DEVELOPING A SCIENTIFIC ARGUMENT

Modeling and practice help students build skills in oral and written discourse.

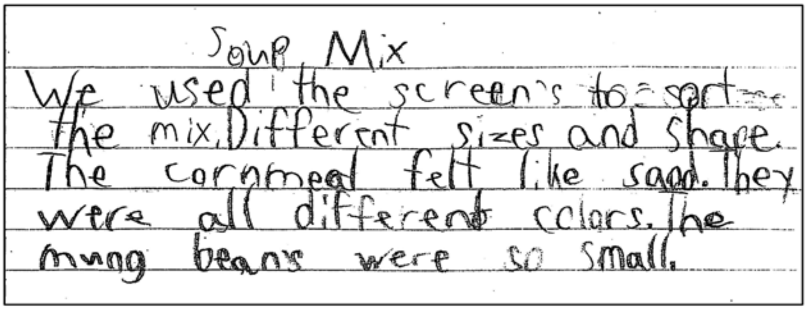
By Lori Fulton and Emily Poeltler

"When you put a solid in a container, it doesn't change its shape, and when you put a liquid in a container it does change, it makes, well it looks like the shape of the container. … I know because solids have their own shape and liquids don't." This is how one second grader defended an argument on how solids and liquids are different.

Arguing an idea from evidence is not an easy task. We found that our students could make claims about an idea and sometimes provide some sort of an explanation, but they struggled to support their claims with evidence. As students were talking and writing about science, they were focused on what they were doing rather than learning—they were not engaged in scientific argument (see Figure 1). Our experience suggested that students needed help learning how to use evidence to support their ideas in both their science notebook entries and during science talks.

Figure 1.

A notebook entry focused on the science activity.



As a result, we formed a study group with other teachers to discuss how to support and develop argumentation skills. The study group ran from 2007–2011, meeting once a month.

In this article we share strategies that helped our students learn to argue their ideas based on evidence. The examples come from second graders studying the FOSS Solids and Liquids unit (Lawrence Hall of Science 2005), but the strategies could be used with second through fifth graders. After exploring the properties of solids and liquids, students were presented with small solids (e.g., rice and cornmeal) that had some properties of both solids and liquids. The students needed to determine if these materials were solids or liquids and argue their point using evidence.

Science and Argumentation

Argumentation in science has a different purpose than it does in other contexts, as it is used "to promote as much understanding of a situation as possible and to persuade colleagues of the validity of a specific idea … [it] is ideally about sharing, processing, and learning about ideas" (NRC 2008, p. 89).

Argument based on evidence is essential to the work of scientists in order to identify the best explanation for phenomenon. Because of this, defending an idea with evidence should be an important component of the meaning-making process in elementary classrooms. *A Framework for K–12 Science Education* (NRC 2012) envisions students engaged in the practices of science, such as "asking and defining problems" (pp. 54–56), "planning and carrying out investigations" (pp. 59–61), "constructing explanations and designing solutions" (pp. 67–71), and "engaging in argument from evidence" (pp. 71–74). While it is common to find elementary students asking questions or carrying out investigations, it is less common to find them engaging in argument from evidence. Yet, we now know that young children are capable of reasoning in more sophisticated ways than previously assumed.

Students engage in argument when they make a claim and defend that claim using evidence and/or reasoning. This takes place within both the oral and written discourse of science, during participation in practices such as "science talks" (Worth et al. 2009) and notebook entries. With science notebooks, students develop arguments using evidence by moving beyond recording what they did and beginning to formulate conclusions that contain claims, evidence, and explanations. During science talks, students engage in argument when they talk with one another. However, the typical classroom discussion follows a familiar pattern: the teacher asks a question, a student responds, and the teacher evaluates the response and begins the process again. This type of discourse is not conducive to argumentation, which requires social interaction around one another's ideas, requiring students to unlearn this pattern.

Supporting Development

There are several ways that teachers can support students' development of argumentation.

