 Back-Pocket Questions for table talk about the tanker

Helping students get started

- What do we think was inside the soda can before we turned it upside down in the water? Why?
- Let's start by talking about what we think may be happening inside the soda can we used for the demonstration about the science.

Pressing further

- What will your experiment tell us about the tanker?
- When you say "pressure," what do you mean?

Follow-ups

- Can you say more?
- Do you all agree? Why?
- What makes you think that?

Who will share out about their experiment and rationale?

During small-group work, the teacher prompted his students to use the ideas and the language of kinetic molecular motion in conversations about their proposed experimental designs. How students used these concepts was up to them, but they had to justify their inquiries using facts and principles. The following transcript represents a visit to a group of three students who were trying to test the idea that phase change inside the tanker—from vapor to liquid water—caused the implosion. The teacher is trying to get them to reason about why the molecules "lose energy" to start the condensation process. In this transcript, the teacher has just moved to this group's table and takes a seat in an empty chair. In the center of the table is the initial model of the tanker that students had drawn the previous week.

KATIE: We could have one soda can that we put in the water bath and one that we just let sit there to see if it collapses. Maybe it would still collapse if it just cooled down after a while.

ABANU: We could measure which one collapses more, or which one collapses first. We could time it. We could see if they crush the same.

KATIE: Both of them.

TEACHER: So, which of the two soda cans in your experiment [points to their model on the table] is like your tanker model here?

ABANU: We saw in the video that it was raining when the tanker collapsed [sketches raindrops falling on top of tanker model as he talks], so we are thinking it's like the soda can we dunk in the water—

TEACHER: [Makes eye contact with Mira and Katie] Do you agree with what Abanu said?

KATIE: [Pauses] Yes—it's like cooling off really fast in the rain, and it makes the steam condense so it takes up less room.

MIRA: Inside, yeah.

ABANU: It cools off fast, it makes the steam condense, and then the pressure goes down inside the tanker, or ummm, in the pop can.

TEACHER: Mm-hmm. Well, I'm kind of interested in the soda can that you heat up and just leave sitting there. Katie, you said it would cool down more slowly and maybe collapse later, but I wanted to hear about how this "cooling off" happens. If we could see with microscope eyes what's going on, what would we see?

[Silence for 10 seconds]

TEACHER: Okay, let's think about the jigsaw pieces you just read, especially the one on kinetic molecular theory. What was the big message from that reading about how molecules move?

KATIE: That molecules are always in motion?

ABANU: Hotter molecules move faster—eh, hotter things have faster-moving molecules. So cooling is when they slow down. So phase change, when liquids heat up they—the molecules—move faster until they break away and get into steam.

TEACHER: So the tanker molecules have to do the opposite of what you just said—they have to slow down. But I don't get how these molecules in the tanker just slow down by themselves; do they just run out of gas?

[Laughter]

KATIE: They lose energy?

TEACHER: But that doesn't tell me *why* they start slowing down. What makes that happen? Let's look at this part of your model [circles a small part of the tanker wall]; what's going on here?

ABANU: They're hitting the wall. Maybe that's where they are losing energy?

TEACHER: Do things lose their energy when they run into walls or the sides of containers?

KATIE: No? Well, yes, they can. A ball won't bounce back to you all the way if you throw it against the wall. Or like a car crashes and it loses energy, it stops; I suppose it crashes into something. But is that how things cool off? Like at the molecule level?

TEACHER: Mira, do you want to weigh in on this question of why the molecules lose energy? Cool down?

MIRA: I agree with Katie.

TEACHER: About . . . ?

MIRA: About when things hit a container they lose energy and that energy goes into the container or into a wall. If molecules hit a wall they can bounce off it, but maybe not as fast.

TEACHER: That's an interesting idea about what might happen to the energy of a molecule in a container—hitting the wall, I mean. Would you all be willing to share your theory later, when we have a discussion about the results from our experiments? Just say, "Here's what we were thinking . . ." It would help everyone in the class.

STUDENTS TOGETHER: Okay, sure.

TEACHER: Okay, so for right now, I want you all to talk about your theory, get clear about how or why these molecules are losing energy. The water molecules are starting to stick to one another to create this condensation inside the tanker; we can all agree on that based on what we know from our last unit on phase change. But you need to be able to say *why* those molecules are slowing down in the first place, and where that energy is going. You already have a good start. [Leaves the table]

What did you notice in this segment of talk? The teacher is asking good questions, yes, but let's push our analysis further. He started by listening, and even in those first brief moments he could tell that these students would benefit from being pressed a bit. He was responsive to the ideas he heard (lines 1–6) from two of his students, using those as the basis for his question about how the proposed experimental setup was like their tanker model (lines 7 and 8). He focused on one important idea—how gases "cool off"—and didn't jump around to other topics, nor did he funnel students into saying any particular words or phrases. Instead, he wanted to hear their reasoning (for example, lines 19–27).

