# Classroom Communities' Adaptations of the Practice of Scientific Argumentation

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**ABSTRACT:** Scientific argumentation is increasingly seen as a key inquiry practice for students in science classrooms. This is a complex practice that entails three overlapping, instructional goals: Participants *articulate their understandings* and work to *persuade others of those understandings* in order to *make sense of the phenomenon under study* (L. K. Berland & B. J. Reiser, 2009). This study examines the argumentative discussions that emerged in two middle school science classrooms to explore variation in how the goals of sensemaking and persuasion were taken up. Our analyses reveals that each classroom engaged with these two goals but that they did so quite differently. These differences suggest that the students in each class had overlapping but different interpretations of argumentation. In addition, comparing across the class' arguments suggests these two goals of scientific argumentation may be in tension with one another. © 2010 Wiley Periodicals, Inc. *Sci Ed* **95:**191–216, 2011

## INTRODUCTION

The field of science education increasingly views science learning as participation in scientific practices. This perspective suggests that fostering student understanding of scientific phenomena requires helping students engage in processes of knowledge construction, through activities and social situations that make the practices of scientific inquiry meaningful and valuable (American Association for the Advancement of Science, 1990; Duschl,

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Schweingruber, & Shouse, 2007; National Research Council, 1996; Lehrer & Schauble, 2006). This paper focuses on a central practice: scientific argumentation.

Scientific argumentation enables students to engage in knowledge construction (Duschl, 2000; Ford, 2008; Newton, Driver, & Osborne, 1999). Empowering students to criticize the ideas being discussed in a culture that values evidence means that they no longer must accept the ideas that sound plausible or are held by the individual with the most clout (e.g., the teacher in a whole-class discussion or a particular student in small group work).

Unfortunately, while argumentation is a key component of the scientific knowledge construction practices, it rarely occurs in science classes (Weiss, Pasley, Smith, Banilower, & Heck, 2003). Newton, Driver, and Osborne (1999) provide evidence of this in an observational study of classroom interactions. They found that the instances of communal knowledge construction through argumentative discourse were "few and far between." Lemke (1990) also demonstrated this absence in his research, in which he characterized the majority of the classroom interactions as being teacher driven. Further evidence of the lack of argumentative discourse lies in the large number of studies designed to foster it. This work has uncovered obstacles to argumentative discourse in science classrooms such as students' lack of substantive engagement with one another's ideas (e.g., Brown & Campione, 1996; Hatano & Inagaki, 1991; Scardamalia & Bereiter, 1994; ) and struggles with constructing claims that align with the available evidence (Hogan & Maglienti, 2001; D. Kuhn, 1991).

This paper examines some of the sources of the challenges surrounding student engagement in this complex practice. In particular, we investigate how classrooms make sense of the practice of scientific argumentation when asked to do so.

## BACKGROUND

By its nature, scientific argumentation is a social practice in which members of a community make sense of the phenomena under study proffering, evaluating, critiquing, challenging, and revising claims through discourse. Kolstø and Ratcliffe (2008) highlight the social nature of this process stating that, during scientific argumentation, ". . . consensual conclusions on facts, models and theories in science will be backed by arguments produced by several contributors, and based on the judgment of a scientific community as a whole" (p. 119). Thus, we see argumentation as entailing three overlapping goals: *making sense* of the phenomenon under study (i.e., constructing claims and explanations), *articulating* those understandings (presenting arguments), and *persuading* others of their ideas (critiquing and evaluating counterideas while defending their own) (Berland & Reiser, 2009). We do not separate these goals to suggest that they occur in a particular sequence (e.g., that one must first articulate, then persuade, and finally make sense) or that they can be performed in isolation. For example, one cannot persuade another of an idea without articulating that idea. Similarly, working collaboratively to make sense of the phenomenon under study requires articulating various ideas. Moreover, it is by moving between the goals of sensemaking and persuasion that students—and scientists—are able to develop shared understandings.

