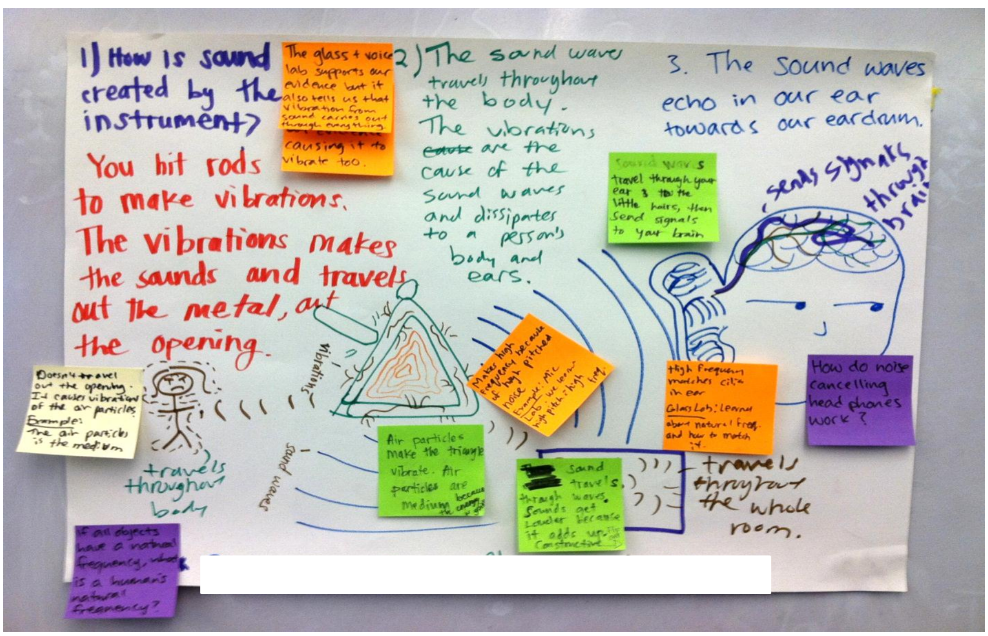
Face-to-Face Tools: Making Changes in Student Thinking Visible Over Time

Models are made to be public representations. There are several reasons for this. For one, models are a way to make thinking visible. In the figure below for example, you can see how a group of 6th graders modeled the transmission of sound from a musical instrument to the human ear. As these students' ideas became visible, their peers and the teacher used sticky-notes to suggest how they might add to their model, revise other parts, and test some of the relationships built into their model. Students engaged in negotiations with peers about their initial ideas and benefited from hearing each other's reasoning about change.

When students change models in response to the arguments of others, it helps everyone reorganize their thinking about a set of science ideas. In particular, drawing and changing models is about re-thinking the relationships among several different science ideas that act together as a system. Models then, are tools for doing public forms of reasoning.



There are also other ways of publicly representing thinking that can be helpful in a classroom. For example you might create an initial list of hypotheses that your students have about a science event and compare these hypotheses with one another, or add to the list of hypotheses over the course of a unit. Another way to represent thinking is to organize each lab activity into a table that documents what was done, what was learned about a particular science idea, and how that activity helped students better understand the "big idea" of the unit (and it's explanatory model).

This paper describes a “toolkit” of face-to-face for use in your classroom. We call them “face-to-face” because they are used with students. All the types we discuss have two things in common. First, they represent *students' ideas* and are constructed, at least in part, by students themselves.

Second, they *change over time as students learn* from observations, experiments, readings, presentations of ideas, and listening to the logic of their peers and the teacher.

Some of the face-to-face tools we discuss here can start on the first or second day of a unit. They are usually put on poster paper or on the board at the front or side of the room. These remain up throughout the unit. Other public representations are best created after students have had some experiences with science activities and with ideas from readings. Other kinds of representations support a final conversation about evidence and explanation. These are many combinations of how these can be used in the same unit.

