What do productive discussions in the middle school science classroom sound like? What is the role of the teacher in such discussions? What are students’ roles? In facilitating a myriad of professional learning experiences (e.g., job-embedded graduate courses, professional learning communities, coaching experiences), we have observed that novice and experienced teachers alike struggle with engaging students in classroom discussions that include scientific argumentation, that is, arguments focused on the validity of evidence-based scientific explanations of phenomena (NRC 2007; 2012). The goal of such arguments is not to prove a point or identify a winner or loser, but rather to identify the explanation of a phenomenon that is best supported by the evidence. Ideally, argumentation in science is about sharing, processing, and constructing knowledge, and any criticism should target ideas and evidence, not the individuals who share them.
In the current reform efforts in science education, constructing and critiquing arguments are considered core processes of science. Through engaging in such practices, students understand the process of argument necessary for advancing and defending a new idea or an explanation of a phenomenon and the norms for conducting such arguments (NRC 2012). Just like scientists, they argue for the explanation they have constructed and defend their interpretations guided by the data they have collected while critiquing and providing counterarguments to their peers. When this occurs, students’ science knowledge becomes more meaningful, and over time they develop a good understanding of how scientific knowledge is produced.

We have observed that without substantial, ongoing support of scientific argumentation in the classroom, teachers and students return to familiar modes of discourse, all too often resembling initiation-response-evaluation (IRE) talk. In IRE talk, teachers ask questions, students respond, and teachers then evaluate and give students feedback on their individual responses. When IRE is the dominant discussion mode, the interactions among students are limited, and students do not experience the process of argumentation necessary for advancing and defending an explanation of a phenomenon. In this article, we describe several strategies we have used to support teachers in engaging middle school students in scientific argumentation as called for in the Framework for K–12 Science Education (NRC 2012). These strategies help teachers develop a community of practice in their classrooms where scientific argumentation is the norm and students participate regularly in sharing and critiquing ideas and presenting counter-arguments to their peers. They can be used by individual science teachers, instructional coaches, science departments, or professional learning communities in schools focused on improving the nature and quality of discourse in science classrooms.

Analyzing video clips

One strategy we have used to help teachers learn how to engage students in scientific argumentation is viewing video clips of discussions in science classrooms (see Resources) to differentiate among different types of classroom discourse. In working with our teachers, we select two to three clips that contrast teachers leading a typical IRE discussion with teachers facilitating a discussion that includes scientific argumentation. We then ask teachers to observe the video clips and identify which strategy resulted in students arguing for the explanation they constructed, using evidence they collected, or considering how evidence supported the validity of their claims. We ask the teachers to examine the questions asked in the videos and identify similarities and differences between questions that simply prompt students to give a response and those that encourage students to use evidence in some fashion. Finally, we ask the teachers to brainstorm how they might shift the line of questioning in the IRE discussion toward scientific argumentation. Some examples of the questions they typically identify to promote students using evidence to support or critique their arguments and to present counterarguments are as follows:

- How do you know?
- What evidence supports your idea/explanation/argument?
- What have you observed that tells you that _____?
- What have you experienced that tells you that _____?
- What is the quality of the evidence for _____?
- Do you agree with this idea/explanation/argument? Why or why not?
- What are other possible explanations for what you observed/experienced?
- Which idea/argument/explanation is best supported by the evidence that we have?

Many times, teachers post these prompts in their classrooms to not only remind themselves to probe students’ responses but also to support students in their attempts to engage in scientific argumentation.

Analyzing recordings

Another strategy we have used to support teachers in engaging students in scientific argumentation is asking teachers to record one of their class discussions. The teachers provide a brief description of the context of their lesson and then share their recordings with two or three fellow science teachers, who analyze the teacher’s role in facilitating scientific argumentation. We ask the group mem-
bers to listen to each other’s recordings without commenting or making judgments. As they listen, teachers silently note the types of questions asked and how the teacher initiated the discussion, provided wait time after asking questions (wait time 1) or student responses (wait time 2), commented on student responses, echoed or restated student responses, asked students follow-up questions, and invited other students to ask questions or offer comments. In the follow-up discussion, the listening teachers point out two or three of the recorded teacher’s actions that led students to construct and critique scientific arguments. At the end of their discussion, teachers respond to the following prompts in their journals:

- Students constructed scientific arguments when I _______.
- Students critiqued scientific arguments when I _______.
- Other teachers effectively facilitated student engagement in constructing or critiquing scientific argumentation when they _______.
- Other teachers inhibited students in constructing and critiquing scientific argument when they _______.
- What changes in class procedures, student groupings, or seating arrangements will I need to make to facilitate argumentation among my students?
- Before our next meeting, I will try the following strategies for more effectively supporting my students in constructing and critiquing scientific arguments:

**Peer coaching**

We also recommend peer coaching as a means to help teachers engage their students in scientific argumentation (Knight 2007). Peer coaching has been shown to positively support the lasting transfer of professional learning to classroom practices (Showers 1984). In peer coaching, teachers identify an area of need, in this case, engaging students in scientific argumentation, and work with a colleague to address this need. The two teachers observe each other during class discussions and record teacher-student interactions and student-student interactions. After the observations, the teachers come together to share the data collected and discuss the nature of the interactions, including how students were encouraged to participate and the level of scientific argumentation that occurred during the discussions. They ask each other thoughtful questions (e.g., How well do you feel students were able to support their scientific arguments with evidence? What if you asked Sara to share why she thought that? What if you asked class members whether they agree with Julio’s idea?), offer positive comments, and provide feedback on how they might foster and better support all students as active participants in scientific argumentation. The teachers often locate and share outside resources to support scientific argumentation in the middle school classroom during these conversations (e.g., NSTA books and journal articles about argumentation in the middle school classroom and investigations and projects that involve students in collecting and using evidence).

In peer coaching, the teachers’ conversations are characterized by mutual trust, respect, and, most importantly, choice. Thus, the language used is supportive and collegial. The teachers choose to work together and choose how they try or modify teaching strategies for involving students in scientific argumentation. As with students, choice is an important factor in teacher learning.

**Building a community of practice**

The last strategy we have used to support teachers in engaging students in scientific argumentation is helping them build a community of practice in their classrooms. Although middle school students may enjoy arguing, they are likely to be inexperienced in providing evidence for their ideas and uncomfortable judging the quality of others’ ideas. Indeed, having their own ideas judged by their classmates may bring some young adolescents to tears and recriminations. However, it is important for students to recognize and understand that science-specific argumentation is about understanding phenomena and using evidence to persuade their peers of the validity of their arguments. Thus, the interaction is guided by shared norms of participation as they engage and interact within the community of practice. We encourage teachers to have conversations with their students, to model for them what it means to have a scientific argument, and to help students understand that practic-
Scientists share and critique each other’s work in the scientific community. The initial step in these conversations is to contrast scientific arguments and everyday arguments. In their conversations with students, teachers should point out how scientific arguments focus on the quality and quantity of evidence supporting scientists’ ideas. Outright personal attacks are considered unacceptable and are a rarity in the scientific community. Teachers can involve students in brief role plays to highlight the differences between engaging in personal attacks and scientific arguments (see examples in Figure 1).

Furthermore, when scientists present their ideas at conferences or send their papers to scientific journals to be published, they do not share their ideas to “beat” other scientists or win an award; they are simply advancing the understanding of the scientific community of a particular phenomenon or occurrence in the natural world. Sharing examples of how scientists participate in a community of practice can be helpful to students. Nonfiction trade books about scientists and their work, interviews with scientists (see Resources), and research reports (see Resources) can all provide insight into the norms of participation in the scientific community. In addition, teachers can access video clips of conference proceedings where scientists share their work and are engaged in conversations with their peers (see Resources).

The next step in building a community of practice is to work with students to generate scientific argumentation “safety” rules and to include examples for participating in scientific arguments, such as the following:

- **Share your ideas in a respectful way** (e.g., take turns talking and listening to each other’s ideas, don’t interrupt or speak over each other, no name-calling or put-downs).
- **Agree with ideas that have convincing evidence** (e.g., “I agree with Shane’s idea...[discuss evidence]”).
- **Feel free to disagree with ideas, but not people** (e.g., “I disagree with Sam’s idea because... [discuss evidence]”).
- **Explain “how I/we know”** (e.g., “I know because ...[discuss evidence]”).

As with all classroom rules, it is best to teach, model, and practice these when they are first introduced, and when problems arise to re-teach, model, and practice them again.

At first, some middle school students may need additional support to join the community of practice. To guide students’ participation, we have worked with teachers to identify scaffolding strategies. One common strategy is to provide students with an organizer (see Figure 2) to complete before asking them to share

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**FIGURE 1** Role plays

**Personal attack**

Note that Terry’s comments do not address Candace’s claim about density. Rather, he makes comments about her personal appearance. If you notice your students engaging in personal attacks, be quick in redirecting their conversation to focus on claims and evidence.

**Candace:** I think that the density of the ball is less than the density of water because I saw the ball float when I put it in water. I know that things that float have a density less than the density of water.

**Terry:** Well, you’re wrong. You obviously don’t know anything about density since your hair looks funny. And have you brushed your teeth today?

**Scientific argument**

Note Candace’s emphasis on evidence and her use of questions to continue the conversation with Michelle about the quality of the evidence used to justify her claim.

**Michelle:** I think the density of the ball is less than the density of water because the mass is less than the volume.

**Candace:** Well, I think that the density of the ball is less than the density of water because I saw the ball sink when I put it in the water. Things that float have a density less than the density of water. How did you measure the mass and the volume? How did you make sure your measurements are reliable?
their scientific arguments. In this organizer, students record their ideas, record evidence supporting their ideas, and use reasoning to explain why the evidence and other scientific knowledge they may have support their ideas.

**Conclusion**

We consider teachers the linchpin in any effort to reform science education, and therefore they must be adequately prepared to implement reform-based science teaching practices such as engaging students in scientific argumentation. When students learn science in ways that mirror how scientists do science, they are better able to understand how scientific knowledge develops and gain deeper understandings of core scientific concepts. Furthermore, the ability to make and evaluate claims based on evidence is not just important in science. According to the Common Core State Standards, students should be able to think critically about what they have read, including making evidence-based claims (NGAC and CCSSO 2010). By shifting their classroom discussions toward scientific argumentation, middle school science teachers can enhance their students’ ability to consider the strength of claims they encounter in any part of their lives so that students always say, “Show me the evidence!”

**References**


**Resources**

**Scientists participating in a community of practice**


EurekAlert (research reports)—www.eurekalert.org

The secret life of scientists and engineers (interviews with scientists)—www.pbs.org/wgbh/nova/secretlife

**Video clips of discussions in science classrooms**

Discussion that includes scientific argumentation: The continental puzzle—www.teachingchannel.org/videos/continental-drift-lesson-plan?id=1

IRE discussion: Time management in 7th grade science—www.teachingchannel.org/videos/classroom-time-management?id=1

**Jennifer C. Mesa** (jmesa@coe.ufl.edu) is the project associate of the National Science Foundation Math Science Partnership grant U-FUTuRES: University of Florida Unites Teachers to Reform Education in Science, in the College of Education at the University of Florida in Gainesville, Florida. **Rose M. Pringle** is the U-FUTuRES co-principal investigator and a science education associate professor in the College of Education at the University of Florida. **Lynda Hayes** is the U-FUTuRES principal investigator and the director of the PK, Yonge Developmental Research School at the University of Florida.