Attention to persuasion and sensemaking both require articulation. Thus, our discussion in this paper focuses on these two goals. Costello and Mitchell (1995) emphasized the importance of these two argumentative goals, saying that

> Argument, unlike formal logic, is a social operation, a particular mode of communication which is oriented to context and to purpose. It functions. . . both to create and to challenge positions and to form and break apart agreement and identity. It is at once generative and coercive . . . . (p. 1)

Ford (under review) made a similar distinction stating that "Individuals basically play two roles [when constructing knowledge in a science community]—constructors and critiquers of knowledge claims—within scientific communities, and the construction of knowledge results from social interactions according to these" (p. 17). Thus, our analyses of argumentation examine both of these "roles" and the overlapping goals or purposes that they entail—the goal of sensemaking focuses more on generating or understanding a claim than challenging it, whereas the goal of persuasion is more coercive and it occurs when the focus is more about critiquing the posited claim.

While they are interdependent, differentiating between these goals is a useful analytic step, because all aspects need to be addressed in classrooms working to foster student argumentation. Identifying and unpacking the elements of a practice can help uncover both resources students bring to learning the practice and the obstacles they face (C. Schwarz et al., 2009). In addition, teasing these goals apart has uncovered challenges facing students when they engage in argumentation. In particular, we found that students' written arguments varied in quality depending on whether the authors were attending to the goal of persuasion: When the written arguments suggested explicit attention to the goal of persuasion, they had better differentiated claims and evidence (Berland & Reiser, 2009).

In addition, differentiating between these overlapping goals communicates the complexity of the argumentative practice; it suggests that there are a variety of ways that one could engage in scientific argumentation. For example, in a classroom, a teacher may emphasize the goal of persuasion over the goal of sensemaking, or vice versa, in his or her support of the students. Similarly, Kolstø and Ratcliffe (2008) suggested that the participants' interpretation of the argumentative task (as a competitive discussion that individuals attempt to win by persuading others versus an opportunity to make sense of complex data) influences the type of information that individuals contribute to support their claims and the ways that they evaluate the claims of others.

## Scientific Argumentation in Classrooms

The social nature of scientific argumentation necessitates that students have opportunities to discuss their ideas with one another. However, studies of classroom discourse reveal that these interactions are infrequent in typical classrooms (Lemke, 1990; Mehan, 1979; Weiss et al., 2003). In fact, comparing typical classroom activity structures to argumentative discourse suggests that the prototypical classroom interaction of IRE, in which the teacher Initiates an interaction by asking a question, a student Responds to the question and the teacher Evaluates the answer given (Mehan, 1979), can be in conflict with this aspect of scientific argumentation. That is, in these prototypical interactions, students talk to their teacher rather than to one another and therefore have few opportunities to engage with one another's ideas (Lemke, 1990; Tabak & Baumgartner, 2004).

Beyond limiting opportunities, traditional classroom interactions may teach students that they have no reason to attend to the ideas of their classmates and, in fact, that doing so may be detrimental to their individual success. Chinn and Malhotra (2002) found that "Many current school tasks [as described in textbooks] may encourage the belief that science is a simple, algorithmic form of reasoning . . . " (p. 213). This simplistic presentation of science means that students are rewarded for demonstrating the right procedure and answer rather than for their reasoning. Moreover, if their teacher is going to evaluate the ideas being discussed then students have no need to do that evaluation themselves: "What would be the point in trying to convince your classmates that your ideas has merit if the teacher would step in and solve the controversy with a simple yes or no?" (Cornelius & Herrenkohl, 2004,

p. 485). This work suggests that fostering student participation in scientific argumentation will require that classroom communities transform their existing practices.

However, studies that examine classroom communities taking up innovative curricular interventions reveal that the transformation from traditional school practices to knowledge building practices is nontrivial. For example, Cohen and Ball (2001) found that instructional interventions typically result in "surface-level enactment[s], with adoption of highly variable selected elements" (2001, p. 76). In other words, classroom communities take up some aspects of the practices put forth in curricular interventions, but not all. In addition, Cohen and Ball and others (Cohen, 1990; Squire, MaKinister, Barnett, Luehmann, & Barab, 2003) found variation in the aspects of the curricular interventions that each class adopted.

