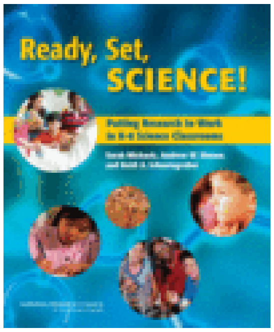

Ready, Set, Science!: Putting Research to Work in K-8 Science Classrooms

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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.

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.

Appreciating Cultural, Linguistic, and Experiential Differences[4]

In efforts to support effective use of talk and argument in the classroom, it is important to remember that scientific language is, to some extent, foreign for *all* students. There are no native speakers of science. In addition, all students are shaped by their cultural backgrounds, and those backgrounds affect how they learn science and communicate in the science classroom. Today's students come from a variety of cultural backgrounds and have different ways of behaving, thinking, and interpreting the world, and they interact differently with the communities and institutions that they encounter in their everyday lives. Children both shape and are shaped by their cultural practices and traditions, so that the relationships between culture and personal belief are fluid and complex.

In addition, people's experiences and histories vary, and a person's ability to negotiate change across cultures and settings may be affected by their history. Thus, teachers' and students' personal cultural experiences have implications for how they learn to talk and act in classrooms generally, and this will have implications for how they experience scientific talk and argumentation. Cultural diversity is important to recognize, because classrooms are not neutral settings. They too are imbued with social and cultural norms and expectations. These norms and expectations are often unstated, which can make it difficult for some students to understand what those norms and expectations are. This observation will become even more relevant over time, as the demographics of the United States continue to shift, and classrooms become even more diverse than they are today.

How does a teacher create the conditions that allow all children—despite their cultural, linguistic, or experiential differences—the same access to classroom conversations and to be held accountable to the same high levels of academic rigor in their talk, reasoning, and representations?

A good place to start is with some important principles and ideas that research in a variety of fields has shown to be true. Regardless of their race, culture, or socioeconomic status, all children, unless they have severe mental disabilities, have well-developed ways of telling stories, giving accounts, providing reasons, making arguments, and providing evidence. Similarly, all children have the capability to think abstractly about situations, concepts, and even about language itself.

With very few exceptions, children come to school as adept language learners and language users. Linguists have shown definitively that all such children are grammatical speakers of their home language—that is, they use language in consistent and rule-governed ways. While their dialects may be different from standard English, all children speak their home dialects with fluency and accuracy. Some children even bring a second language to the classroom at a level of sophistication and fluency that few of their teachers are able to match.

If all children have linguistic abilities, why does it sometimes seem that certain students are not adept language users? Why does it seem that some students don't bring much, if any, language from home or aren't able to speak about academic subjects? Why does it seem that certain students are good at talking about science and others are not?

The primary reason for this is that speakers of all languages have a tendency to perceive differences in the way other people speak and identify these differences as "inadequacies" or "deficits." For teachers, this tendency can create problems in the classroom. A focus on deficits in students' language makes it harder for the teacher to connect with students, harder to build on their strengths, and harder to create the conditions for rigorous and productive discussion, reasoning, and presentations in science.

Every child in this society learns culturally appropriate ways of using language and of taking meaning from written texts in the early years at home. Every cultural group in this society has sophisticated ways of integrating the oral and written language around them into daily life. However, ways of using oral and written language are closely tied to culture and the different ways members of a culture have of interacting with others. In some cultures, the use of language in the home is closely related to the ways in which language is typically used in schools, while in other cultures it is not as closely related.

For example, Yup'ik children in Alaska typically learn by observing experienced adults and participating as helpers in adult work and other activities. Verbal interaction is not central to their learning process; observation and participation are considered more important.[5] Because of this, a reliance on explicit verbal instruction may be less effective or even disconcerting to children from this cultural background.

As another example, researchers in Hawaii, part of the Kamehameha Early Education Project, have shown that part-Polynesian children perform much better in small-group reading instruction if they are allowed to talk without waiting to be called on. Effective teachers allow these students to "overlap" their talk with one another in much the same way they do when talking or storytelling outside of school.[6]

Carol Lee has found, in her research with predominantly African American high school students in Chicago, that at times in a lesson, students would break into animated discussion, all seeming to talk at once, speaking over or interrupting one another.[7] On the surface, the discussion might have appeared chaotic. However, Lee showed that this kind of discussion could be highly productive in advancing the academic purpose of a lesson. She found that the students' talk, when analyzed closely, showed evidence of rigorous thinking and of students hearing and building on one another's contributions.

