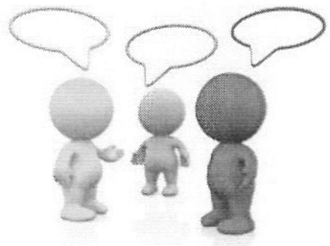
K-5 Science Cadre:
Productive Science Talk

November 18, 2015



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Goals: Participants will . . .

- Participate in an science investigation and science talk
- Be equipped to better facilitate productive science talk in the elementary classroom.

****Please take breaks as you need them**.**

Thank you for your participation! We appreciate you and are so glad you came. If you have any questions, please don't hesitate to get in touch with Lesley or Virginia.

Next Sessions: January 19, February 16, and April 26

My Think Sheet

5 Making Thinking Visible: Talk and Argument

As we noted in Chapter 1, science requires careful communication and representation of ideas. Scientists frequently share formulas, theories, laboratory techniques, and scientific instruments, and require effective means by which to understand and disseminate these types of information. They share their ideas and observations in myriad ways, including the use of text, drawings, diagrams, formulas, and photographs. They communicate via PowerPoint slides, e-mail exchanges, peer-reviewed research articles, books, lectures, and TV programs or documentaries. They participate in research groups, academic departments, scientific societies, and interdisciplinary collaborations.

Often, scientific collaboration takes the form of disagreement and argument about evidence. In this way, communities of scientists challenge and validate one another's ideas in order to advance knowledge.

These practices have analogues in science classrooms.[1] Effective science teaching can employ some of the same methods of communication and representation that are used by scientists in the real world. This chapter and the subsequent one focus, respectively, on the ways in which students can use language and argument, as well as other forms of representation, to communicate and further develop their ideas. As the case studies in previous chapters make clear, science teaching and learning involve more than just conducting interesting demonstrations in the hope that students will somehow, on their own, discover the underlying concepts behind the outcomes. Effective science teaching and learning must also include communication and collaboration, which require both spoken and written representations of the world.

In this chapter, we explore how talk and argument work in science and the role they play in good science teaching. We focus on language, both oral and written, as the primary tool for communication in science and the primary mechanism for making thinking public. Science provides unique opportunities for students to adopt and use new forms of argument and new representational tools. Because so much of what happens in classrooms is communicated and processed through speaking and writing, language plays a particularly important role in teaching and learning science. It is one of the most important ways for the teacher to understand and assess how students are thinking.

Language also provides students with a way to reflect on and develop their own scientific thinking, alone or with others. Teachers play a critical role in supporting students' use of language, guiding them toward a greater understanding of the language of science.

Learning Through Talk and Argument

In order to process, make sense of, and learn from their ideas, observations, and experiences, students must talk about them. Talk, in general, is an important and integral part of learning, and students should have regular opportunities to talk through their ideas, collectively, in all subject areas. Talk forces students to think about and articulate their ideas. Talk can also provide an impetus for students to reflect on what they do—and do not—understand. This is why many seasoned teachers commonly ask students to describe terms, concepts, and observations in their own words.

Two additional ways to think about talk in learning have specific applications in science. First, the language of science can be very particular. Certain words have precise, specialized definitions. It is quite common, however, for children and adults alike to confuse specialized science definitions with the more familiar definitions commonly associated with those words. An example of this, as mentioned earlier, relates to the word "theory," which in science is understood to mean "a well-elaborated body of scientific knowledge that explains a large group of phenomena." In common parlance, the word "theory" is often used to refer to a guess or a hunch. By having students read and discuss instances in which different definitions of a word are used and then explain how they've come to understand it, teachers can help students distinguish between science-specific and more common meanings of a word.

Another form of talk that has unique applications in science is argumentation. Like the language of science, it too needs to be distinguished from nonscientific interpretations in both definition and practice.

Argumentation can take several different forms. It is important that educators and students recognize and understand the science-specific forms of argumentation and how they differ from the common forms of argumentation in which people engage in daily life. For example, the kinds of arguments in which a person may participate with family members, friends, or acquaintances are often acrimonious or focused on the desire to make one's point and "win" the argument. Or in the case of more formal debate, such as the kind politicians engage in, contestants are scored on their ability to "sell" an argument that favors a particular position.