He made clear efforts to involve a student, Mira, by turning his attention (his gaze) toward her (lines 12 and 13) and asking if she agreed with her group, then later reserving space for her to comment on the group's working hypothesis (lines 48–50), even to the point of asking her to elaborate on her initial response (lines 51–54). The teacher asked valuable follow-ups at lines 12–13, lines 38–40, and line 51. Each instance made the student's ideas the object of discussion. He also made an important move at the end of his visit (lines 61–67). He was laying the groundwork for the upcoming whole-class discussion about the design of their experiments. Teachers know that getting students to contribute to these public conversations can be difficult, so we recommend preparing two or three groups to kick-start the talk by getting ready, while they are still in small groups, to share their ideas later. In this case, the teacher gave these students some hints about talking to the whole class so that they could make decisions ahead of time about what to say to their peers and how they would say it. Again, we refer to this move as *priming*.

In this round of visits, the teacher did not focus on the details of experimental design, such as identifying variables or how outcomes could be reliably measured. Rather, the science itself was discussed. We don't suggest that investigational procedures are unimportant, but we also recognize that talk about measurement, error, and the like can be premature when students don't first clarify what they are choosing to study and why.

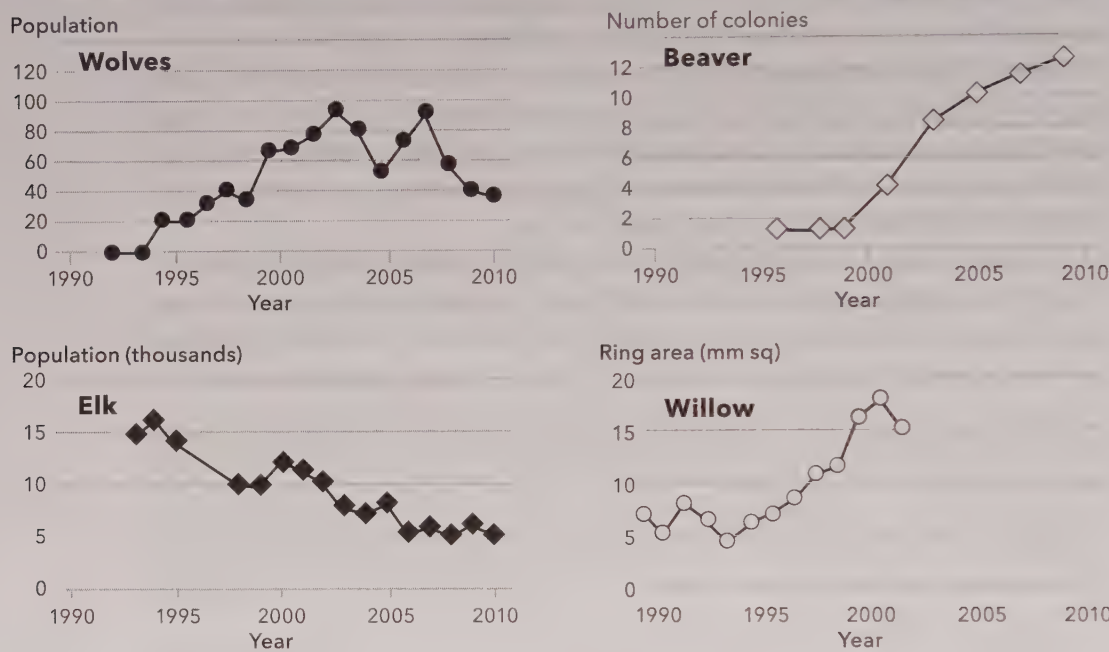
This exchange with one group of students took about four and a half minutes. In a classroom with, say, nine groups of three students each, you could have these conversations with everyone in a standard class period. You'll be thinking on your feet the whole time, but you are ensuring that all of your students have been intellectually challenged that day.

Here's another set of example BPQs that are responsive to student thinking, from the tenth-grade ecosystem unit on the reintroduction of wolves to Yellowstone National Park. Groups were given graphs of different animal populations and plant growth (figure 9.2),[2] then given these prompts to help them start:

- If you had to describe to a person what the trends were for one of your organisms, how would you communicate that? You could use terms like "increasing over time," "decreasing, then increasing," and "increasing slowly, then increasing more rapidly." These are not the only ways you could describe the trends, but you can use them if you want to. Discuss this with the members of your group.
- Now look at the wolf population graph. Discuss with your group what is represented on the x- and y-axes, and if these are different from the axes on the graph of your organism.
- Refer back to your organisms' fact sheets. Are there any links between the wolf and other organisms? These links might be direct, or indirect, or you may see no links at all. To help you, here are some questions to ask yourselves: *How might changes in the graphs of wolf population and another organism be related to one another? For example, does the wolf population affect another species over time? Does that species affect the wolf population over time?*

The goal here was for students to use the graphical data in figure 9.2, along with other information, to continue to revise and build explanations for how the reintroduction of wolves changed the ecosystem. The teacher recalled how some of her students the previous year struggled to understand what the graphs meant, while others were successful in reading the graphs but overlooked basic information they had been given earlier about the organisms as they tried to theorize about what was happening. Knowing this, she sketched out BPQs that could help groups with either of these issues.