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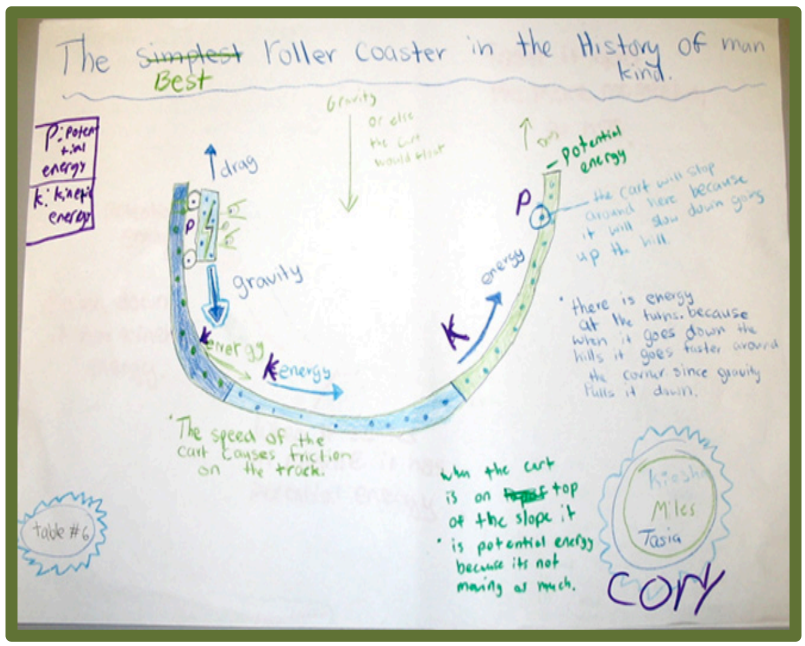
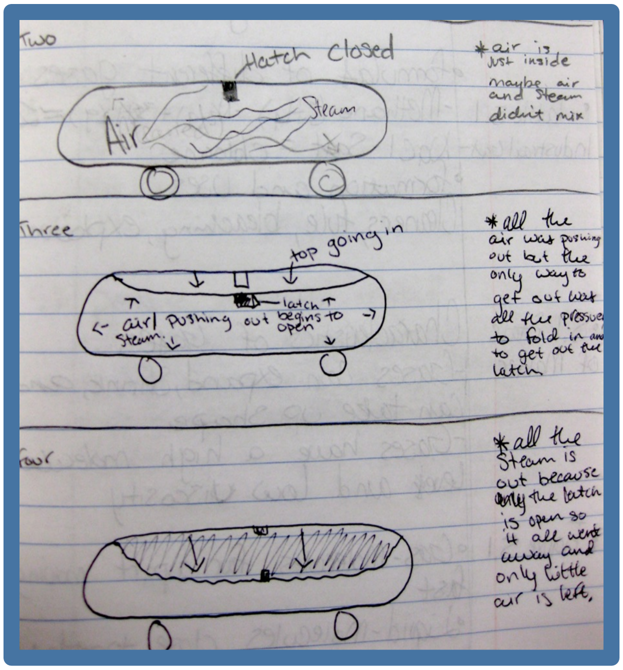
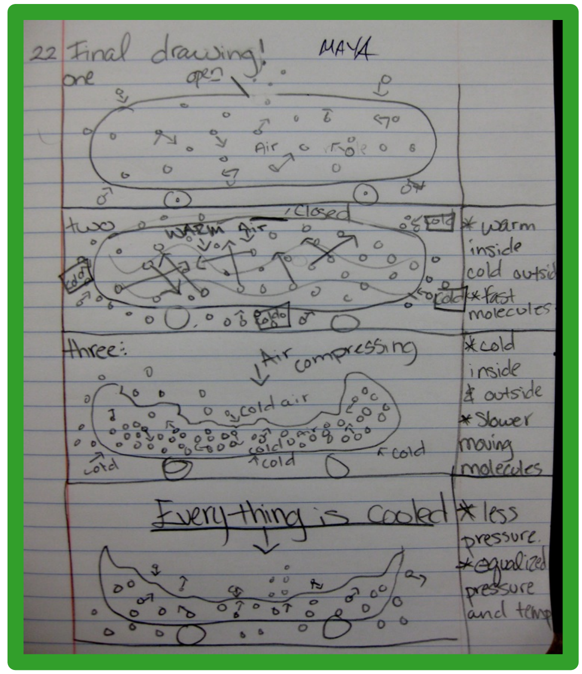
1. Small group models



The most versatile way to represent students' thinking is the small group model. Students in small groups create their own initial models at the beginning of a unit, then change these over the course of a unit. These could be representations of the puzzling phenomenon that the teacher has introduced on the first day, or the teacher might ask students to draw a model that is about an event or process similar to the puzzling phenomenon that will be the focus of an entire unit.

For example, one of our teachers used a rough outline of a roller-coaster to have students draw out their initial ideas about how potential and kinetic energy explain the motion of the cars. In another classroom where the teacher was talking about density and buoyancy, she had them do a 3-part “panel drawing” of a plastic canister that was filled with alka-seltzer and then submerged in water. The students were asked to draw a “before-during-after” sketch in which they labeled not only what was visible but also their theory about what unobservable forces and events might be causing the sinking, floating, and sinking again of the canister.

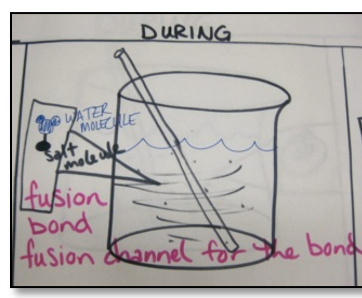




Strategies for focusing students on the phenomenon and eliciting the most from students

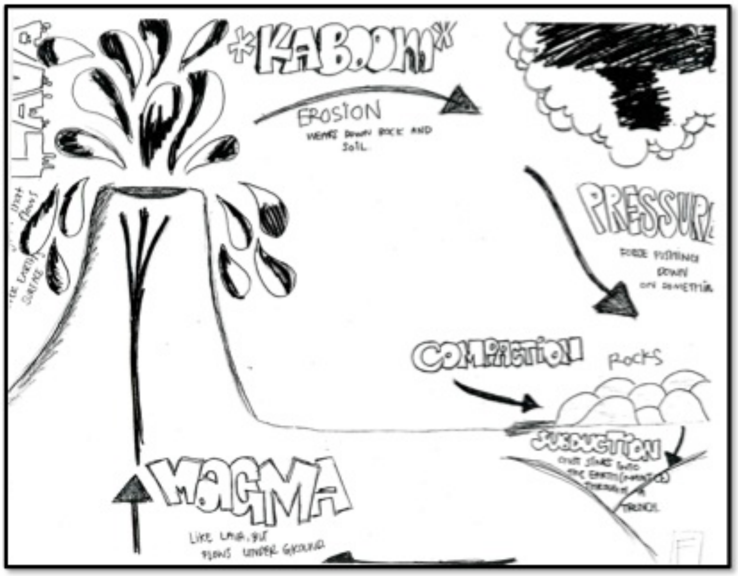
1. We have learned that the *before-during-after* drawings are particularly helpful for students to show what they think is happening. Above we have a three-part drawing. The anchoring phenomenon for the unit was a railroad tanker car that had mysteriously imploded after being steam cleaned on the inside. The first set of drawings was done at the beginning of the unit, and the second set was drawn later in the unit. Notice how much more of an explanation is elicited, even in the first drawings, when asking for before-during-after.