A beginning step is to help students understand that a scientific argument is a discussion of ideas—one in which people may not always agree. When that happens, they challenge the idea by putting forth evidence to dispute it or asking questions for clarification. It is important for students to understand that this is not a personal attack, but rather a discussion based on the evidence to build understanding.

We found that students needed support with the expectations and language of argument and that they needed opportunities to practice what they were learning.

Expectations

We recognized that our students did not understand the expectations of engaging in argument based on evidence. One way we found to help students understand our expectations was through the use of a class notebook with which we could model the components of a conclusion. Our class notebook, which we kept on a SMARTBoard (it could also be kept on chart paper), served to synthesize the learning for that day. At the end of science time, students shared information learned, which we used to create an entry, thinking aloud as we did so. Using this strategy, we were able to model a variety of techniques, including the use of a claim supported by evidence and an explanation. This type of modeling emphasized the *Framework*'s scientific and engineering practices of "analyzing and interpreting data" (pp. 61–64) and "constructing explanations

Figure 2.

A class notebook entry.

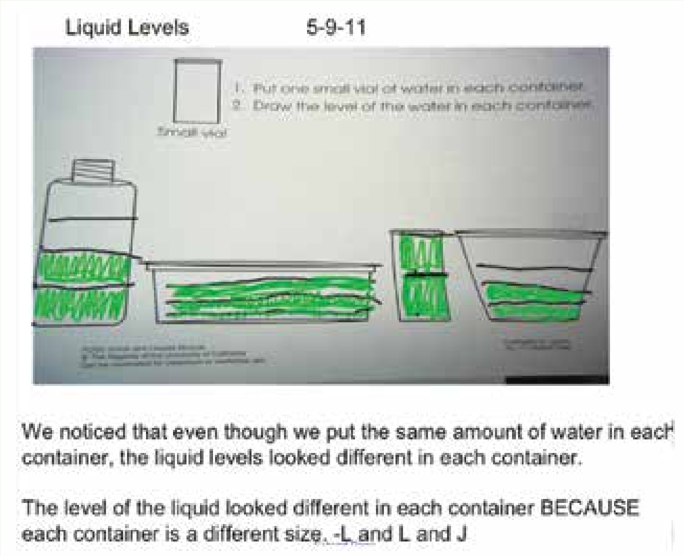
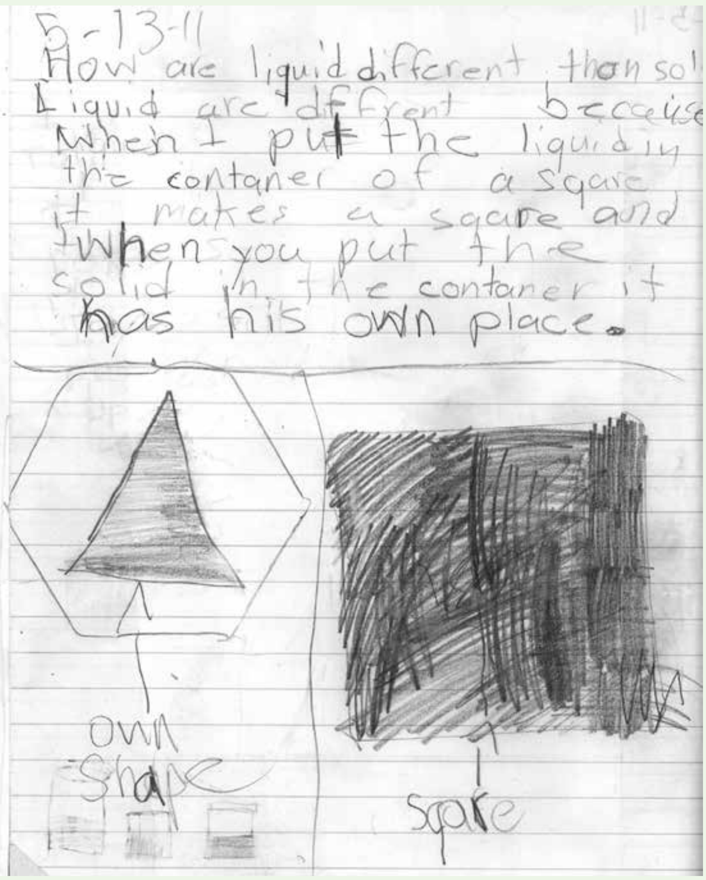


Figure 3.