In addition to coming to school with different discourse experiences and styles, some children have had far less exposure than others to many of the kinds of practices that form the basis of scientific activities and investigations, including providing explanations, analyzing data, making arguments, providing evidence for their claims, and interpreting texts. An extensive body of research suggests that such cultural differences often lead to negative judgments about a student's intelligence or the quality of their thinking. These judgments can affect a teacher's expectations of how a student should contribute or participate in classroom discussion. Research also shows that it is hard for teachers to recognize and build on the reasoning of a student whose methods of communication may not be the same as their own. These subtle and not so subtle miscommunications with respect to language and culture in the classroom can lead to serious problems of equity and access, creating barriers to communication, student-teacher trust, and the conditions that nurture active participation and effort. This, in the end, can result in significant decreases in student motivation, participation, and learning, which can have far-reaching, real-life consequences in regard to knowledge and performance.

One way for teachers to overcome cultural and linguistic differences in students is to treat them as if they were highly intelligent foreign diplomats. This simple strategy is reliant on common sense. People recognize that foreign diplomats think and communicate in ways that they cannot always immediately understand or relate to, but they assume, nonetheless, that foreign diplomats are intelligent and possess unique talents and skills. Similarly, in a fast-paced classroom conversation, it may be difficult to immediately understand a student's unique intelligence, wit, insight, and analytic skills. But the teacher can assume that they have an innate capacity to think deeply, to reason abstractly, to coordinate theory and evidence, and to develop sound arguments. An assumption of competence makes it easier to build on and promote students' contributions, even if those contributions are incomplete, not entirely explicit, or are expressed in a nonstandard dialect. Once students are invited into the conversation, are given opportunities to engage in coherent instructional tasks, are able to hear and build on the contributions of their peers, and have scientific reasoning modeled for them by teachers and peers, they gradually take on the language and forms of competence that are valued in science.

Strategies for Inclusiveness

But how does one listen through cultural differences? How does one ensure that every student participates in the conversation and is held to the same rigorous standards in providing evidence, justifying claims, and representing ideas in ways that others can understand? How does one promote equity and access in the face of tremendous sociolinguistic diversity? How can teachers create the conditions for rigorous science talk simultaneously with children from many different cultures and language backgrounds?

According to researchers, there are two effective strategies that teachers can use. First, they need to make the rules of participation visible in the science classroom, instead of assuming that students implicitly know what the rules are. When engaging in new or unfamiliar scientific activities, teachers may need to provide explicit, detailed accounts of expectations, including, if necessary, structured or scripted roles to play in discussions.

The goal should be to establish and maintain what Okhee Lee has described as *instructional congruence*.[8] With instructional congruence, the nature of an academic discipline is meshed with students' language and cultural experiences to make science accessible, meaningful, and relevant. Students are given opportunities to master new ways of thinking and participating, while teachers ensure that students know that their existing norms and practices are valued.

The work of establishing, understanding, and modifying classroom norms for scientific thinking must be ongoing. Students themselves can help create these norms by proposing, debating, and establishing criteria for what counts as a good scientific question or what counts as persuasive evidence. For example, in one particular classroom, criteria for judging good questions and persuasive evidence were adopted by the students as the norm. Then, midyear, new ideas about questions and evidence surfaced as students evaluated their work. Some students argued that they should amend their criteria of what qualified as a good question by adding that a good question should encourage "piggybacking" (good questions are inspired by the findings of others and in turn inspire related additional questions). They changed their criteria to reflect their new understanding that knowledge in the scientific community depends on the sharing of information and evidence, and that new knowledge is often built on the contributions of fellow scientists.

Research shows that children are adept at learning how to participate in public speaking activities in the classroom. They quickly learn what the implicit norms, rights, and obligations for speaking are. When students resist taking on the roles or norms of classroom activities, it is not because they're not smart enough to know what the norms are. Rather, it often means that students resist assuming these roles because it means taking on a social or academic identity with which they feel uncomfortable. Students must feel that they belong, and they must *want* to belong. When classroom discourse is successful, every student is treated as a full member of the group, with all of the rights and status of membership, even before they have fully mastered the discourse.

The second strategy for effectively promoting equality in discourse is making evident the connections between students' everyday thinking, knowledge, and resources and those of practicing scientists. In the Chèche Konnen research program, researchers conducted studies with Haitian Creole students and their teachers over 15 years to identify key points of contact between students' ways of knowing and scientific ways of knowing. For example, they observed that the students visualized themselves in problems, regularly evoking analogies, arguments, and narratives as a means of making sense of phenomena—all common strategies among scientists.

One student who was investigating animal behavior—in this case, the preference of ants for different kinds of habitats—imagined himself in the different habitats. His original intention had been to set up an experiment to establish whether ants prefer an environment that is dark to one that is brightly lit. But as this student imagined himself as an ant crawling through the soil, he began to wonder how either side of the chamber—lit or unlit—could possibly appear light to an ant underground.[9] The Chèche Konnen research program demonstrates how the cultural practices of urban, language-minority students can be drawn on to support high-level scientific reasoning and problem solving.[10]

Some of the strategies discussed earlier in this chapter, such as student and teacher revoicing, the modeling of scientific argument, and the use of wait time, are especially helpful in classrooms in which there is great linguistic diversity among students. These strategies help slow the pace of the discussion, allowing time for complex ideas to be expressed, listened to, repeated, revoiced, and responded to at length. This facilitates the acquisition and use of scientific language and of discourse structures. It exposes students to complex scientific reasoning, allows them to practice it with support and guidance from their teacher and peers, and gives them opportunities to become confident and competent in presenting their claims, models, and explanations as well as at challenging evidence and asking questions.

In establishing norms for inclusion so that students of different cultural backgrounds and experience can understand and build on one another's ideas, teachers must also find ways to ensure equitable access for all students to participate in the talk that surrounds scientific investigations. Equitable participation does *not* mean that every student must participate in every conversation. Rather, it means that *access* to every conversation must be equal. In discussing equitable participation, one must assume that there is a structured, robust scientific conversation being held, not merely a turn-taking event in which the goal is for everyone to offer an opinion or idea. Assuming this to be the case, equitable participation requires that everyone hear what is being said and that everyone have equal time to develop their ideas and be heard, respectfully, by all. Participation is not equitable if some students routinely dominate the conversation while others are routinely excluded. Again, the goal is not to allow every student to say something. The goal is to ensure that the conversation stays focused, that each student can hear what is being said, and that each student has opportunities to contribute relevant ideas if they so choose.

In order to develop their ideas and arguments, students must be able to think aloud, practicing what some teachers and researchers call "first draft thinking" or "exploratory talk." During this sort of initial exploratory talk, students' communication is sometimes halting, with pauses, repetitions, hesitations, and false starts. It can be difficult to follow. Their ideas may be flawed in some way. But the goal is for students to have an opportunity to clarify their initial ideas and for others to listen, attempt to build on those ideas, and adjust or improve on them.

For students there is often much at stake beyond their success or failure at learning science, so getting them to express thoughts about which they are not certain can be particularly challenging. Some students may fear being seen as bookish and may shy away from expressing their thoughts. Others may worry about expressing ideas that are not fully formed. Still others may take every opportunity to insert their voice and dominate classroom discussions. This makes for a complex social dynamic that is critical for teachers and students to learn to monitor.

In creating an environment that supports equitable participation in classroom discourse, it is critical to pay special attention to English language learners. In science, in which vocabulary and discourse are so important, limited proficiency in English can make it difficult for teachers to recognize or gauge the depth of a student's understanding of scientific concepts, which in turn makes it difficult to build on what the student already knows.

Many teachers assume that English language learners must become fairly proficient in English before they can learn much about science. This is not the case. Research suggests that the science classroom is a good environment in which to teach diverse language populations, because talk in the science classroom is often about materials and events that all of the students see and experience together. This provides a basis for the development of vocabulary and discourse practice. It also motivates the reading of associated texts.

There is evidence that with good instruction children from all cultural and language backgrounds can learn science. However, research is not yet clear as to which methods work best under which circumstances. One clear objective for the future must be to build on the unique strengths and needs that students of diverse backgrounds bring to the classroom. This should be a central focus of teacher preparation courses and of ongoing professional development in regard to making science teaching and learning equitable and accessible to all students.

The following case study demonstrates how students' culturally diverse ways of speaking and thinking interact with school tasks and curricula.

Science Class

SUCCESSFULLY SUPPORTING DIVERSITY[11]

Jocelyn Wright taught a combined third- and fourth-grade multiethnic class in a large city in Massachusetts. There were a large number of Haitian Creole–speaking children in her school, as well as a transitional Haitian Creole bilingual program. Ms. Wright spoke quite a bit of Haitian Creole herself, and she valued the linguistic and cultural resources her diverse group of children brought from home.

The class was doing a science activity on the topic of balance, using a balance scale with small metal weights placed at different points of the scale on both sides. In this science unit, over the course of several weeks, the students worked on a series of balance problems.

After a particular problem was posed, students were asked to predict, by a class vote, whether the weights would balance or whether they would tip to the right or to the left. Once the students voted for their choice, they debated or discussed their predictions and their reasons for those predictions with each other as a group. After the discussion, they had a chance to vote again in case they had changed their minds on the basis of someone else's explanation or argument. Finally, the teacher performed the demonstration, and the students went to their seats to fill out a worksheet explaining their reasoning.

Approximately four weeks into the unit, the students had progressed through a series of balance problems, predicting, debating, and changing their minds. At this point, the students had been introduced to the formula "multiply weight times distance," to help them figure out how the balance would behave. They had already practiced solving balance problems of this type, but there was still some confusion among the students as to when to multiply and when to add.

Sabrina, a fourth grader, argued that the configuration shown below would balance (see Figure 5-1). She demonstrated her reasoning to the group by writing on the small whiteboard easel:

$$2 \times 5 = 10 \quad \Big\| \quad 1 \times 1 = 1 \qquad 3 \times 3 = 9$$
$$1 + 9 = 10$$

Sabrina said, "Three weights on the 'three point' equal nine, the single weight on the 'one point' equals one, so the total force on the right side of the scale is ten. Then, on the other side, two times five equals ten, so since both sides equal ten, it will balance."

Josianne asked to report next. Josianne, a native speaker of Haitian Creole, had moved to Ms. Wright's class two months earlier from a transitional Haitian bilingual classroom.

Ms. Wright used a "handing off" procedure for turn-taking during science discussions, which

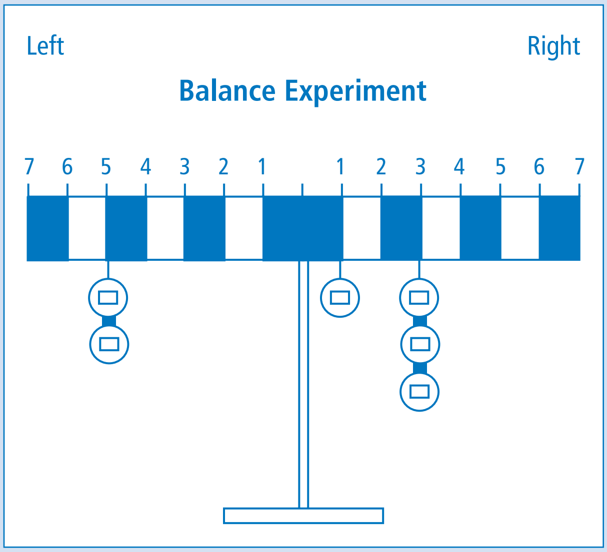

FIGURE 5-1
Balance with weights.

required that the current speaker nominate the next speaker, so Sabrina called on Josianne.

Josianne: "I agree with you [referring to Sabrina] because I was thinking it will balance."

Ms. Wright: "And what made you think that?"

Josianne: "Because, I think it will be balanced, because, I was thinking. I think it will be balanced."

Ms. Wright probed further to try to get Josianne to reveal some of the reasoning behind her conclusion.

Ms. Wright: "So, do you remember what made you think that? Were you just persuaded by what other children were able to say?"

Josianne: [shaking her head no] "Uh-uh."

Ms. Wright: "Can you give us some words for your thinking?"

Again, Ms. Wright tried to encourage Josianne to explain her reasoning, but Josianne seemed to struggle.

At this point, Ms. Wright asked Josianne if she would like to bring the next speaker into the conversation. After more students explained their mathematical reasoning, the class held a second vote. Ms. Wright performed the demonstration, which showed that the scale did, in fact, balance. She then asked the students to return to their seats and put down in writing their reasoning for why it balanced. Josianne returned to her seat and wrote the following:

"Because I was thinking it have to be balance, and I vote for balance."

Ms. Wright thought that Josianne's answer might reflect her limited proficiency with English. She asked a colleague to work one on one with Josianne to try to determine whether she could explain her reasoning. All of Josianne's answers were given first in Creole and then in English.

Teacher: "Can you tell me why you thought it would balance or why you now think it would balance?"

Josianne: "I say because I was thinking in my brain. And my brain think it will be balance."

Teacher: "Okay. Can you say more about why?"

Josianne: [puzzled] "Say more about why?"

Teacher: "Why do you think it will be balanced? What did your brain think to get you to think it would be balanced?"

Josianne: [grinning] "I don't know because I didn't ask my brain."

Teacher: "*Ask* your brain about the weights and where they are and why you think it would be balanced or why you think it did balance. Why does it have to balance? Why doesn't it tip to the right or to the left?"

Josianne: [impatient] "Because I make multiplication in my head! I say, here it's two, and this five, two times five here and three time three is nine plus the one point is ten."

Josianne had clearly known the reasoning behind her answer all along but had not understood what the teacher was asking her to explain. When Ms. Wright's colleague asked her why she didn't explain "all that multiplication stuff" in the first place, Josianne responded, "I didn't understand your question."

Josianne knew her multiplication facts and how to apply them to the problem. But she did not understand the discourse of school science. She interpreted Ms. Wright's questions and those of her colleagues as asking her about the status of her knowledge and how she came by it. Did she guess? Was she persuaded by her classmates? Or did she figure it out for herself?

In as many different ways as she could, Josianne was trying to explain that she had figured it out for herself. However, in the discourse of school science, reasoning the proof, the theory, the model, or the mathematical reasoning has to be made explicit. This might have been obvious to the other students in the class who participated in the discussion. But as this example illustrates, "why" questions can be interpreted by students in many different ways. They can be interpreted as asking for an explanation, a demonstration of one's reasoning, a motive, evidence, and so on, depending on the discourse conventions particular to a given domain.

What's instructive in this example is that Ms. Wright did not give up on Josianne. During the group discussion, she tried asking the same question of Josianne in several different ways, and eventually she moved on to another student so Josianne wouldn't feel uncomfortable. Ms. Wright sensed that the problem lay in her own inability to tap into Josianne's understanding. In the end, it wasn't specifically language that made the difference for Josianne. It more likely was the reframing of the "why" question that helped Josianne to understand. The newly framed question did not ask *how* Josianne knew, but *what about* the configuration of the weights made the balance arm tip.

In the fast pace of classroom life, it takes a careful eye (or just as likely, ear) and a stock of good questions and tasks to successfully gauge students' understanding. It helps if teachers presume that their students have ability, reasons, and complex ideas, even if this is not at first apparent, and then work hard to help them demonstrate these abilities.

Representing ideas through talk and argument plays an essential role in learning in general and a more specialized role in the learning and practicing of science. In the science classroom, students need opportunities to talk through their own ideas and hear and respond to those of their peers. When discussion is conducted only through the filter of the teacher or the textbook, students have fewer opportunities to formulate and develop their own understanding and ideas or to practice listening to peers and building arguments collectively. In many classrooms, students are given scant opportunities to think aloud, let alone engage in argumentation that is uniquely scientific. In order to engage in effective scientific argumentation, students must embrace norms and habits that focus on data, analysis, and the building of ideas in a collective, cumulative fashion.

Building classroom environments like those of Mr. Figueroa, Ms. Carter, and Ms. Wright can be challenging. The ways in which these teachers structure and elicit student talk and argumentation is an ongoing and often complex process. The methods described in this chapter can serve as entry points for improving the practice of classroom discourse and for adjusting the ways teachers may structure student interactions related to science.

In order to do this, teachers will need opportunities to observe science classrooms like the ones described in this chapter. They'll need to experience firsthand what it is like to be members of a community governed by scientific norms for talk and argumentation. And they'll need help reflecting on those experiences and planning appropriate ways to create scientific talk and argumentation structures in their own classrooms. They'll need access to resources that illustrate these practices and provide additional explanations for how to implement them.

In asking teachers to move away from the well-established patterns of classroom interaction to embrace student talk and argumentation as a central feature of the science classroom, we must recognize that they will require support. Typical patterns of discourse in schools, such as the I-R-E pattern described earlier, are so pervasive in U.S. culture that they can even be observed in young children as they play school. School system administrators, curriculum developers, and science teachers and educators will all need to understand and participate in the challenge of moving to more effective methods of promoting talk and argumentation in the science classroom.

For Further Reading

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