Our teachers and their students have also come up with other novel ways to show the passage of time during an event. In a high school physics classroom studying force and motion, the teacher had students draw what unobservable events and processes were at work as a young man did a back flip after running up to a wall and pushing off of it (shown to students on a video). They decided to use a single frame to draw the man at five different stages of the run—including him standing still at the beginning.



2. We have also found that for micro-level events, it helps if you ask students to "draw what you would see if you had microscope eyes." It sounds simple, but works well in chemistry and biology. In the drawing to the right, the students are expressing what happens as compounds go into solution in a beaker. They use the convention of a "blow-up" section of the beaker.

As the unit progresses, students will learn more scientific ideas and have experience with activities that will allow them to make changes in these small group models. Students can be asked to re-draw their models or add to a sparse model that they had started with. There are many possibilities.



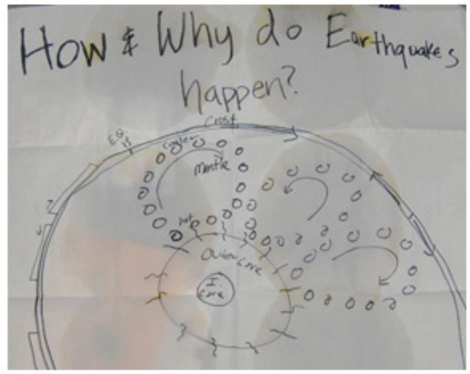
We now offer a MAJOR caution. Make sure the model is about a ***particular*** event or process with some context to it. By context we mean that the event or process happens in a particular time or place or under particular conditions, and that ***all these special conditions matter*** to the explanation. If you ask students to model a generic phenomenon (like the water cycle or how levers work) they will simply reproduce textbook explanations. We refer to this as "posterizing" someone else's science ideas. The "Rock Cycle" diagram pictured here is **NOT** a good example of modeling. Technically it may look like an explanatory model, but it is generic (not about any place or set of circumstances in particular). "Posterizing" is not intellectually challenging, all the students in the class would likely have the same models drawn.

Helpful advice from our teacher colleagues who have successfully used small group models:

- Always ask students to draw both observable and unobservable features. The exception here might be the initial models of early elementary students.
- Agreement about drawing conventions is important. After students have drawn an initial model, have a conversation with them about how the class should represent certain ideas, so that everyone understands each other's drawings (i.e. What do we all agree that arrows will mean? How will we agree to draw molecules? How will we show that time is passing?).
- As an equity move, have each student within a group use a different color marker or tell students you want to see everyone's handwriting somewhere on the model.
- For drawings that may be hard to sketch out, provide a template with outlines for students to use as a guide. When we ask student, for example, to draw out what they think is happening during homeostasis (such as regulating body heat in humans), we provide an outline of a human body—that's all they need to get started. Their drawings are then a bit more comprehensible to the teacher and to peers in other groups.
- Have students change the model only once or twice in the middle of the unit, not every other day. They will get "model fatigue" if you go back to the drawings too often.
- To make comparisons between models more manageable for students (since there may be several in one classroom) and to promote equal participation, have each student in a group visit other groups' models to look for how one particular relationship in the model differs across these drawings.

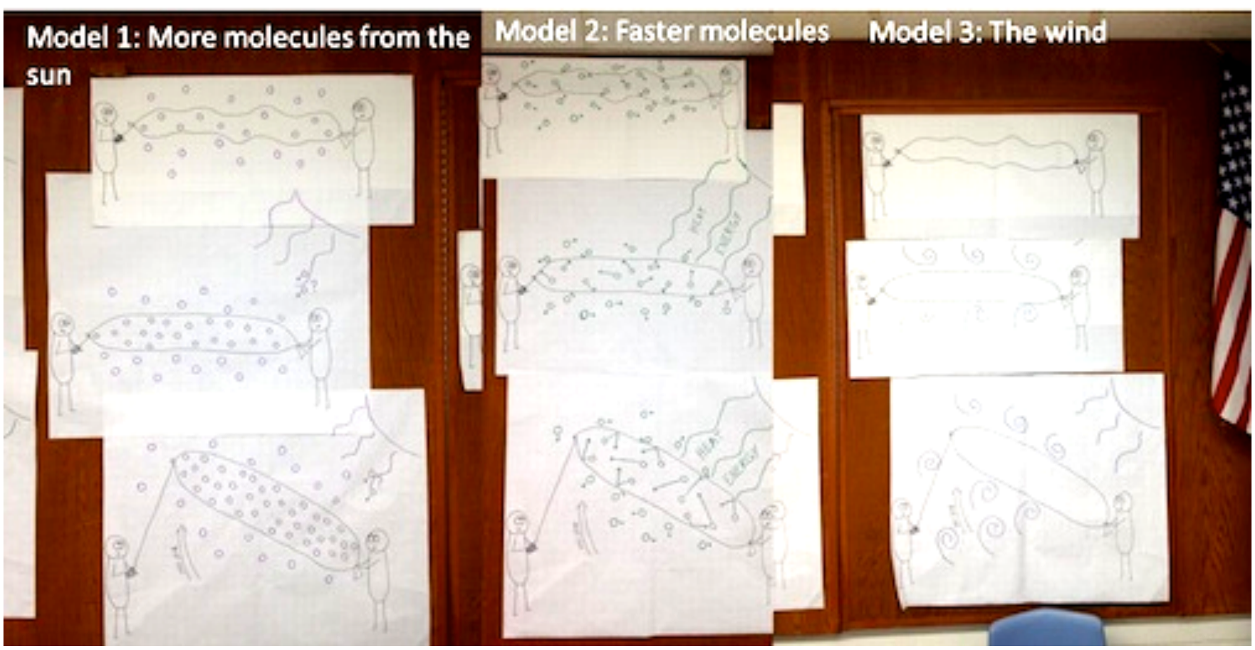
2.Whole class consensus models.