FIGURE 9.2 **Yellowstone population graphs**



Source: Reprinted from William J. Ripple and Robert L. Beschta, "Tropical Cascades in Yellowstone: The First 15 Years After Wolf Reintroduction," Biological Conservation 145, no. 1 (2012): 205–213, with permission from Elsevier.

As students began to work, she approached one table and listened for a couple of minutes. The students were becoming frustrated by not understanding the graph of willows, which measured not population, as in the other graphs, but the average diameter of their branches (elk browse on willows, not killing them but preventing their growth). The teacher sat down with her students, clarified what the y-axis represented, and then said, "Let's start by looking here [placing the tip of her pen on the first data point in the series]. If we look across at the y-axis, and then down at the x-axis, then what is this one point of data telling us? Just this one?" Students were able to agree that "at Year Zero, the average willow branch researchers measured was about seven square millimeters in area." A second question asked students to look at a later data point in the series and describe what it represented. The students remarked, "Ten years later the average branch was about eleven square millimeters in area—okay, okay, we got it." The teacher, however, persisted: "What does it mean that these numbers are going up? Don't try to tell the story about another organism here; just describe what's happening to the willows if these branch measurements are going up."

She left them with that question and moved to another table where a second group of students had cut out their graphs and aligned them vertically on the table to see more precisely when certain trends began to show up for each organism. This was a good sense-making move on their part, but after a few minutes they were stalling out on how to create a story about the ways in which these populations were influencing each other. The teacher listened for a couple of minutes, then offered, "So, you are saying that the wolf population is going up, and the beaver population is also going up." One of the students explained that maybe the wolf was killing off a predator of the beaver, and that this could explain the rise in their number of colonies. The teacher replied, "I like your cause-and-effect reasoning here, but you are making some assumptions here without basic facts about these organisms, like their habitats, prey, reproductive cycles. Maybe we can make headway by getting out the information cards about each species—we used these last week, remember?" After the teacher left the group, students pulled out their cards and did some quick reading; they called the teacher back after a few minutes to report that beavers benefited from the increasing willow and cottonwood stands. These plants were beginning a comeback after elk became reluctant to graze on them. Why? Because the wolf packs began patrolling the lowland and riverside habitat where the willow and cottonwood grew.

Most questions that catalyze students' thinking are really just prompts for focusing on one part of a complex story first, so they have an anchor for constructing the rest of the explanation (as with Yellowstone student group 1), or alerting students to relevant information they already have in hand but are not using (Yellowstone student group 2). Every visit you make to students during an activity is unique. You have to think on your feet, even with well-crafted BPQs. But this effort to support sense making is worth it. All it takes is one comment, tailored to students' thinking, to stimulate insights or even breakthroughs in explanations.

We have worked together with hundreds of teachers to identify what makes the "moving among the tables" practice most effective for young learners. The following list reflects our state of the art right now, meaning that this general pattern seems to work better than others to ensure both rigor and equity during the interactions:

1. *Listen first.* Move to the group, and listen to get some sense of the ideas they are using.
2. *Press and point.* Ask questions that either probe students' thinking, or redirect them to some part of the activity or representation that is important to help them reason further (ask about specific parts of their representation or what they are wrestling with, rather than generically asking, "What are you thinking?"). Physically pointing to some part of their representation or a tool they are using is important.
3. *Follow up.* Ask, "What do you mean?" or "Why do you think that?"
4. *Include everyone.* Ask follow-ups to other group members, such as "Do you agree?" or "Want to add on?" Make eye contact with all members of the group. This is a subtle but powerful way to invite students to participate.
5. *Prepare for later share-out (priming).* Determine if the group has a unique idea that should be opened up to the whole class, make a note, and ask if they'd be willing to share. Prep your students about what and how to share in front of the class if they are nervous. Write the group's idea at the bottom or on the back of the BPQ card, so you can remember who agreed to share.
6. *Pose the leaving question.* Encourage students to keep the conversation going after you leave by posing a final question to them.

These rounds are productive for students because the questions you ask focus on their own puzzles, push their initial ideas further, or compel them to voice *how* they know what they think they know. But the rounds also set the stage for a later public conversation about what was learned and how new ideas apply to the anchoring event. The next chapter takes us to that whole-class discussion.

One additional note: if you have not yet referred to the two maps we've created in appendix B, it might be a good time to check them out now. They show where this practice and the other core practices are used during the course of a unit of instruction. We lay out all the lessons that make up two units; one is the fifth-grade unit on sound energy, and the other is the tenth-grade unit on ecosystems we discussed in this chapter. Appendix B provides the bigger picture of how the lessons fit together and when you would use the different core teaching practices.

HOW TO GET STARTED

The most challenging part of this practice is moving among the tables, because you have to be responsive to students' ideas and to who is *not* talking. We advise, for your first try at this, that you select an activity and a written guide for students that clearly have the potential to engage them in reasoning, rather than have them fill out a work sheet. Without this condition in place, the discourse moves you make will fall flat. Write up a set of BPQs, and try them out with just two or three tables. We suggest just two or three because you will find yourself in the midst of sense-making conversations with students and these can take time (10 minutes or more).