Both of these forms of argumentation differ from scientific argumentation in important ways. In science, the goals of argumentation are to promote as much understanding of a situation as possible and to persuade colleagues of the validity of a specific idea. Rather than trying to win an argument, as people often do in nonscience contexts, scientific argumentation is ideally about sharing, processing, and learning about ideas.

Scientific argumentation is also governed by shared norms of participation. Scientific argumentation focuses on ideas, and any resulting criticism targets those ideas and observations, not the individuals who express them. Scientists understand that, ultimately, building scientific knowledge requires building theories that incorporate the largest number of valid observations possible. Thus, while scientists may strongly defend a particular theory, when presented with a persuasive claim that does not support their position, they know they must try to integrate it into their thinking.

Encouraging Talk and Argument in the Classroom

In spite of the importance of talk and argument in science and in the learning process in general, K-8 science classrooms are typically not rich with opportunities for students to engage in these more productive forms of communication. Analysis of typical classroom practice suggests that patterns of discourse in classrooms typically adhere to a turn-taking format, often characterized as "recitation." A teacher asks a question with a known answer and a student is called on and responds. The teacher then follows up with a comment that evaluates the student's response.

This talk format is sometimes referred to as the I-R-E sequence, for teacher *I*nitiation, student *R*esponse, and teacher *E*valuation. Researchers have found it to be the dominant, or at least the default, pattern of discourse in classrooms. As such, students come to expect and accept it, and after a few years of using the I-R-E sequence, it's often difficult to get them to use a different pattern.

While I-R-E recitation can be helpful in reviewing prior knowledge or assessing what students know, it does not work well to support complex reasoning, to elicit claims with evidence, to get students to justify or debate a point, or to offer a novel interpretation. I-R-E patterns are likely to support only some of the strands of science learning (e.g., Strand 1) but not others (Strands 2-4). The I-R-E discourse pattern is not a particularly good one if the goal is to encourage and support argumentation. But changing long-standing discourse patterns in the classroom is not a simple undertaking. Students and teachers will require extensive modeling and ongoing support to become comfortable and competent with more effective talk formats.

The kind of discourse that encourages scientific talk and argument is different—in subtle and not so subtle ways—from the I-R-E pattern of discourse. To begin with, teachers ask questions that do not have "right" or "wrong" answers or to which they themselves don't know the answers. For example, a teacher might ask, "What outcome do you predict?" and follow up the initial question with comments such as, "Say more about that." They may ask other students to respond, saying, "Does anyone agree or disagree with what Janine just said?" or "Does anyone want to add or build on to the idea Jamal is developing?"

Teachers may also ask students to use visual representations, such as posters or charts, to make their thinking more accessible to the rest of the class. They may follow questions with "thinking" or "wait" time, so that students have a chance to develop more complex ideas and so that a greater number of students have a chance to contribute, not just those who raise their hands first.

Teacher-initiated questions might also ask for clarification, for example, "Does anyone think they understand Sarah's idea? Can you put it into your own words?" They might pose alternate examples or theories, or "revoice" a student's contribution, saying, for example, "Let me see if I've got your idea right. Are you saying that our measurements will be less accurate with shoes on?" This strategy helps make the student's idea, restated by the teacher, more understandable to the rest of the class. These "talk moves" implicitly communicate that it takes effort, time, and patience to explicate one's reasoning and that building arguments with evidence is challenging intellectual work.

The table on the next page shows six productive classroom talk moves[2] and examples of each, which teachers can use to help students clarify and

Talk Move	Example
Revoicing	"So let me see if I've got your thinking right. You're saying _________?" (with space for student to follow up)
Asking students to restate someone else's reasoning	"Can you repeat what he just said in your own words?"
Asking students to apply their own reasoning to someone else's reasoning	"Do you agree or disagree and why?"
Prompting students for further participation	"Would someone like to add on?"
Asking students to explicate their reasoning	"Why do you think that?" or "What evidence helped you arrive at that answer?" or "Say more about that."
Using wait time	"Take your time. . . . We'll wait."

expand their reasoning and arguments. These talk moves are illustrated throughout this book in the different case studies.

In addition to talk moves, teachers can engage students in a number of talk formats, each of which has a particular norm for participation and taking turns. Examples include partner talk, whole-group discussion, student presentations, and small-group work. A number of studies have suggested that productive classroom talk has many benefits in the classroom. It can lead to a deeper engagement with the content under discussion, eliciting surprisingly complex and subject matter–specific reasoning by students who might not ordinarily be considered academically successful.