When students are less experienced with how to draw and change models, the teacher can start a unit by focusing on a single drawing or set of drawings that the class as a whole "owns."



A "whole class consensus model" can be started immediately after students have had some introductory experience with a puzzling phenomenon. On a piece of poster paper, or the whiteboard, the teacher can draw a very basic pictorial representation of the phenomenon that students are exploring. Then, with input from students, the teacher can add labels on this drawing that indicate students' hypotheses about underlying events or processes that influence the phenomenon. These are the students' initial hypotheses in diagrammatic form. The teacher coordinates drawing this initial consensus model, with help and input from students. As the students engage in upcoming rounds of activity and discussions, they should (with the teacher's assistance) *decide how they want to change the model*.

At first, these drawings should be really spare (simple, not cluttered). Notice how the whole class earthquake model above has only a few parts to it. Students may have only idea "fragments" to contribute that are not necessarily contradictory to the scientific explanation, only very simple. These are ideal for noting on the consensus model, because they can be *built upon and changed later as students learn more*. Also, the teacher should use student language in the initial model rather than imposing scientific language at this point. It's their model.



In the image above, students came up with three different possible explanatory models for a "solar tube"—which is a mylar balloon that inflates when exposed to the sun's rays and can then float away. The teacher captured three theories, one in each drawing. As the unit progressed, the students tested different parts of each of these models, and also began to make changes and add explanatory detail to the more plausible models. In the end, they thought that the most convincing explanation incorporated two of these models, rather than being a single model—an outcome similar to authentic scientific discovery.

If you want to try a more manageable version of whole class models, you can do "testing a list of hypotheses." These hypotheses are not full explanatory models, but they would get you and your students on the path to representing tentative ideas, then testing those ideas and changing them over time. The illustration we use here is of yeast mixed with warm water and sugar in a flask. The yeast is undergoing cellular respiration and producing carbon dioxide. The students have expressed four different, but partially overlapping hypotheses.

You can list potential hypotheses that students initially have about “what’s going on” in a target phenomenon. These answer the question, “What might be contributing to or causing X?” These hypotheses can be very simple to start with. They are usually a mix of one-sentence observations, inferences, and mini-theories, but they are not full blown explanations. Don’t deny students’ contributions because they are brief or because they aren’t using scientific language.

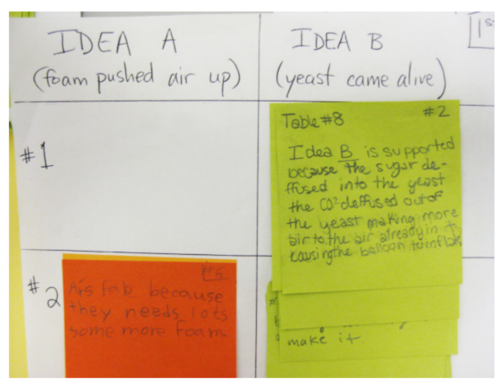
Hypothesis 1. "The foam is pushing the air up into the balloon."

Hypothesis 2. "The air is warm in the flask, and it is rising."

Hypothesis 3. "Something is going on like when you mix baking soda and vinegar."

Hypothesis 4. "The yeast is coming alive and is producing a gas of some kind."

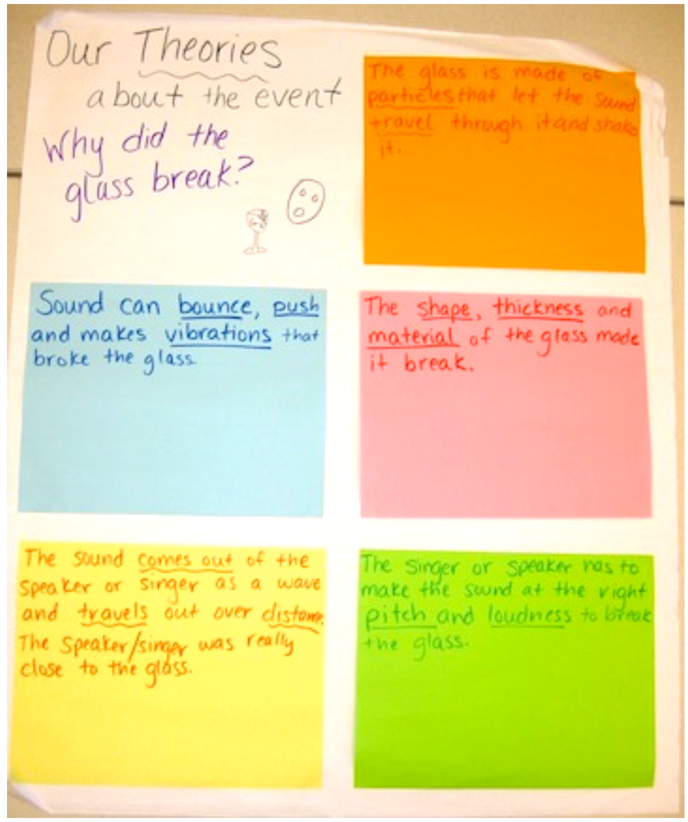
This might be followed by probing for more pieces of the causal story. Place a question mark behind each hypotheses at first so students understand that the hypotheses are not yet supported by evidence. As you then engage in cycles of reading, activity, and connecting with everyday experiences, you can gather evidence and ideas that can be applied to the list of hypotheses. Some hypotheses might get crossed out as implausible, others might be supported, others might be elaborated upon as time goes on, and some hypotheses might be linked with others.



After a couple of activities and readings, you may be ready to ask students to start a public conversation about how the evidence they’ve generated can support or contradict an explanation. One way to do this is to place on the board (or a piece of poster paper) two competing explanations for the phenomenon or puzzling question that you’ve based your unit on. Ideally, one of these can be an explanation that some of your students had originally favored, but is not complete or lacks scientific cohesion. The other explanation should be scientifically coherent, and ideally also generated by your students. Under each explanation is a list of the activities or readings the students have done recently.

Then, in small groups, students are given a prompt (such as a picture) from a lab activity or reading they have done. On this prompt can be some statement about what the key ideas were that students have learned from the activity or reading—this could have been generated by the students themselves when they did the activity. All the small groups can then spend 5 or 10 minutes deciding if what they had learned from that activity or reading supports one or both of the explanations, or if it contradicts one or both of the explanations. If it supports an explanation, they can write on a yellow sticky note why it supports a particular explanation. If it contradicts or does not support an explanation they can use a blue sticky and explain why. At the end of this round a student from each group comes up to the board and in the box that represents that particular activity or reading (below one of the explanations) they can place their sticky note.

The teacher then reviews the sticky notes with students and moves on to the next type of evidence. There may be 1 or 2 rounds of this activity during a class period. The teacher can decide to have a whole class discussion after each round or wait until the final round to engage in this discussion.



This can be repeated two or three times during a unit, and the sticky note table can remain up in the room in the interim.

Caution! This activity does not, by itself, help students come up with a rich causal explanation; you should couple this activity with going back to some whole group model or small group models, and have students periodically re-write or re-draw their causal explanations.

Helpful advice from our teacher colleagues who have successfully used whole class consensus models:

- All of the points to think about from the "small group models" section also apply the whole class consensus models.

- If there are clear misconceptions that students initially think should be part of this model, then you'll have to think of a way to label these as "still in doubt"— you can, for example, label them (or all the ideas) with large question marks to indicate the tentative nature of these ideas.

- Next to the drawing, or below it, there should be space for "Questions we still have about…" This will tell you a lot about what parts of the phenomenon they are interested in. You should capitalize on these questions in your instruction and use their questions to identify where their “gaps” currently are.

• Use small group models more regularly than whole class models. The small group models reveal more student thinking, generate a sense of ownership, and require more intellectual work.

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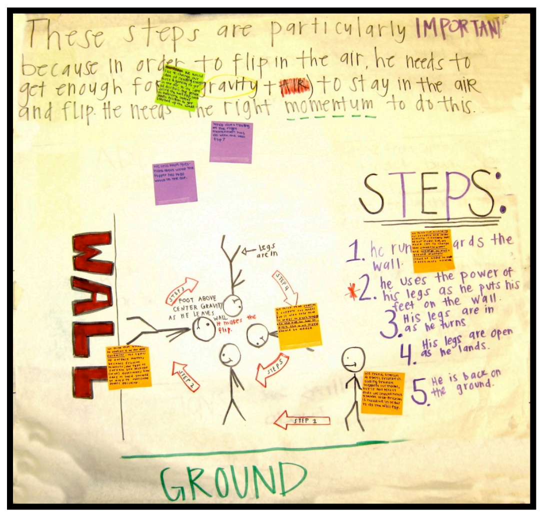
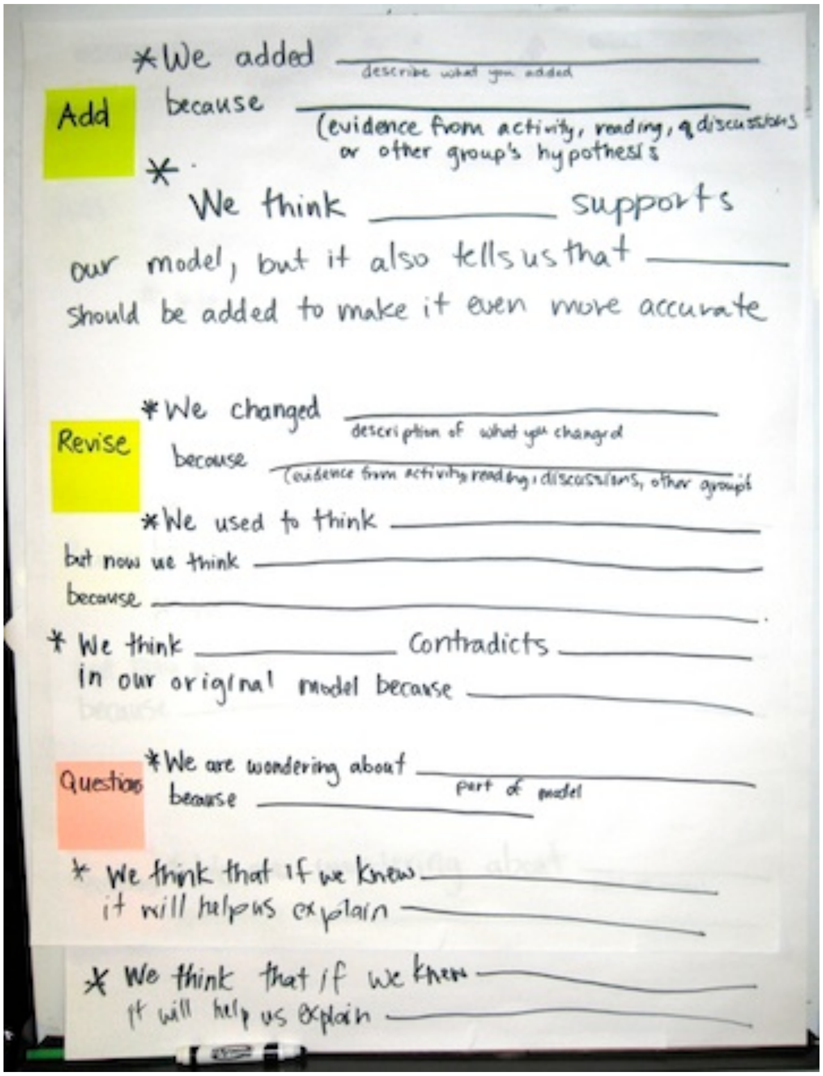
3. Sticky-notes and language scaffolds as tools for changing models

Models are meant to be changed. Models can have ideas added to them or ideas deleted from them. They can have relationships changed. The ideas embedded in them can be questioned by students. Students learn from both suggesting changes and receiving suggestions for change.

We have found that "sticky-notes" are the best way for the whole class to experience how ideas can shift with new information, evidence, or logical argument. These are small, color-coded notes that are applied by students directly to the models. The color represents the type of comment one wants to make about some aspect of the model. The comment is written on the note, rather than on the model itself. We learned to use the notes, in part because re-writing on the model itself got sloppy, and the owners of the models felt that their ideas were being "over-written."



We have also found that with some scaffolding, students become quite capable of offering productive forms of commentary. This is partially because the color codes guide and restrict the types of comments. There are no color codes, for example, for commenting on how artistic the drawing is or how legible the handwriting is. We generally group comments under three categories: "Adding an idea," "Revising an idea," or "Posing a question." In the model of the man doing a back-flip (described previously), the orange sticky note on the lower left is adding on an idea that came from an activity the students had just done: *We think according to Station 4 with the different surfaces, the type of surface matters because friction matters. The type of surface you kick off of (wall) determines how hard or easy it is to overcome static friction*. This caused the group that received the comment to make changes in their model to make it more accurate and to reflect more of what they had learned about friction.



Students are not familiar with talking (or writing) this way. We use sentence frames as a way to guide their writing. We have seen that students not only use these sentence frames, but after a few weeks, they begin to take up the "grammar" of science talk in their own speech with peers and with the teacher. Among other benefits, the sentence frames are a way for students to start talking about evidence, and how it should be applied to an explanatory model.

Helpful advice from our teacher colleagues who have successfully used sticky notes

- Because students are reluctant to comment on the drawings of others, especially early in the school year, we have had them "practice" by placing notes on their *own* models after a couple of lessons. They learn how to look at their own models, and how to write notes in full sentences that provide reasons for requesting possible changes.

- We ***always*** provide sentence frames for them to use. It encourages them to think about how one form of model change is different from another, and helps them use scientific ways of talking/writing to express the rationale for possible changes. It also keeps comments from being trivial in nature. We have yet to find the “perfect” sentence frames!

- One of the sentence frames should be about a puzzle or a question that a group has, this opens the door to really new ideas or to gaps in the potential explanation that could not be expressed in any other way.

• Don't have too many comments on each model, only one or two groups should really comment on another group's particular model.

• Spend time, after the commentary, for the owners of the model to read the notes and decide if they should act upon the suggestions.

Face-to-face tools that help students coordinate evidence with their explanations (this follows rounds of activity and reading).

4. "Gotta-have" explanation checklist.

The "gotta-have" checklist is a set of ideas or concepts they think must be included in the final explanation. This is more constructed by students than by the teacher. This may start with very simple statements or even just terms, but the list should grow over time—added to by students, with occasional prompting by the teacher. Again, as the students engage in cycles of reading, activity, and connecting with their everyday experiences, they add to this checklist. If they are missing some key elements of the final causal explanation, it should alert you as the teacher to modify your instruction to address these missing pieces.

The "Gotta-have" explanation checklist is ***not*** a list of vocabulary words that have to be included in drawn or written explanation. As the checklist is developed, lesson by lesson, it needs to be composed of IDEAS, or RELATIONSHIPS that the students now believe are important to a final explanation. These items on the checklist are not "giving away answers." They remind students of what is important to talk about or draw out, and these are ideas that they have come up with themselves during the unit. Here is an example of a "gotta-have" checklist that was developed by students during a unit on the Gas Laws. The anchoring phenomenon for the unit was a railroad tanker car that had imploded after being steam cleaned, then mistakenly sealed up.

You need to include in your explanation:

- ☐ *How molecules cause pressure*
- ☐ *About differences in conditions inside versus outside the tanker at every phase*
- ☐ *About heat energy and how it affects parts of the system*
- ☐ *About how changes in the volume of a container affects pressure*

Helpful advice from our teacher colleagues who have successfully used "Gotta-have" checklists:

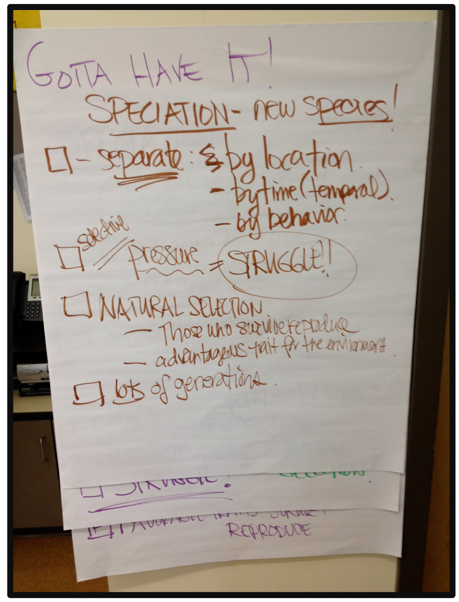
• The checklist is one of the most manageable tools to use in the classroom, a good representation to try out first.

• An explanation list can be started at the beginning of the unit, but should be added to or subtracted from every few days as the students learn more.

• Students should co-develop the list with you—it is a representation of their thinking, not yours.

• Keep away from making it a vocabulary checklist. Including the word "how" (see Gas Laws checklist above") sometimes helps you as a teacher express the items as ideas, rather than as words.

• When students are creating their final explanatory models, *make sure they have access to the checklist*—it works very well as a common set of ideas that the teacher can refer to as he/she circulates around the room and observes the construction of the final models.



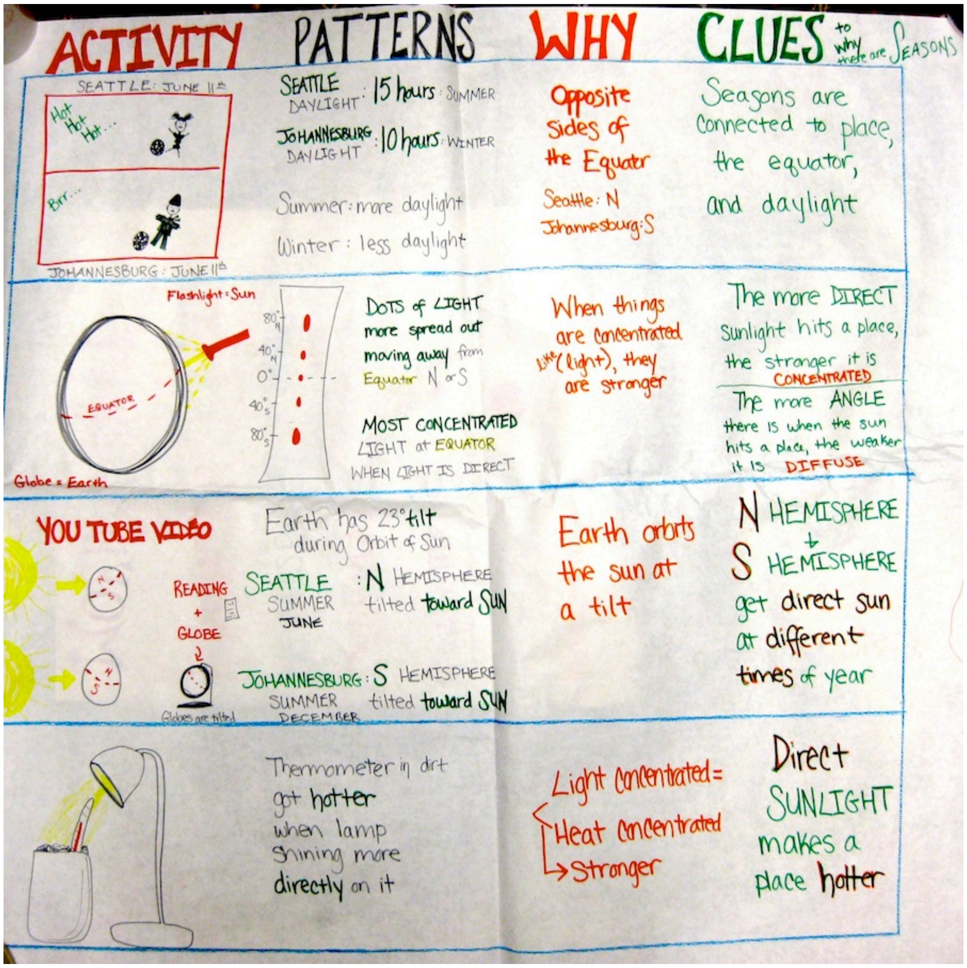
5. Summary tables

The summary table is one of the most indispensible tools in modeling (the first shown here is for a middle school unit about "Why are there no seasons if you live near the equator?", the second is from a 3rd grade unit on why a singer can break a glass with his voice). Because a model is supposed to change over time, and in response to new evidence or arguments, students need to have some record of what they have done over the past few days, in order to draw upon different activities or readings. Without some representation of what they have done or read, they would have to depend on memory, and each student's memory is different. So, just as scientists do, the teacher can help students keep a record of activities and ideas.

We have found that the best way to keep a record of activity and ideas is to create a table with four columns—1) Activities we did, 2) Patterns or observations, what happened?, 3) What do you think caused these patterns or observations?, 4) How do these patterns help us think about the essential question or puzzling phenomenon? As you can see in the figures included here, there are many variations created by our teachers. They are all adaptations that are useful for their particular classroom needs.

The table is placed on a wall in the classroom and it remains up throughout the unit. After each round of reading and activity, students are in charge of discussing how the activity helps them think about the phenomenon, and filling in one complete row.

As the unit progresses, more and more rows get filled in and, ideally, students start to piece together a more coherent and complete explanation by looking "down" the fourth column. Some teachers argue that they don't have enough wall space to keep summary tables for every class period, however there are always ways around this by using a flip chart or simply making space on your walls. Teachers often have commercial posters up that are not really helpful in supporting students' learning (think about taking them down)—the summary table is far more powerful for helping students reason with evidence.

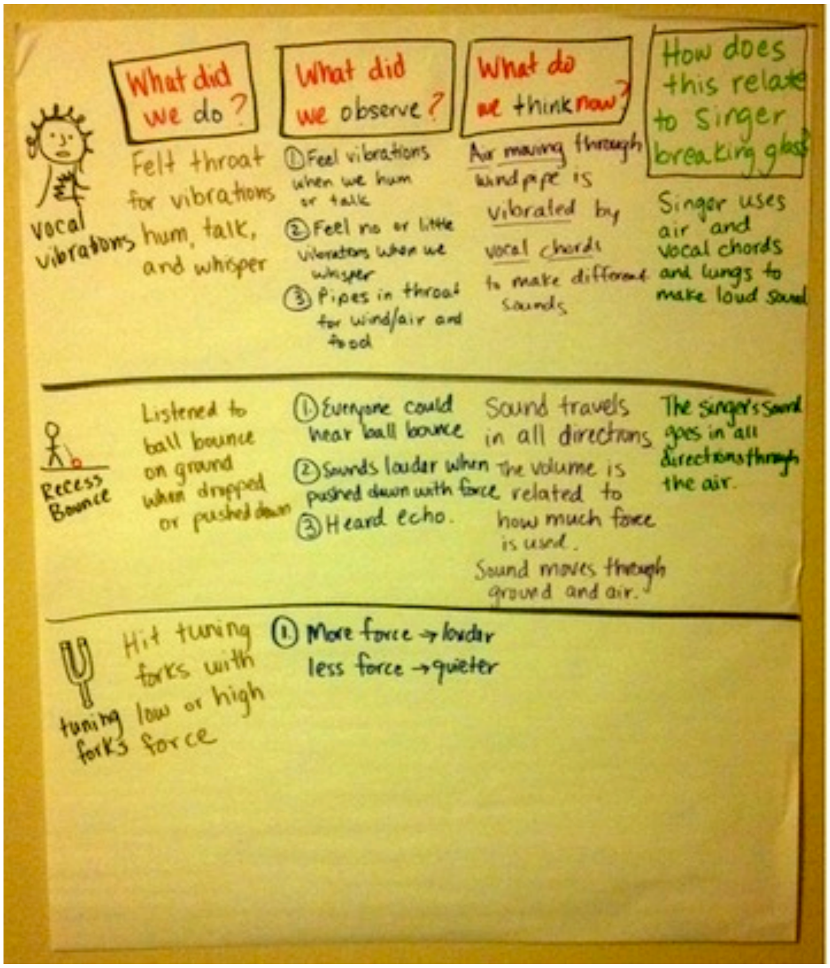


Helpful advice from our teacher colleagues who have successfully used Summary Tables:

• Don't put too many columns into your summary table, and don't have more than five rows.

• The students should be in 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 (we've seen this happen), it is unhelpful and confusing for students. Fill in each row immediately after each activity.



• Help students make sense of what they've learned from each activity. There has to be time allocated to this at the end of the class period and perhaps also at the start of the following class period.

• When students are drawing and writing their final explanatory model, have them use one or two rows on the summary table to express a type of evidence that they are using to support part of that explanation. Especially early in the year, you don't want students to try to use the whole summary table and all the evidence expressed within it to support their explanations.

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We hope this brief guide has given you ideas about how you might support the thinking of your students. The toolkit discussed here is not static, you can experiment with the different combinations of support and what shape the tools take, but do keep in mind that the aim for all these tools is to support more students in participating in thinking and talking about science ideas in your classroom.