During your visits, see if you can get everyone in the group to contribute something to the conversation, even if it is just agreement about what a peer has said. Don't worry so much about getting to all the groups in your classroom during your initial attempts. Focus on the numbered points listed earlier. Try to enact them at the right places and times in the conversation. One issue our teachers encounter in their first attempts is that they tend to press their students with questions, but not use follow-ups. This becomes a steady stream of "how and why" questions that sounds like an interrogation rather than a conversation. We urge you to use the follow-ups to develop students' ideas and soften the interactions.

As you work on this practice, you'll start to internalize the moves; they'll come to you more spontaneously and you'll worry less about mentally "checking off" steps. You'll feel yourself improvising more as you take command of this strategy, recognizing when you are being responsive to students' ideas and getting them to unpack what they say, to compare and contrast claims, and to question each other. As you gain experience, try to engage more small groups in each class. See if you can target these mini-conversations to last about four minutes so that every group will get precious time with you to develop their ideas.

TEN

CORE PRACTICE SET #3

Supporting Ongoing Changes in Thinking: Collective Thinking

WE KNOW FROM the previous chapter that serious sense making can happen during small-group activity. There is, however, another level of talk that you have to facilitate at the whole-class level, in which students take up the next challenge—comparing and contrasting the ways different groups have understood and used science ideas. These public conversations are crucial for learning because they allow students to hear their peers reason in ways that they may never have considered. This is important in a classroom where the goal is to construct better and more defensible explanations over time, rather than focusing exclusively on right answers to work sheet questions. In the whole-group conversation, everyone gets reacquainted with the norms and skills of commenting on the ideas of others, and they experience how uncertainty about science claims is handled when a community builds knowledge together.

The talk, as you might imagine, can get unwieldy. Ideas may erupt from all corners of the room but fail to build upon one another; or, your precocious student in the front row might blurt out a Nobel Prize–winning explanation before anyone else has processed the question you led with. On the other end of the spectrum (or at the same time), entire groups of students may feel they can't or won't participate. And even when students willingly contribute in an organized and equitable way, our own teaching minds are racing through questions like: *Where are we going with this and what's my next move?* For all these reasons, creating predictable routines helps students understand how they can contribute and helps you manage the talk as well as the inevitable dead air.

STRUCTURING WHOLE-CLASS CONVERSATIONS

We recommend that you segment the whole-class discussion into three manageable parts, or mini-conversations about:

- Patterns or trends—what happened in the activity?
- What do we think caused these patterns or observations?
- How does this help us think about our essential question or puzzling phenomenon?

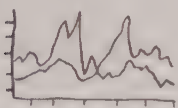
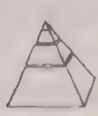
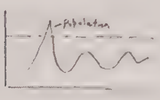
You'd occasionally modify these based on the type of activity students just completed.

Each of these segments has its own goal, which helps students understand the kinds of talk they should offer. In the first conversation, students describe observations or outcomes they recorded during the activity. This is an easy entry into making thinking public because it doesn't require students to explain anything at length or risk making claims. The second conversation builds upon the first—asking students to infer what happened to cause those observations or patterns. The third conversation answers the "so what?" question, getting students to apply what they learned to situations that go beyond the activity itself.

Breaking down the discussion like this keeps you and your students focused on doable talk goals. This talk, however, can disappear into thin air unless it gets documented in an organized way. For this reason, we want students to keep records of the main agreements or disagreements, so they can participate in the moment but also recall days later what was said. For this task, we use a tool called a *Summary Table*. This table can be drawn out on a flip chart or projected as a document from your computer. It typically has a row for each major activity done during a unit (no more than four or five), and three column headings that apply to each activity. These headings reflect the three segments of the conversation we mentioned previously. As you will see in the figures included in this chapter, there have been many variations of this tool created by our teachers, with special features that suit their particular classroom needs.

Table 10.1 shows a completed Summary Table from the tenth-grade unit on wolves in the Yellowstone ecosystem. The teacher used a simple template,

TABLE 10.1 **Summary Table from a tenth-grade biology class studying the reintroduction of wolves to Yellowstone**