Some of the reasons why productive classroom talk is so important, and why it may be effective, include the following:

- It allows students' prior ideas to surface, which in turn helps the teacher assess their understanding.
- Discourse formats such as extended-group discussion might play a part in helping students improve their ability to build scientific arguments and reason logically.
- Allowing students to talk about their thinking gives them more opportunities to reflect on, participate in, and build on scientific thinking.
- It may make students more aware of discrepancies between their own thinking and that of others (including the scientific community).
- It provides a context in which students can develop mature scientific reasoning.
- It may provide motivation by enabling students to become affiliated with their peers' claims and positions.

Many educators reading the classroom case studies in this book might doubt whether this kind of productive talk can really take place in science classrooms. They might think, "It looks easy for them, but the students in our district couldn't do this." Or, "Maybe my students would like this, but I don't know if I can bring it off successfully. What if no one talks? What if I can't understand what they're trying to say? What if they make fun of each other?"

These are reasonable concerns. Instruction that supports productive scientific discussion is difficult to enact, even for seasoned veterans. The kinds of discussions described in the case studies are largely improvisational, and students' contributions can be unpredictable. The improvisational and unpredictable nature of these discussions can be intimidating for teachers, school administrators, science specialists, and teacher educators who share responsibility for creating safe, orderly, and productive science learning environments. In addition, some educators are uncomfortable encouraging or condoning any kind of argument in the classroom. That's understandable, given how much time is spent in schools mediating conflict and persuading students of the value of civil exchange.

Teachers need support, skill, and persistence to help students grasp the difference between respectful scientific argument and the kind of confrontational, competitive argument they may be used to. The success of the former is dependent on students having the shared understanding that the goal of the argument is to reach a point of mutual understanding or consensus. The latter relies on the assumption that the goal of an argument is winning. Students of any age, from kindergarten through middle school, will need help to recognize the distinction between disagreeing with an idea and disagreeing with a person.

Mediating effective scientific argument also requires the teacher to have sufficient knowledge to perceive—on the fly—what is scientifically productive in students' talk and what is not. Younger students, English language learners, or students exploring a new topic will tend to use language that is ambiguous, fragmentary, or even contradictory—especially in a heated conversation. In these moments, the content and structure of students' arguments can be difficult to follow. Yet if the educational goal is to help students understand not only scientific outcomes and the concepts that support them but also *how* one knows and *why* one believes, then students need to talk about evidence, models, and theories.

Position-Driven Discussion

In Chapter 4, we saw a class engage in a collective discussion about whether adding air to a volleyball would increase its measured weight. This discussion and the ensuing activity involved all of the students in a teacher-guided, whole-group discussion. This was a discussion of a very specific kind—what might be called a "position-driven" discussion. It involved a demonstration that was poised to run but was not run until after students exchanged predictions, arguments, and evidence. The proposed problem had more than one imaginable outcome, so the students could predict and argue for different outcomes. In addition, it featured materials and scenarios familiar to the students, so that each student believed that they could anticipate the outcome. By using familiar materials and phenomena, students can more readily conjure up their own ideas and experiences and tap into these as they build explanations. This makes it possible for every student to participate in a more meaningful way.

A position-driven discussion generally forces the student to choose from two or three different but reasonable answers. In the case of the students in Mr. Figueroa's class in Chapter 4, the students had to decide whether the volleyball with 15 extra pumps of air would be (1) heavier, (2) lighter, or (3) weigh the same. This kind of discussion generates productive and lively talk. It also calls on students to actively participate in reasoning, theorizing, and predicting. Students take positions and attempt to formulate the best arguments and evidence they can in support of their position. Sometimes, informal votes are taken to see where the students stand with respect to one another, followed by more opportunities for students to change their minds, argue, and revote. In position-driven discussions, everyone is focused on the same phenomenon but is required to commit to one position or another and to argue for their respective predictions or theories. Everyone is also free to change positions on the basis of another person's evidence or arguments—typically with the proviso that one says, as specifically as possible, what it is in the other's position that one finds useful or persuasive.