Student response to a focus question.



and designing solutions" (pp. 67–71) (NRC 2012). Figure 2 is an example of a class notebook entry from an investigation on liquids. Students' ideas were recorded using the diagram and words, emphasizing what they observed (their evidence), along with a claim and an explanation. The students who contributed the ideas were recognized using their first names (represented by their first initials here) at the end of the entry.

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Another way we helped students develop the expectation of using arguments in their writing was by asking focus questions, open-ended questions that focused students on the content rather than the activity. Such questions are difficult to answer without using evidence and set the expectation that writing and discussion should be about what we were learning rather than what we did in the activity. Figure 3 is an example of a student's response to the focus question "How are liquids different than solids?" in which she uses evidence to argue that the way a material behaves in a container helps determine if it is a solid or liquid.

In order to argue a point, we found that students needed to learn how to talk to one another rather than to the teacher, so we introduced science talks. During science talk, we sat in a circle so students could see and talk to one another. We took some time to discuss expectations and norms and established these as a class. Below are the expectations generated by our students.

- Listen
- Look at the speaker
- Take turns talking
- Have a calm body
- Speak loudly and clearly

We posted the norms in a place where students could see them and refer to them at any time. This helped our students move beyond talking to us to talking to one another, creating an environment in which argument could take place.

Language

The language of argument was new to our students. We found that modeling served as an important support. One way we modeled the language was through "think alouds" during class

Table 1.

Generic sentence starters to support argumentation.

Claims	Evidence	Explanation
I think ... I observed ... I noticed ... A ... is an example of ...	I found ... My evidence is ... My reasons are ...	This happened because ...

notebook entries and science talks. We modeled the language used in various situations such as constructing a written conclusion, questioning someone's claim, asking for evidence to support an idea, and constructing a critical response to an idea for which they have counter evidence.

We found that sentence starters or frames (Table 1) also helped students with the language of argumentation (see Fulwiler 2011 for information on sentence frames). However, we found that students could become dependent upon these, so it was good to use frames specific to the lesson, add new starters/frames every so often, or change them after a period of time.

We also supplied frames to help students develop the language needed for argumentation in science talks, such as how to agree/disagree, ask questions, or invite others into the conversation. We posted sentence frames they could refer to, which included:

- I agree with … and would like to add …
- I disagree with … because…
- I don't understand your idea … Can you tell me more about …
- … what do you think about this idea?
- I have a question for …

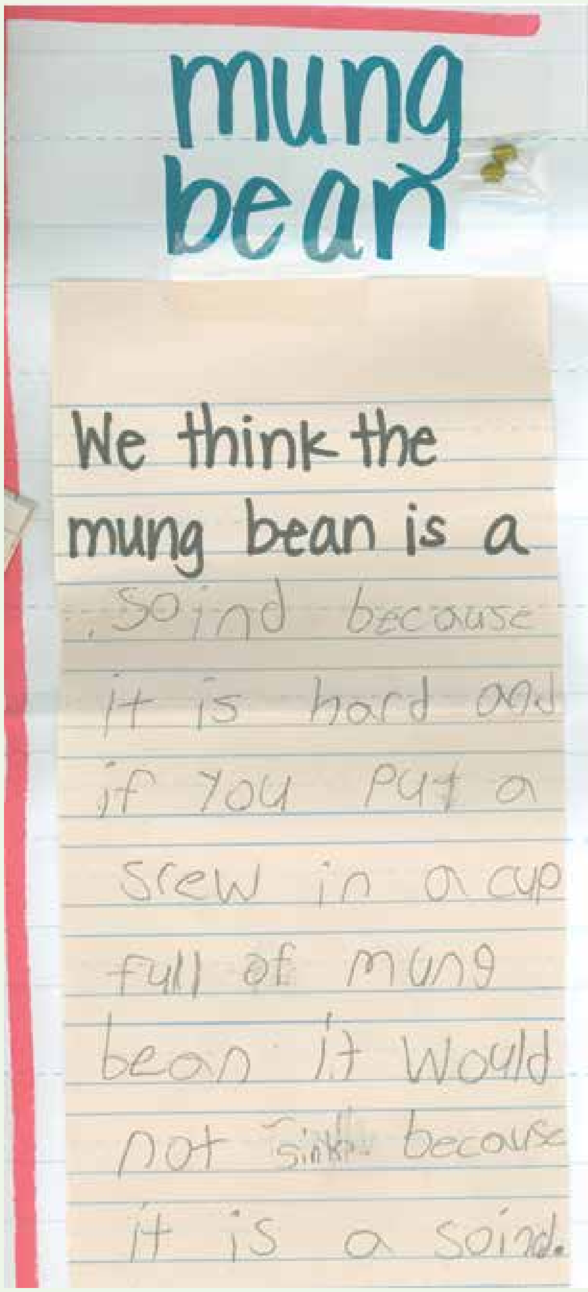
We used similar sentence frames to help students construct their arguments, such as:

- I think … is a … because (e.g., I think cornmeal is a solid because each little piece has its own shape.)

Help in developing language can also come from other students. Another teacher from the study group structured an opportunity for her students to work together to create a written argument to share with the class. After working with small materials, the students were asked to determine whether their material was a solid or liquid and create a written piece that could be added to a class poster. Using the frame, "We think the … is a … ," the students argued their point using evidence they had collected while working with the materials (see Figure 4). Such strategies support development of the *Framework's* scientific and engineering practices of "constructing explanations and designing solutions" (pp. 67–71) and "obtaining, evaluating, and communicating information" (pp. 74–77).

Figure 4.

Students' written response on the class poster.



Practice

Students also benefited from practice working with arguments using evidence. To deepen student thinking about written arguments, we had students critique anonymous notebook entries based on the use of claims, evidence, and explanations. They then examined their own entries to determine if they included all of the elements. This resulted in a greater awareness of all components and students moved beyond simply making claims to supporting those claims with evidence and explanations.

We asked students to rehearse their argument before writing or sharing it with others by recording their response on an electronic device like an iPod. We found that when students recorded their answer to a question and listened back to it, they modified their response, adding more evidence to support their thinking.

Arguing an idea orally was new for our students, who needed practice learning to talk to one another rather than to us. We practiced these ideas through focused discussion games, such as Talking Through the Circle (Heller-Winokur and Uretsky 2008). In this game, students passed yarn through the circle to students as they shared their scientific ideas. This helped our students learn to take turns and engage everyone in the conversation. While such games do not support the development of arguments directly, they help students develop the skills necessary to engage in argumentation.

Our students eventually became comfortable talking to one another. While their conversations were sometimes difficult to follow, they knew they were talking to one another rather than to the teacher, as demonstrated in this excerpt, where students discussed whether cornmeal was a solid or liquid based on their evidence.

Student 1: "Cornmeal is a liquid because if you put it in a container it will make that shape of the container that it is in."

Student 2: "I disagree with you [Student 1], because cornmeal is a solid, because it cannot change its shape unless someone else changes its shape. If you put it in your hand, it doesn't change its shape. It's a solid. …"

Student 3: "I agree with you [Students 2, 4, and 5], that cornmeal is a solid and it is not a liquid. Because if it was a liquid, it would not have its own shape, and if it was a solid, it would have its own shape. And, like it's a solid, if you put it in a container, it takes the shape of it, but the shape of the little circle [referring to an individual piece of cornmeal], it will still be there."

We were not part of this exchange, but listened as the students argued with one another.

Allowing the students to lead the discussion can be difficult, but worthwhile. To build "a culture of talk" (Worth et al. 2009, p. 31), we explicitly taught the skills needed, invited students to talk without raising their hands, listened rather than talked, allowed silence to occur as students gathered their thoughts, and mapped discussions so they could see how the conversation flowed. In doing this, we supported our students in developing the *Framework*'s scientific and engineering practice of "engaging in argument from evidence" (pp. 71–74).

PHOTOGRAPHS COURTESY OF THE AUTHORS

During a science talk students discussd whether cornmeal was a solid or liquid.

Supporting English Language Learners

Our school is urban with 82% of the population classified as having Limited English Proficiency and 92% qualified for free and reduced-price lunch. The language and practice of argumentation are often new to all students; however, English language learners (ELLs) have the added struggle of learning this in a second language. We addressed this with certain practices. Our lessons were based on "sheltered instruction," a common approach to support students' understanding of content material through a set of teaching strategies that promotes the use of academic English within the content areas. In addition to the strategies shared above, we created a language-rich environment with word walls where students could access the academic language and sentence frames to support their development of scientific discourse. We also provided time for students to talk through an idea; having them talk with a partner prior to writing or a whole-group discussion can help clarify their thinking.

Assessing Progress

Developing argumentation takes time; however, even young students are capable of arguing an idea based on evidence. To determine if students are making progress, the teacher can formatively assess the science notebooks and the science talks. Within the notebooks, the teacher can first look for a shift in the entries from what they were doing to what they learned as students focus more on the content and trying to make sense of it rather than what they did. The teacher may also notice that, in the beginning, students rely on sentence frames to include claims, evidence, and explanations in their entries. Even with this support, do not be surprised to only see claims at first. Students seem to struggle more with explanations and evidence, but over time they are able to incorporate these as well. Eventually, full-fledged arguments, developed in the students' own language, will be evident within their entries.

Within the science talks, the teacher should not be surprised if students seem rather timid at first. However, as the teacher models how to engage in a scientific argument (e.g., modeling disagreement or asking for evidence) students will begin to embrace the language and practices of argumentation. Eventually, the teacher may choose to "remove" him or herself from the conversation to focus on how students conduct their arguments and what they emphasize within those discussions; this also helps the students focus on talking to one another. By sitting outside of the circle, the teacher can map the conversation to see who is involved and who is not, and observe connections between ideas versus the introduction of new ideas. In addition, the types of connections can be tallied to see if students are agreeing, disagreeing, asking for evidence, and so on. Such information can help teachers determine next steps for their instruction to help move students forward, such as making connections to one another's thoughts, inviting quiet people into the discussion, or disagreeing with an idea in a constructive manner.

Conclusion

We found that our second-grade students were capable of arguing an idea when provided with support (see Figure 5). Argumentation seemed to promote their understanding of the science content. On a written pre- and posttest, in which students had to explain how solids and liquids are different and provide evidence to support their thinking, 69% of our students showed an increase in their understanding of this idea compared to 21% of students from a class that was not engaging in this type of argumentation. While we cannot say that focus on argumentation alone led to this, we believe it was an important factor. Helping students develop the skills needed for argumentation is a long process; however, we believe the time invested pays dividends in the end. ■

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Figure 5.

Strategies to support the development of argumentation.

- Modeling language in science talks and class notebook entries
- Using a think aloud to clarify the thought process
- Providing opportunities for students to develop arguments together
- Having students rehearse their argument by recording it on an electronic device
- Providing sentence frames that structure the language of the argument

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Connecting to the Standards

This article relates to the following National Science Education Standards (NRC 1996).

Teaching Standards

Standard B: Teachers of science guide and facilitate learning.

Content Standards

Grades K–4

Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academies Press.