Given the need for classroom communities to transform their practices to engage in scientific argumentation, and the expectation that classroom communities adapt curricular innovations, it is critical to examine not only the success of enactments of argumentation but also the variation in their transformation. Enyedy and Goldberg (2004) demonstrated the importance of understanding this variation in their analyses of the ways that classroom cultures influence the sense that the communities make of the new practices that are intended in curricular interventions. These authors concluded,

> . . . before we can argue that curricular innovation is effective (or not effective), we need to carefully examine more than just the ideal structure of the intervention and the aggregate results on an assessment. We must also examine the local ways in which the activities were instantiated and enacted by real teachers and students. (p. 927)

This suggests that evaluating whether classroom communities have taken up the desired practices requires looking at more than whether some prescribed outcome has been reached. Instead, it requires examining the ways in which students engage in these practices. Thus, in terms of scientific argumentation, one cannot introduce the practice and only study the outcome (e.g., the learning gains or the completeness of the students' arguments). Rather, we must explore the ways in which the classroom discourse was aligned and misaligned with the goals of argumentation to understand those outcomes. To that end, this paper uses two of the focal goals of scientific argumentation, sensemaking and persuasion, to examine the ways in which classroom communities adopt and adapt this complex practice. In particular, this study examines the question: How do classroom communities engage with the argumentative goals of sensemaking and persuasion?

Since scientific argumentation is rarely found in classroom discourse (Driver, Newton, & Osborne, 2000; Lemke, 1990; Mehan, 1979; Weiss et al., 2003), examining how classroom communities engage in argumentative discussions requires that we work with teachers to create situations that could support student participation in this practice. To that end, we engaged in design research (Brown, 1992; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003; Edelson, 2002), both designing learning environments to foster student participation in scientific argumentation and studying student participation in these contexts. The argumentation that emerged in these classes was clearly influenced by our design strategies and the existing classroom cultures. Thus, we begin by describing the study context—the learning environments we examined in this study. We then describe our research methods. We then turn to the classroom discourse, describing the different ways each classroom community engaged with the goals of sensemaking and persuasion.

## Study Context

The following sections describe the learning environments we explored in this study to provide a context for interpreting the argumentative discourse that emerged in the participating classes. We do this by providing an overview of the curriculum design and the theory behind it, as well as descriptions of the participating classes.

### Fostering Scientific Argumentation Through Curriculum Design

Our design work was done in the context of the Investigating and Questioning our World through Science and Technology (IQWST) initiative to design and research a middle school science curricular series that supports student participation in scientific practices (such as argumentation) as they engage in project-based investigations (Krajcik, McNeill, & Reiser, 2008; McNeill, Lizotte, Krajcik, & Marx, 2006; Schwartz, Weizman, Fortus, Krajcik, & Reiser, 2008). In particular, this paper focuses on two sixth- and seventh-grade classrooms as they enacted an 8-week ecosystems unit (Finn, Kuhn, Whitcomb, Bruozas, & Reiser, 2006).

One class in this study (Ms. B's class) enacted a pilot version of this unit in 2005. The second class on which we focus (Mr. S's class) enacted the second iteration of the unit in 2006. The pilot version of the ecosystems unit used by Ms. B in 2005 was broken into halves. The first half of the pilot unit focused on learning goals surrounding relationships between organisms (e.g., predator/prey, parasite/host) and competition for food or other resources. The second iteration of the unit, enacted in Mr. S's class in 2006, used revisions of the lessons from the first half of the pilot unit and new lessons regarding the characteristics of living things. In this paper, we focus on one lesson that was enacted in both versions of the unit. This lesson exemplifies the three design strategies that we used to support student engagement in scientific argumentation throughout the unit. These design strategies were distilled from design research focused on the practice of scientific argumentation (e.g., Brown & Campione, 1996; de Vries, Lund, & Michael, 2002; