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TALKING SCIENCE

Classroom discussions and their role in inquiry-based learning environments

Science is a social process—one that involves particular ways of talking, reasoning, observing, analyzing, and writing, which often have meaning only when shared within the scientific community. Discussions are one of the best ways to help students learn to "talk science" and construct understanding in a social context. Since inquiry is an important strategy for teaching science (NRC 1996; AAAS 1993), teachers face the challenge of facilitating meaningful discussions in an inquiry- or project-based setting. This article presents three types of discussions that can be used in inquiry-based activities and provides an example of each in a sample investigation.

Discussions in the science classroom

In traditional classroom discussions, teachers ask the questions—which often have a single right answer—and students are told whether or not their responses are correct. The questions asked tend to focus on factual knowledge or experience (e.g., "What did we observe?" or "What did we do?"). These discussions are typically referred to as "IRE dialogues": The teacher *initiates* a question, a student *responds,* and the teacher immediately *evaluates* whether the answer is correct or incorrect.

This type of discussion is useful, as it provides a quick, whole-class review before moving on to new activities. But too often this kind of question-and-answer activity is the primary form of classroom discourse—placing the teacher at center stage and students' questions and their learning in the background (Solomon 1992). A *real* discussion, on the other hand, is an interplay of meanings and ideas from both students and the teacher.

In our opinion, the negotiation of ideas is the preferred form of classroom discourse. Students need opportunities to express their own ideas (even if they are not always correct or well-structured), listen to their peers ideas, evaluate and critique ideas, and revise and integrate them as well. The result of this process should be evidence-based ideas or explanations that students can use to explain phenomena and stimulate further learning.

Classroom talk should center on engagement and thoughtfulness. Students should ask questions that arise from their own interests or confusion—and they should ask questions of each other as well as of the teacher. Teachers should pose questions that push students to think more deeply about what they have observed, experienced, or read. Discussions can provide students with opportunities to express their understanding and learn from each other, but only if some form of authentic dialogue takes place.

To this end, we present three types of discussions that promote students' thinking: brainstorming, synthesizing, and sensemaking discussions. Figure 1 (p. 46) displays the three types of discussions and some suggested prompts for each. In practice, classroom discussions are often not limited to just one type but include elements of more than one, as demonstrated in the following sections.

Context of the example discussion

In the unit the example activities are drawn from, the main learning goal is for students to develop a particulate view of matter. Students investigate the question: "How can I smell things from a distance?" After experiencing how a strong odor from a harmless source (e.g., air freshener or vanilla) spreads in the classroom, each student constructs an individual model of how smelling an odor occurs and uses that model to explain how odors travel. (**Safety note:** The chemicals in fragrances can cause irritation or allergic reactions in sensitive people.)

The initial models reflect students' preexisting conceptions and are the starting point for a process of revision through a variety of inquiry activities. In addition to the phenomenon of smell, students investigate various behaviors of gases: adding air to the existing air in a sealed container, removing air from a flask, and compressing and decompressing air in a syringe.

Students consider their early models in relation to subsequent activities and revise their models to account for all of the phenomena they have observed. This process gradually develops their understanding of the particulate nature of matter. The initial models students draw may reflect a continuous view of matter, a particulate, or a mixed one, any of which effectively serve as the basis for further learning (Merrit, Shwartz, and Krajcik 2007).

Types of discussion

Brainstorming discussions

In this example, a brainstorming discussion takes place at the beginning of the unit. Its purpose is to allow students to share their experiences, in this case, with odors. The following prompts can be used to initiate the discussion described in the previous section:

- Have you ever walked into your home and smelled what was cooking before you saw it? Tell us about it.
- Why can you smell food inside a restaurant even when you are still outside?
- Did you ever smell burning leaves in your neighborhood, even though the fire was too far away to be seen?
- Why do you think you can tell what is causing an odor without even seeing its source?

Synthesizing discussions

One of the early discussions in this unit aims to derive a class consensus model of how smelling an odor occurs, after students have constructed individual models. Consensus is reached through a synthesizing discussion in which students evaluate their individual models. A synthesizing discussion involves putting ideas together, or assembling multiple activities into a coherent whole. It also includes generalizing from specific activities to a broader conclusion. At this point, the consensus model does not have to be "correct," but rather serves as a starting point for further investigation. It is a thinking tool and a way to represent students' own ideas.

A synthesizing discussion helps students organize their knowledge and integrate their ideas about models in general, the conclusions from their inquiry regarding the behavior of air, and the main inquiry question (i.e., "How can we smell things from a distance?"). It also helps students realize how their individual thinking is similar to or different from their peers' thinking about the same phenomenon, and how ideas emerging from various individual models can be synthesized into a meaningful consensus model. The following prompts can be used in such a discussion:

- What do we want to represent with the model? How does the model represent what happened?
- Using the model, explain what you observed.
- What is the model *not* able to show?
- What do the models have in common? How are they different?
- What should the criteria be for evaluating the models?
- What are the best features in each model?
- What kind of a consensus model do you think would be best to describe how the odor gets from the source to our noses? What should such a model include?
- What did we learn from the characteristics of air that might be relevant here?
- What did we learn about the phases of matter that might be relevant here?

While some of the suggested prompts for this discussion may fit within the synthesizing category (e.g., "What did we

FIGURE 1

Types of discussions.

Type of discussion	Characteristics	Suggested prompts
Brainstorming	Sharing ideas without evaluating their validity or value.	◆ What do you know about...? ◆ What do you or others think about when they hear the word...? ◆ Who has a different idea/response/way of thinking about this? ◆ What else is on your group's list?
Synthesizing	Putting ideas together. Generalizing from specific activities to a broader conclusion. Making connections to personal experiences, previous lessons, or knowledge constructed in other units, lessons, or subject areas.	◆ How does...help us think about other times when...? ◆ How can we put these four ideas together into one process that we might call a cycle? ◆ What happens first, second...? ◆ What do we know about...so far? ◆ Yesterday we talked about...how does today's activity help us think about it differently? ◆ How does what we have just done connect with...?
Sensemaking (Pressing for understanding)	Figuring things out or making sense of activities. Going deeper, beyond surface answers. May involve challenge, debate, or argument in which students justify their ideas. May involve revision of previous ideas as students learn new information that calls into question the limitations of what they "knew" previously.	◆ How does *x* compare with *y*? ◆ How do you know *x*? What evidence supports that idea? ◆ What does it mean to say...? ◆ Why does our old model not work to explain this new phenomenon? ◆ How could we figure this out? ◆ What new questions do you have? ◆ Why do you think we are seeing something so different from what we predicted?

learn from the characteristics of air that might be relevant here?"), others fit within the sensemaking category (e.g., "Using the model, explain what you observed."). The inclusion of sensemaking prompts is necessary to remind students of their conclusions from previous activities and to support them in presenting their thinking to peers. The overall purpose of this discussion is to integrate ideas, even though it includes both types of prompts.

It is also important to develop norms for reaching consensus. The teacher may accomplish this by asking: "Does everybody agree? Is everybody happy with that?" If one or more students disagree, the teacher may ask the class: "What should we do to resolve this?" In one piloting class, the solution was to have two models and to postpone the decision until they had more evidence to favor one model.

Inquiry often requires that students reach a consensus regarding various things: the validity of the data gathered; the way to represent the data; the meaning of the data; and, as in this example, a model they can all refer to. Reaching a consensus is one example of the necessity of discussions. The consensus discussion serves both to promote students' learning and to construct a community of learners; it also models the discussions among practicing scientists.

Sensemaking discussions

A sensemaking discussion usually follows each investigation, experiment, demonstration, or simulation. Its purpose is to get students thinking more deeply about their experiences and their answers. An example of a simple sensemaking discussion is that which follows the activity of smelling a strong odor, using these suggested prompts:

- Does it make a difference whether the lid is on or off? Why?
- What does it mean that the odor "got out"?
- What does it mean that the odor "moves"?
- Why could person A smell the odor before person B?
- You smelled two (or more) different substances. How did two different odors get to your nose? Do you think that all odors get to your nose the same way?

Mixed discussions

In reality, many sensemaking discussions branch out to include synthesizing elements, as exemplified by the following example. The following is a class sensemaking discussion of the compression experiment. One student (who we refer to as "Sam") uses his model of air to explain what happens when it is compressed. Sam claims that air particles move only when air is compressed. The bold font emphasizes key sentences that guide the class discussion.

Teacher: If I was not compressing the gas, would the air be moving?
Sam: I do not think so.
Teacher: **I will write it here as a scientific claim**: "If you do not compress the gas, it will not move." **Think about our question for a minute: How do I smell things from a distance? If we do not compress the gas, it will not move. Does anybody want to argue this claim, or support it?**
Melissa: If it is only moving when it is compressed, then you would have to compress everything to smell, because the odor is traveling to our nose.
Teacher (to Sam): What do you think about that?
Sam (seems confused): I am not sure…
Teacher: OK, so you do not call this a claim, but you are asking, "Is this true?" What do you think of Melissa's argument, class?
Angela: I think I like it.
Teacher: **What kind of evidence would you need to make sure that you felt OK with this?**
Mark: The reason I think it can move: The air is moving even if it is not compressed. **If the air could not move, you would not be able to inhale it**. So we would not be able to breathe.
Teacher: **Does that argument help any of you?** What do you think?
Ben: I think that if we had a kind of gas in a jar and opened that jar, some of the gas could leave the jar, and we would not have done anything except move the top of the jar, which is not compressing.
Teacher: Aha! **So he is telling us to go back to the very first day, when the class originally smelled each substance. If I just take the lid off, I am not really compressing the gas, right?** Could we smell it?
Students: Yes.
Teacher: So now, **it looks like we have evidence that we might want to get rid of our original claim. Right?**

This discussion is basically a sensemaking one. Sam claims that air moves only when compressed. The teacher tries to help students figure this out by synthesizing this issue with the larger inquiry, asking them to think about their question: "How do I smell things from a distance?" Other students refer back to previous experiences and connect ideas from these experiences to contrast Sam's claim. The purpose of the knowledge synthesis is to make sense of the compression and movement issue.

In this example, the teacher poses a question, and five students respond. The teacher asks clarifying questions or recaps students' answers only when further support seems necessary to move the conversation forward.

Conclusion

Guiding discussions, in contrast to leading IRE dialogues, presents some challenges. Both the teacher and the students need to acknowledge the value of learning from peers. In such a learning environment, authority is shifted from the teacher to the students, and knowledge is built gradually by the whole class, instead of by the teacher simply providing facts.

Developing norms of discussions—or accepted and polite ways in which the class discourse should be handled—is also a challenge. Norms should be developed for active participation (i.e., presenting, commenting, constructively critiquing, and persuading) as well as for passive participation (i.e., listening and respecting various opinions). The teacher should use strategies such as "wait-time" to give all students time to think and answer, instead of judging an idea as correct or incorrect immediately; ask students to support statements with evidence; and provide scaffolding when necessary. (**Editor's note:** For more on wait-time, see this month's Prepared Practitioner column on p. 10.) The teacher should remove himself or herself from the conversation and encourage students to help one another make sense of something together.

During any scientific inquiry, discussions are powerful mechanisms that allow students to construct meaning of abstract scientific concepts, connect an activity to the main learning goals of an investigation, and reflect on their own experiences. They also help students develop analytic and argumentation skills. Discussions are a way to acclimate students to the culture of science, as debating and revising ideas is a major practice of any true inquiry process. ■

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