ACTIVITY	WHAT WE OBSERVED	WHAT WE LEARNED	HOW IT HELPS US UNDERSTAND THE ECOSYSTEM
Niches–jigsaw reading on coyotes vs. wolves 	Some organisms compete for the same space or food. They are adapted to play similar roles in ecosystems.	This is a niche. If the environment they live in changes, it can change which organism is more successful.	The wolf and coyote have overlapping niches. They compete for some of the same kinds of food. When wolves were killed off, coyotes took over. When they came back, the coyotes declined but not all the way because they can eat a wider range of things.
Keystone species and interactions with other populations 	Elk decreased in population after wolves introduced. All other species (both animals and plants) increased.	Claim: As wolves increase, it indirectly causes willow to go up. This is because wolves eat elk [and] drive them away from riversides, [and] then willow can grow more. Claim: Bison and elk compete for same grass. When elk get eaten by wolves, bison increase.	Wolves are linked to all other organisms directly or indirectly. Wolves require more energy; they eat mostly elk. Elk is [a] "keystone species" because it is linked to wolves, willows, bison, [and] those crazy beavers, and can also erode river banks.
Conservation of energy and trophic levels 	At each trophic level only 10% of the energy got passed to [the] next level.	Energy can get lost as heat and metabolism when you move around a lot. Can't get it back into the ecosystem—its [sic] lost.	There is not room at the top of the pyramid for a lot of predators. So much energy is lost at each level of pyramid that there is room for only a few top predators like wolves or bears.
Carrying capacity 	In our "Oh Deer" game we saw that the population of deer decreased when it used up all its recourses, but came back a few years later. Then [it] went down again.	Organisms can only grow in population as long as there are resources for them. They can overshoot their carrying capacity and start to have less [sic] babies because they have less energy to hunt or be healthy. But later the resources come back and so does the organism that depends on them.	All populations in Yellowstone will go up and down in regular cycles, but when [the] ecosystem is disturbed, you can have [the] population crash or skyrocket.
Calories and biomass 	Plant-based foods don't create much heat when burned. Fats, proteins burn hotter.	Plants don't contain much stored energy, per kilogram. Fats have molecules that release energy when digested.	Herbivores need to forage all the time to get enough energy to live. Carnivores try to select prey they don't have to chase much to get the energy-rich food.

Good terms or phrases to know: niche, stored energy, conservation of energy, competition, carrying capacity, dynamic equilibrium, claim, evidence and reasoning.

projected on a screen from her laptop. As she managed the whole-class discussions, she had a student volunteer type the final statements into each cell in the row for that day. Notice how the entries in each row require students, as a group, to make deep sense of one or two central ideas. From top to bottom these ideas are: niches; keystone species and their interactions with other populations; trophic levels and conservation of energy; carrying capacity; and calories as storable and transferable energy. Sense making happens as students are deciding what to enter in the "What we learned" column (a variation of "What do we think caused these patterns or observations?"), because they have to use new ideas to interpret the outcomes of the recently completed activity. Sense making also happens as they negotiate the "How it helps us understand the ecosystem" column (in other words, "How does this help us think about our essential question or puzzling phenomenon?"), because they must apply new ideas and relationships to the anchoring event.

Some of our teacher colleagues fill in the lefthand "Activity" column, including the drawings, at the beginning of a unit so that students can see what ideas will be coming up and in what sequence. This encourages some students to read ahead or to predict how the forthcoming science concepts play a role in the anchoring event. English language learners can also translate these key terms before the lessons are enacted, so they are better prepared to participate in conversations.

In broad strokes, here is how a row gets built—more detailed descriptions will follow. When a major activity is completed (investigation, lab exercise, simulation, etc.), you create a new line on the table. Together with your students, you use the column headings as prompts to talk about what they learned and why it matters. You can allow students to take charge of different parts of the conversation or more actively manage it yourself; either way, you'll want to hear from as many students in the room as possible. By "hear from students," we don't mean them just chipping in ideas, but actively commenting on the observations, theories, and puzzlements of others. Gradually, you fill in the row on the table with "bumper sticker" summaries that the whole class feels okay with. There are frequently unexpected insights, contradictions, or confusion about what different groups of students experienced during the activity or what they think. These make your negotiations about what gets written more challenging, but also more valuable for the class to participate in. It is fine to put two conflicting ideas into a cell or put "???" with the intention of filling it in later, when students have more information.

It's important to note that the object of the Summary Table work is *not* to fill in the row as quickly and decisively as possible. The purpose is to have a *sustained conversation* in which students compare and contrast ideas, learn how to build on or critique their peers' reasoning, and apply new science ideas to events that go beyond the activity itself.

Because models and explanations are supposed to evolve over time, and in response to new evidence or arguments, students need to draw upon records of what they've done over the past few days, and to reflect upon what was learned. For these reasons, the Summary Table is one of the most indispensable tools for supporting explanation and modeling. Without some durable representation of what they have done or read, students would have to depend on memory, and each student's memory will have gaps. So, just as scientists do, students keep track of activities and ideas. As the unit progresses, more rows get filled in and, ideally, students start to piece together more coherent and complete explanations by *looking across* the records from different activities in the Summary Table.

Using Summary Tables to Manage Different Parts of These Conversations

Before the whole-class conversation begins, create a new row on the Summary Table by giving the activity a short name (later in the unit you'll be referring to this row by the name you pick, so make it descriptive rather than cute). Have an artistic student do a simple sketch that represents the activity the class just completed. When your students are ready, you can direct them to get out their notebooks and create their own row (not the whole table) with the appropriate headings. When we first started using Summary Tables we found that *students would ask us if it was okay to make their own copy*, to which our teachers enthusiastically said, "Yes!" In most classrooms, we could see that students wanted to add more information to their notebook versions of the table than what we had on the whole-class display. We could see they were making a genuine effort to put into their own words what they saw in the activity, what they felt they learned, and why it mattered to their explanations. This was also a way of keeping more students engaged during the discussion. For these reasons, the notebook entry is now standard procedure in many classrooms.

