Using Argument to Reason About Science Practice

Students can productively argue about a lot more than just claims and their evidence.

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We have been working for nearly two decades with teachers across all grade bands to promote productive argumentation. From this experience, and those of others interested in the same goals, we have extracted a simple strategy for promoting and supporting productive argumentation wherever it arises during students' engagement in science and engineering practices (SEPs). Organizing and guiding arguments over a full range of science practices not only helps students learn important disciplinary concepts, but also to understand how science really works.

Argument in Science

The *Next Generation Science Standards* (*NGSS*) define *argumentation* as a practice of evaluating competing explanations (or engineering solutions) using available evidence. This, however, is only one kind of thing scientists, and science learners, can productively argue about. Manz (2015) draws from a substantial body of research on the conduct of professional science to show that arguments arise in science during all aspects of scientific work. Any aspect of practice can become contested, from the questions being asked, the methods being used to answer them, to the quality of the answers generated. Argument is the discourse through which these contests move toward some stable resolution. We find it helpful to consider argument as running through all of the seven SEPs described in the framework, as suggested in Table 1. The table shows only some of the arguments that might arise within any particular SEP. Naturally, in this formulation argument disappears as a separate practice, instead it is the practice that runs through all of the others.

Two features of scientific argument crucial to making it happen productively in classrooms are that it is *dialogic* and that it aims toward *consensus* (Sandoval, Enyedy, Redman, and Xiao 2019). Arguments can arise only when people realize they disagree about something, and they can only be resolved if those people aim to reach agreement. From our work with teachers over the last several years we have developed a set of strategies that any teacher can use to create opportunities for arguments and guide them toward a productive resolution (Figure 1). Further, in working closely with teachers to promote arguments in their science lessons, we derived a small set of powerful talk moves teachers can use to keep arguments focused and productive (Table 2).

We describe and illustrate these strategies with an example from an elementary classroom, for a few reasons. One, the teacher, Ms. Green, was a master at orchestrating rich, productive arguments. This enables the work that she does to position students to argue productively to be seen clearly. Two, the example shows that even young children can argue well. Third, this is an argument about how to analyze and interpret data, showing how argument can be applied beyond simply evaluating explanations. This example comes from

TABLE 1

SEPs and some arguments that can arise in each.

Science and Engineering Practice	Potential Arguments
Asking questions and defining problems	What question to ask, or problem to solve
Developing and using models	Which model is best
Planning and carrying out investigations	How to design; how to measure; how to conduct
Analyzing and interpreting data	How to analyze, how to interpret
Using mathematics and computational thinking	Which math to use; how to use it
Constructing explanations and designing solutions	Which explanation or solution is best
Obtaining, evaluating, and communicating information	What information is worth getting; what sources are trustworthy; what evidence to communicate

Ms. Green's combined grade 3/4 classroom about a year before the *NGSS* were released; an extensive analysis of this case is presented in Sandoval, Enyedy, Redman, and Xiao 2019. While the topic of this example is somewhat outdated, our aim is to highlight the strategies Ms. Green uses and how they guide students to a sensible resolution to a legitimate problem they encounter in their classroom investigation.

Orchestrating Productive Arguments

Elicit divergent ideas. Arguments only happen when people disagree, so teachers have to create contexts in which students are likely to disagree and then elicit the range of divergent ideas students have. The purpose of eliciting student thinking here is not to discover which student thinks the right answer. Instead, the goal is to elicit a public disagreement that can be usefully argued about. Asking students to predict the outcome of a demonstration or an experiment, asking them to draw and then compare initial models of something—there are myriad ways to elicit divergent student thinking.

As part of a unit on the musculoskeletal system, Ms. Green had her students count the number of bones in the body. They used charts provided by their curriculum (FOSS 2005), and worked in groups of three to count the number of bones in areas of the body (skull, torso, arms, legs). Each body area was counted by at least two groups. Ms. Green elicited divergent ideas by having students post their counts on the board at the front of the room. Not surprisingly, the counts did not agree.

Identify competing ideas. For students to argue, they have to know they disagree. Sometimes this is obvious, other times not. An important role for teachers is to clearly identify competing ideas and how they differ so that all students in the class can recognize the nature of the disagreement.

As her students are looking at the counts they have put up on the board, Ms. Green draws their attention to each group's count of the bones in the leg. Here, Ms. Green identifies the two discrepant counts that constitute the disagreement, 52 versus 62, and she also frames the class problem as convincing one

FIGURE 1

Steps to managing productive argument.

- Elicit student thinking to surface divergent ideas.
- Identify competing ideas.
- Develop criteria for choosing the "best" idea.
- Provide resources to settle competition.
- Seek consensus resolution.

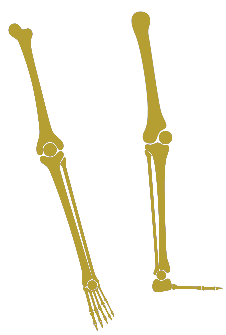


TABLE 2

Talk moves to scaffold class arguments.

Teacher Talk Move	Description
Press for consensus (PC)	Questions or comments that push class toward consensus: “Do we all agree?” “Who has a different idea?”
Press for persuasion (PP)	Identify competing ideas and press students to convince each other: “How can you convince them?” “What would it take for you to agree with her?”
Re-voice methods/criteria (RM)	Listen for and label student generated means for persuasion, or criteria for evidence, believability, and so on: “So, you’re saying it’s not a fair test.” “You’re saying you don’t want the average because nobody actually has the average.”
Focus epistemic issue (FE)	Moves that reorient the class to the dispute they are trying to resolve: “Remember, we’re trying to resolve _____.” “How is that related to our disagreement?”

or both groups to change their count.

Ms. Green: How could somebody in 52 bones group convince somebody in the 62 bones group that your number is right? Or, is there anybody who can convince any of these people to change the numbers? How could you convince someone? How could you change their mind?

Ms. Green pressed her students to convince one another that one of the posted counts is correct, *a press for persuasion*. This orients children to the purpose of the discussion, to reach a consensus count. It also orients them to think about standards of persuasion.

Develop criteria. A virtue of scientific arguments is that scientific communities develop shared criteria for settling them. They argue about the criteria, too, of course, but the key point is that criteria for resolving disputes become public and agreed upon. It is very hard to support productive argument without shared criteria for what will count as persuasive. At the same time, it can be very hard for students, especially before they have some experience, to develop criteria prior to arguing. A key role for teachers is thus to listen for and identify criteria when they emerge.

Ms. Green calls on Ben. Ben asks to see the chart of the leg skeleton, which Ms. Green hangs from the board with a magnet. Ben says,

A few things that you could’ve gotten wrong or mistaken on this chart [gesturing toward leg chart], because here [pointing toward top view of foot] it shows the difference between than there [pointing toward side view of foot]. And usually it’s only showing the back of the foot. So… I saw on other pictures that they showed the back of the hand [extends right arm, palm down, forearm held in left hand] and like that [rotates right palm up, down, and up] and we confused it, and we weren’t sure if it was this part [arm palm up] or this part [arm palm down] that we should count.

Several students are confused by Ben’s discussion of counting wrist bones when the disagreement is about how many bones are in the leg. So, Ms. Green interjects, from the side of the room, saying, “Ben, your point is that the perspective can make it hard to count. Is that fair?” Ms. Green clarifies for the class, through a revoicing method move (Table 2), that Ben is raising a possible source for discrepant counts, thus implying that navigating the perspective changes in the charts is crucial to arriving at an accurate count.

Later in the argument, another student, Carlos, is describing to the class how his group decided on their final count by counting multiple times and choosing as the accurate count the number they reached most often. Ms. Green asked the class if anyone had done it a different way. Sara then described how her group at first averaged their initial counts but decided that didn’t make sense because the average could produce a number of bones “that no one actually has.” The class then agreed that the “most common” count (i.e., the *mode*) was the most accurate method for producing counts.

Provide evidentiary resources. For arguments to be productive, that is to lead to some new understanding about a phenomenon, or a concept, or how science is done, they have to be resolvable. We do not want arguments resolved simply by the force of one speaker over another. We want data or other forms of evidence available as resources to settle disagreements. Resources can be external materials provided by curriculum or other sources, like the bone charts in this example.

They can also be generated by students, such as data tables or graphs students construct from their own work.

In Ms. Green's class, the bone charts are the primary resource available for settling the discrepant counts. Students come up to the front of the room and gesture directly over the charts (Figure 2) as they work through options for shifting from the side view of the leg, ankle, and foot to the top view of the ankle and foot. It becomes clear that the two leg groups disagree on the presence of an extra joint in each toe of the foot, thus producing five more bones in each foot, and the 10 count discrepancy.

We emphasize here that where resources for settling disputes cannot be provided, that may be a sign to avoid an argument. This need not always be the case, but it should raise a warning.

Seek consensus. In our experience, the most important feature of a productive classroom argument is that all participants should be trying to move to a consensus resolution. There is a great deal of focus in science instruction on individual sensemaking, and of course we want individuals to make sense of the science they are engaged in. Yet, when individuals have to work through disagreements to a resolution, they tend to make more sense for themselves about the issues at hand.

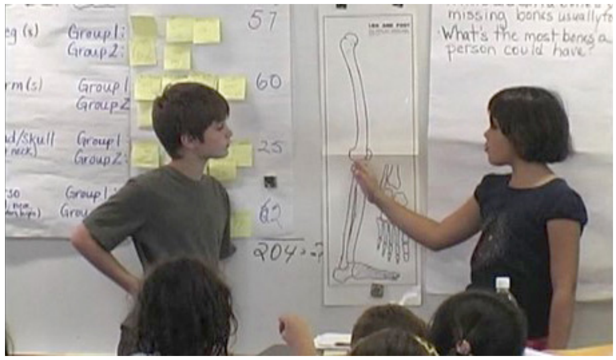
At the start, above, Ms. Green asked how groups could convince each other. As the argument went on and Emmy counted again in front of the class, Ms. Green again solicited agreement by asking the class, "Are you convinced?" (*a press for consensus*). Ms. Green routinely gave her students room to disagree and pushed them consistently to reach consensus when they did so. As a result, her students made striking gains in their ability to construct and evaluate causal arguments through the course of the school year (Sandoval, Enyedy, Redman, and Xiao 2019).

Argument Opportunities

We encourage teachers not to think of arguments as a specific, fixed activity. Rather, we have found that arguments are productive when they arise out of spontaneous disagreements occurring in students' scientific work. Of course, this means that the timing and duration of a particular argument can be unpredictable. So, we encourage teachers to think about which lessons may be more likely to generate disagreements and then build in time to let those arguments play out. Arguments are an opportunity for children to consider the criteria for particular science practices. Our example focuses on the criteria for a good method for counting. The disagreement arose because Ms. Green allowed groups of students to come up with their own strategies for counting, anticipating they would disagree.

FIGURE 2

Emmy demonstrating her group's counting strategy.



Because the disagreement is authentic, the argument and its resolution mean something for the students. Ms. Green, like other teachers we've worked with who manage arguments well, repeatedly structured opportunities throughout the school year for these kinds of disagreements to arise.

Conclusion

Ms. Green's example shows that argument can be promoted during and about any of the SEPs in the next generation framework. Moreover, she demonstrates that engaging children directly in the messiness of science practice helps them learn how the sciences work: what makes established scientific claims believable—and scientific methods trustworthy. So, do not think of argument as a special science practice on its own. Instead, practice argument during all aspects of doing science with the next generation.

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