Position-driven discussions are designed to push for divergence in predictions and theories. They also capitalize on the wide variety of life experiences and resources inherent in an ethnically and linguistically diverse group of students. Such discussions are a powerful form of "shared inquiry" that mirror the discourse and discipline of scientific investigation.

In position-driven discussions, as in most effective classroom talk and argument formats, the teacher's role is to help students explicate their positions as clearly and cogently as possible, not indicating, even subtly, how close to the "right" answer they may be. The teacher does not evaluate student contributions as correct or incorrect, as is often common in traditional teacher-guided discussion or recitation. Instead, the teacher typically supports students by revoicing their contributions and pushing for clarification. This helps both the speaker and the rest of the class move toward a greater understanding of their own and everyone else's reasoning.

This emphasis on having a clearly explained theory or position over having a correct theory or position continues until the demonstration is run and students see the actual outcome. This focuses students on finding explanations or answers in the outcomes of evidence, not merely in authoritative sources like textbooks and teachers.

One important aspect of a position-driven discussion is the framing of the question with which the discussion is launched. This is not always an easy task. It requires that the teacher produce a clear, easily understood question that will provoke a range of reasonable responses and positions, none of which can appear obviously correct. In addition, the question must be carefully selected and sequenced among other science-related tasks so as to advance the thinking of the group as a whole. It is unreasonable to expect a teacher to develop such framing questions without the support of a rigorous, coherent curriculum, colleagues, or an instructional coach.

Science Class

ESTABLISHING CLASSROOM NORMS FOR DISCUSSION[3]

It takes time to get students to understand that more than one explanation for a scientific event is possible and that alternative explanations should always be examined. One way to encourage this thinking is for teachers to frequently introduce and discuss alternative beliefs and explanations or describe the ways scientists disagree and resolve their disagreements.

Some researchers, in collaboration with science teachers, have found that argumentation in classrooms is more likely to occur when students are permitted and encouraged to talk directly with each other, rather than having their discussions mediated by the teacher. Other researchers have found that teacher-mediated whole-group discussion is more productive. Most successful teachers use a combination of talk formats to provide opportunities for both of these types of discourse. No matter what the format, teachers need to work actively to support classroom norms that emphasize responsibility, respect, and the construction of arguments based on theory and evidence.

As we described earlier, the most productive classroom environments, in all subject areas, are those that are enriched by talk and argument. But many students and teachers are not accustomed to or comfortable with extensive student talk in the classroom, so it is important to understand how to define and establish effective, acceptable classroom norms for discussion. Following is a case study that illustrates some methods for establishing and using norms for discussion.

Gretchen Carter's 28 sixth-grade students are a diverse and challenging group, with over 70 percent of them eligible for free or reduced-price lunches. Among her students are six children who recently immigrated to the United States and who leave the room each day for intensive English language instruction. In addition, she has four students using individualized education plans (IEPs), including one student, Lucy, who has been diagnosed with autism. Lucy rarely speaks in class but is treated by her teacher and peers as a full participant in classroom activities.

Ms. Carter works hard to establish an environment of cooperation and respect in her classroom. Her mottos are "No single student is as smart as all of us put together" and "You have the right to ask for help, and the duty to provide it to others." She has also established norms for her students for respectful participation in small-group work and whole-group discussion. Each student has a set of rights and obligations printed on green paper and pasted into the first page of their science notebooks. The students and Ms. Carter refer to these rights and obligations as the "Green Sheet." The Green Sheet outlines the rules for talk in Ms. Carter's class. She developed the rules over a number of years, so she no longer negotiates them with her students at the beginning of each year. Instead, she hands out the Green Sheet and discusses it with her students, asking them to describe the rules in their own words and to give reasons why the rules are appropriate and effective. The Green Sheet rights and obligations are as follows:

Student Rights:

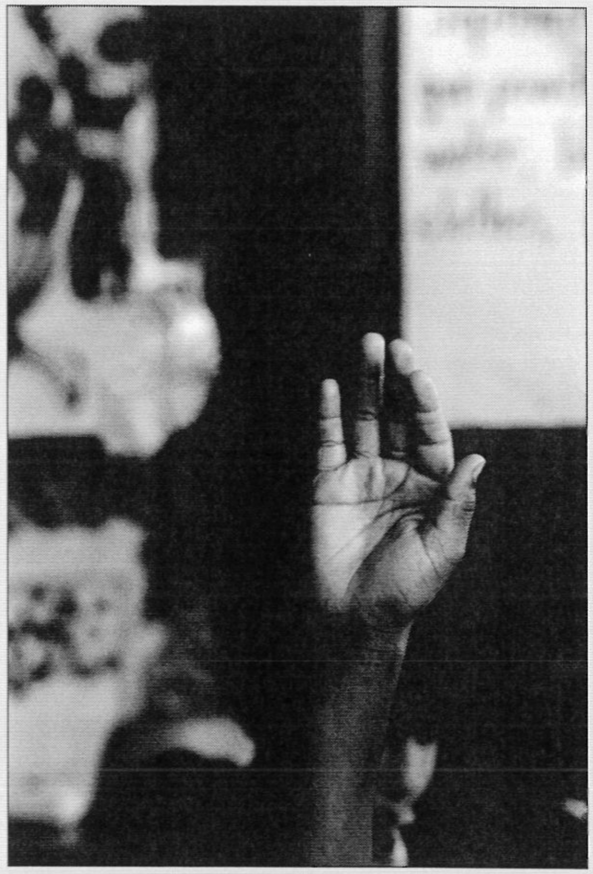
1. You have the right to make a contribution to an attentive, responsive audience.
2. You have the right to ask questions.
3. You have the right to be treated civilly.
4. You have the right to have your ideas discussed, not you, personally.

Student Obligations:

1. You are obligated to speak loudly enough for others to hear.
2. You are obligated to listen for understanding.
3. You are obligated to agree or disagree (and explain why) in response to other people's ideas.

Once the rules have been discussed, Ms. Carter consistently reminds her students of them, pointing out any infractions. Ms. Carter uses a color-coded discipline system in conjunction with these rights and obligations. Each student starts the day on green. A warning is given for misbehavior, and a further infraction results in a change to yellow. After one more warning, another infraction puts a student on red and the parent is called after school. If there is a serious infraction, she stops the class and has everyone turn to their Green Sheets to find the right or obligation that relates to that particular infraction. She then discusses that right or obligation at length with her students. Disrespectful comments get a warning. Repeat offenses get the offender a color change. Over a period of weeks, the rules become thoroughly internalized by her students and Ms. Carter rarely needs to refer to the Green Sheet. It remains a resource, however, available for review if discussions get off track.

Students know that she will keep enforcing the norms consistently, week in and week out. As a result, Ms. Carter's class is known for its good behavior. In addition, her students appear to be willing to ask questions, put forward their ideas, and respond fully and respectfully to each other's questions. These are all signs that Ms. Carter has succeeded in making her classroom a safe place for students to engage in challenging academic thinking, problem posing, theorizing, and problem solving—by making their thinking visible to one another and to themselves.



Checklist

Goals for Productive Discussions and Nine Talk Moves

Talk Science in the Inquiry Project

Goal One Help Individual Students Share, Expand and Clarify Their Own Thinking	Notes/Frequency of Use
☐ **1. Time to Think** - Partner Talk - Writing as Think Time - Wait Time	
☐ **2. Say More:** "Can you say more about that?" "What do you mean by that?" "Can you give an example?"	
☐ **3. So, Are You Saying…?:** "So, let me see if I've got what you're saying. Are you saying…?" (always leaving space for the original student to agree or disagree and say more)	
Goal Two Help Students Listen Carefully to One Another	
☐ **4. Who Can Rephrase or Repeat?** "Who can repeat what Javon just said or put it into their own words?" (After a partner talk) "What did your partner say?"	
Goal Three Help Students Deepen Their Reasoning	
☐ **5. Asking for Evidence or Reasoning** "Why do you think that?" "What's your evidence?" "How did you arrive at that conclusion?"	
☐ **6. Challenge or Counterexample** "Does it always work that way?" "How does that idea square with Sonia's example?" "What if it had been a copper cube instead?	
Goal Four Help Students Think With Others	
☐ **7. Agree/Disagree and Why?** "Do you agree/disagree? (And why?)" "What do people think about what Ian said?" "Does anyone want to respond to that idea?"	
☐ **8. Add On:** "Who can add onto the idea that Jamal is building?" "Can anyone take that suggestion and push it a little further?"	
☐ **9. Explaining What Someone Else Means** "Who can explain what Aisha means when she says that?" "Who thinks they could explain why Simon came up with that answer?" "Why do you think he said that?"	

TERC
The Inquiry Project: Bridging Research & Practice
Supported by the National Science Foundation

Adapted from: Chapin, S. O'Connor, C., & Anderson, N., (2009). *Classroom Discussions: Using Math Talk to Help Students Learn, Grades 1-6.* Sausalito, CA: Math Solutions Publication

Smelly Balloons

Sniff out the scents hidden inside balloons

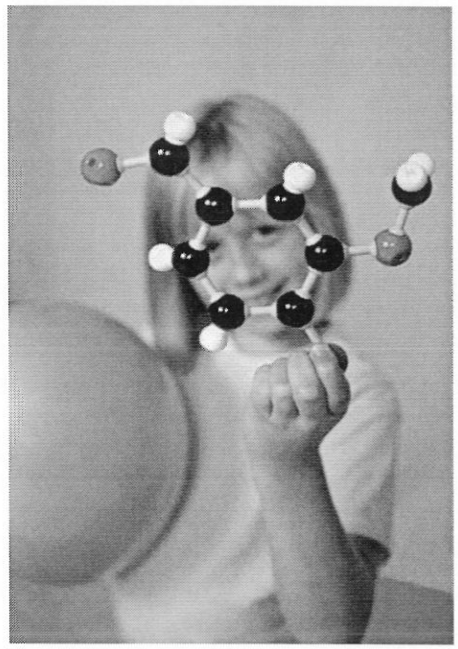
Activity Guide

Try This!

SAFETY: If your balloons are latex, warn visitors of possible allergic reactions.

1. Each balloon has a different scent inside it. Your challenge is to figure out which scent is in which balloon.
2. Smell the balloons. Can you identify all the extracts?

What's Going On?



Matter is made of atoms that bond together to form molecules. These particles are too small to see, but we can smell some of them! Scent molecules are so small they can travel through the balloon membrane.

Scent molecules are very volatile, which means that they easily vaporize from liquid extract into a gas. We added a liquid extract to the balloon, but it soon vaporized, filling the balloon with scented air.

Air gradually leaks out of the tied balloon. This is because the tiny air molecules inside the balloon move through the pores of the balloon's skin, in a process known as diffusion. Air always diffuses from areas of higher pressure to areas of lower pressure. An inflated balloon has greater air pressure inside it, so the air gradually diffuses into the lower air pressure surrounding the balloon.

Learning Objectives

- Molecules are too small to see, but we can smell some of them.
- Scent molecules are so small they can travel through the balloon membrane by diffusion.

Materials

- Selection of scented balloons *(Requires advance preparation; see below.)*

Advance Preparation

- Round balloons in different colors
- Variety of extracts (e.g. vanilla, strawberry, garlic, smoke)
- Pipettes or eye droppers
- Balloon pump

1. Use a pipette or eyedropper to put about ½ teaspoon extract in a balloon. Insert the dropper as far as possible into the balloon before you squeeze it, so the extract doesn't get onto the neck of the balloon.
2. Holding the balloon carefully so you don't get extract in your mouth (or balloon pump), blow up the balloon and tie it.
3. Shake the balloon a few times to encourage the extract to vaporize.
4. Repeat steps 1-2 for all your extracts. Choose a different color balloon for each extract.
5. Make a key identifying the scent in each balloon. Optional: Make a list of the scents—without keying them to the balloon colors—for visitors to see.

Credits
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The Camille & Henry Dreyfus Foundation

Name____ Grade______

Productive Science Talk Implementation Reflection

Directions: Intentionally plan a science talk to include in an upcoming science lesson. Use talk moves from the handouts shared at the cadre session. After hosting the science talk, reflect on the science talk in the spaces below. If there isn't a need for student discussion in the lesson, then tweak the lesson. Please then email this form back to Lesley Merritt (lmerritt@uark.edu) or Virginia Rhame (vrhame@starfishnw.org). Thanks.

Describe the science lesson where you engaged students in science talk. Include in your description the purpose for the science talk.

How did your science talk differ from an I-R-E discussion?

What were the successes of the science talk (both you & students)?

What were the struggles of engaging your students in productive science talk (both you & students)?