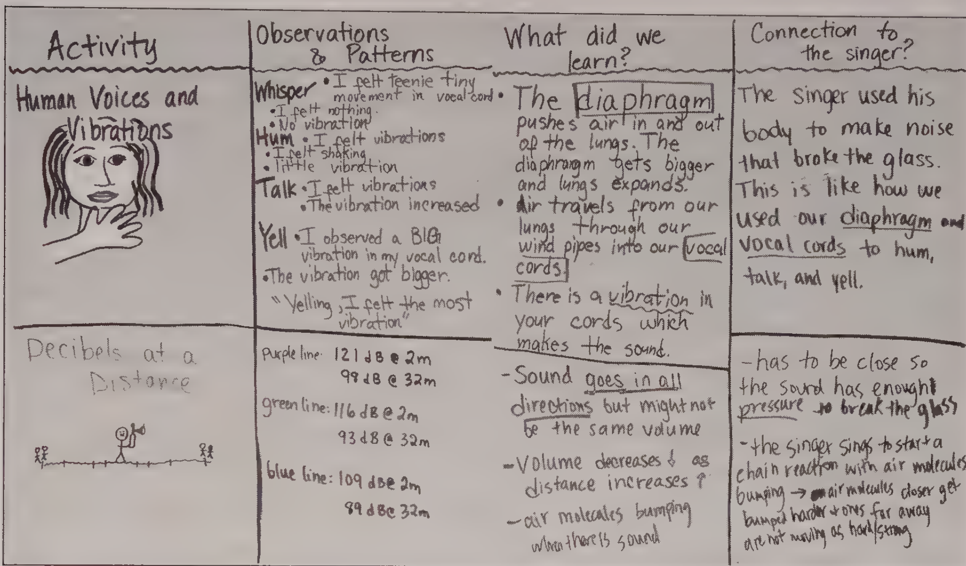
The first talk prompt you give students is: "So what kinds of patterns or observations did we see?" This question may be different depending upon the type of activity you did (a version of this can also be done with assigned readings). Many of our teachers ask students to come up to the front of the room and share artifacts they produced as part of the lab work (mini-models, flow charts, annotated maps, etc.). Students can even answer questions from their peers about their creations and jump-start peer-to-peer talk that way. Just be aware that this kind of sharing can take a while, so don't spend too much of your "time budget" on this first of three conversations.

We've learned *not* to write the first thing that a student says into the Summary Table row. Rather, you should allow at least two or three contributions, then let students compare and contrast them. Remember to use your discourse moves here. For example, this is a good occasion to press ("What do you mean?" or "What is your evidence?"), encourage peer-to-peer talk ("How is your idea different from what she has just said? And talk to her rather than to me, please"), or revoice ("So what I hear you saying is . . ."). Monitor your own air time. If you do all the talking, then you are the one doing the sense making rather than your students. And stay away from funneling—I know that we sound like a broken record here, but in too many "discussions" we still see teachers trying to get their students to say a specific word or phrase.

Be aware that some students, when asked to talk about *what* the trends and observations were (the first of the three mini-conversations), will instead eagerly begin explaining *why* these patterns emerged. They are prematurely addressing the next column's prompt. Gently ask them to hold off on their interesting insights until the observations and trends part of the conversation is aired out and recorded.

After a few minutes with the trends and observations column, you will want to move on, asking the class: "Based on what we've heard, what do we think is causing these patterns? What can we agree on?" Here, too, you'll have to use your judgment about how to proceed. Often, your students will have some contribution that you feel is too simplistic, or you'll have to write more than one idea in the cell, or you'll have to write a partial idea with a question mark behind it. All of these are fine. Whatever ends up being written in each cell should be in students' language, not in polished textbook prose that you feel is the proper answer (see figure 10.1's entries about the "Human Voices and Vibrations" activity and the "Decibels at a Distance" activity). We give the same

FIGURE 10.1 **Summary Table entries for the "Human Voices and Vibrations" and the "Decibels at a Distance" activities**



Activity	Observations & Patterns	What did we learn?	Connection to the singer?
Human Voices and Vibrations	Whisper • I felt teenie tiny movement in vocal cord • I felt nothing. • No vibration Hum • I felt vibrations • I felt shaking • little vibration Talk • I felt vibrations • The vibration increased Yell • I observed a BIG vibration in my vocal cord. • The vibration got bigger. "Yelling, I felt the most vibration"	• The diaphragm pushes air in and out of the lungs. The diaphragm gets bigger and lungs expands. • air travels from our lungs through our wind pipes into our vocal cords. • There is a vibration in your cords which makes the sound.	The singer used his body to make noise that broke the glass. This is like how we used our diaphragm and vocal cords to hum, talk, and yell.
Decibels at a Distance	Purple line: 121 dB @ 2m 99 dB @ 32m green line: 116 dB @ 2m 93 dB @ 32m blue line: 109 dB @ 2m 89 dB @ 32m	- Sound goes in all directions but might not be the same volume - Volume decreases ↓ as distance increases ↑ - air molecules bumping when there is sound	- has to be close so the sound has enough pressure to break the glass - the singer sings to start a chain reaction with air molecules bumping → air molecules closer get bumped harder + ones far away are not moving as hard/strong

advice for the final column about "How does what we learned today help us understand the anchoring event or essential question?"

Let's go back to our time budget. Typically, students can stay focused for fifteen to twenty minutes, total. The final two mini-conversations take the longest to negotiate with students. Thus, it is smart to leave extra minutes for filling in "What is causing these observations?" and "How does this apply to our anchoring event?" In some classrooms teachers have shortened the first mini-conversation (about observations), but in a productive way. Rather than waiting for hesitant volunteers to speak up, they've asked groups of students to write on a sticky note what they observed, then come to the front of the room and place the notes, one on top of the other, on the Summary Table cell. The teacher takes a quick look at the different statements, asking some groups to say more about what they've written. This jump-starts the conversation, and in large classes, it allows every group to have their ideas become part of the Summary Table record.

Another way we've focused the last two conversations is to present opposing opinions from different fictional students. Student A has one idea to contribute and Student B has a different idea (about what caused the patterns/trends, or what the activity has to do with the anchoring event). Everyone in class is likely to feel like they can comment on one or both of the contrasting ideas, and this keeps the conversation from going off in a thousand directions. Of course, we would not want to push this routine too far by constraining novel and generative explanations by students; that would be a big loss for everyone's learning. On the other hand, you will occasionally have to hold students accountable for their statements to be consistent with known science. It's prudent to challenge some conclusions by directing their attention to earlier discussions or readings they've done ("How does your claim fit with the jigsaw articles we read on sound energy?").

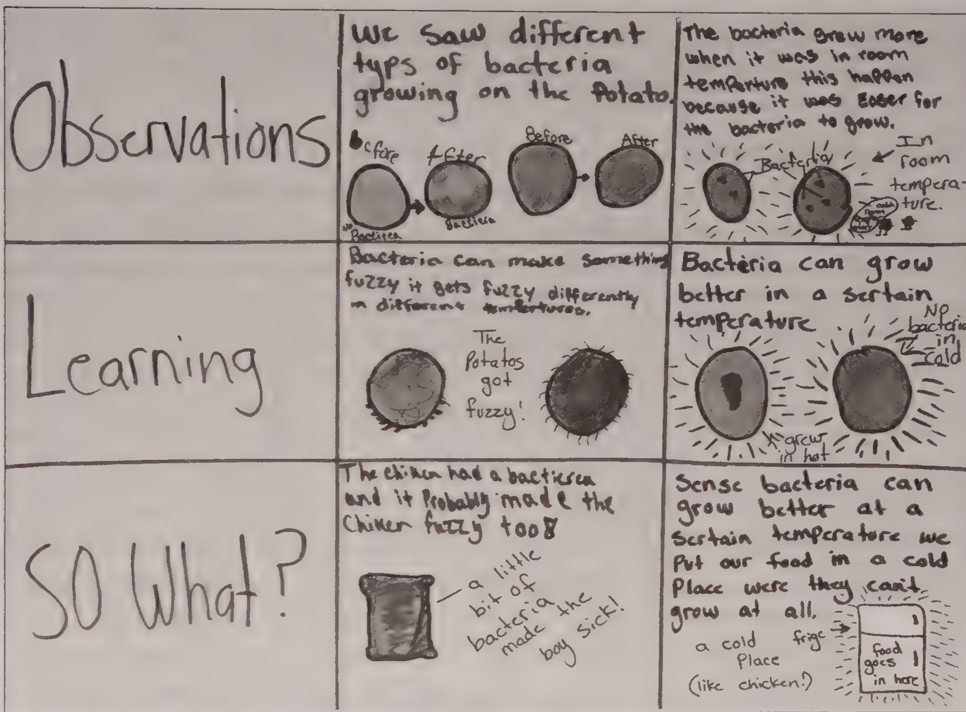
Using Summary Charts Instead of Summary Tables for Elementary Students

The Summary Table accumulates a lot of text by the end of a unit, and all these words can overwhelm elementary-aged students. To remedy this, our K–6 teachers often substitute Summary *Charts*, which document students' ideas from only one activity at a time. Each Summary Chart uses the same basic prompts (column headings) as the Summary Table, but students' sense making for a single activity fills the available space.

In a fifth-grade classroom unit on micro-worlds, the anchoring event was a case of food poisoning by salmonella bacteria. Students explored how the microbes interacted with the person's body as they multiplied over time, then declined. Figure 10.2 shows a Summary Chart created by students for an activity focused on bacterial growth. In each of three sections (labeled Observation, Learning, and So What?), students have recorded responses. Clearly there is much more real estate to write and draw on if you dedicate one poster for each activity. Another benefit is that the drawings that represent the activities can, in many cases, be treated like scientific mini-models that stimulate conversations and help students make sense of the phenomenon.

These charts were created by groups of students. The teacher then constructed with students a "consensus version" that was placed alongside individual groups' charts on the classroom walls. In conversations later in this unit,

FIGURE 10.2 **Variation on a Summary Chart for fifth-grade activity on bacterial growth**



students referred to their own charts more often than the consensus version, suggesting that they felt they had created a useful resource for themselves.

STRATEGIES FOR EQUITY AND ENCOURAGING FULL PARTICIPATION

For all these conversations, you'll want to pay attention to who may *not* be participating and what can be done about it. Students in many classrooms don't feel like they know the rules of joining in when it comes to whole-class discussion. Using the Summary Table provides structure and a talk routine that students can recognize. As you use this tool on a regular basis, more of your students, including English language learners, will recognize how to engage in the conversations. But Summary Tables are not magic—you still need to be proactive about encouraging widespread participation. Next we discuss several strategies we have found to work well, especially in combination with one another.

Point Out Talk Norms

Because students will be referencing each other's ideas in these conversations, ask them to use the sentence frames that are on the wall of your classroom (see chapter 4). They should, for example, use the prompts that help them add to a peer's comment ("Building off _____'s idea, I'd like to add that _____"), politely disagreeing ("I hear what you're saying, but I differ with the part where you said _____, and here's why _____"), asking for clarification ("What did you mean by _____?"), or asking for evidence ("What data tells you that?").

Stop Signaling for "Correctness"

Don't give signals to students that the Summary Table/Chart is a giant work sheet that needs to be filled in with correct answers. These signals can be unintentional, but they do undermine the talk. For example, it is unhelpful to write the first thing a student says in the Summary Table/Chart row instead of hearing multiple views and asking the class to consider similarities and differences. You'll get the same show-stopping effect when you use the terms "right" or "you got it," or even "answer." Once you utter those words, the whole class thinks you heard something you were trying to sniff out and the game is over—no need to add comments to a response the teacher has just labeled as "correct." Frame the activity as a sense-making conversation before it begins.

Prime Groups of Students to Participate

Prime student groups while they are still working on the activity itself, as you move among the tables (see chapter 9). This gives students a chance to debate what they want to say to the whole class later in the Summary Table/Chart conversation, and even rehearse it with your help. Priming helps quiet students contribute and provides opportunities for English language learners to play a role in the presentation of ideas, through talk or drawn representations.

Use "Turn and Talk" Judiciously

Use the simple moves of "turn and talk to your neighbor" when you shift to filling in a new column. This serves a similar function to priming students during small-group work: it gives them a bit more time to compose a response or just to try out an idea with a peer before offering it to the whole class.

These four strategies work together to support wider participation and help students to take risks as they talk to each other about ideas. You might also find it helpful to follow this advice from our teacher colleagues who have successfully used Summary Tables:

- Don't have more than four or five rows (for middle school or high school versions). Choose only the major activities to document on the Summary Table, not every one.
- Students may be able to take charge of negotiating what goes in each column after a reading or activity. At the elementary level, the teacher would take more responsibility for crafting the sentences.
- Don't wait until the end of a unit to fill in the rows for all the activities (we've seen this happen); this is impossible for students. Fill in each row immediately after each activity.
- When students are drawing their final models and writing their explanations, have them use one or two rows on the Summary Table/Chart to identify evidence they are using to support part of that explanation. You don't need students to use the whole Summary Table/Chart and all the evidence expressed within it to support their explanations, but make them accountable for supporting their claims with what they learned through activity and reading.
- Because the completed Summary Table represents activities, new ideas, and the application of these ideas, some teachers create a Summary Table for themselves during the design of a unit. This helps them determine if the combination of activities they are planning includes all the necessary big ideas for students to create final explanations and models. This practice also makes it clearer whether the activities are in a logical order or not.

HOW TO GET STARTED

You can acclimate yourself to whole-class sense-making talk by initially focusing on one science activity and prepping yourself for that conversation. Rehearse in your mind what you'll say during critical moments—for example, when students go silent, when a student wants to spill out the whole explanation using technical vocabulary that others don't have access to, or when two groups of students hold firmly to contradictory interpretations of what they've experienced. Plan a strategy for each of these cases and be ready to use it. Find a private space and say your responses out loud to hear what they sound like.

You'll need to prepare your students, too. On your first attempts, you might script out the words you'll use to frame the conversation to them in order to make everyone as comfortable as possible about contributing. Spend a bit of extra time giving multiple examples of "what counts" as an initial response in each of the columns, and don't forget to model for students the varied ways they can add to, differ with, or challenge a peer's ideas.

Try videotaping your second- or third-period class of the day, after ironing out some of the kinks from period 1 (elementary teachers may not have this option). Alternatively, you can have a colleague observe you trying this out. You can take data on how many students participated in the conversation, or how you responded to students' contributions. It may be informative if you identify how many of the four ways to increase participation (pointing out talk norms, not signaling for correctness, priming students, using turn and talk) you actually used during the class. You and your colleagues can experiment together and then discuss what could be done differently, or identify conditions that seem to help productive talk happen for most students. These "best" conditions may indeed be unique to your classroom.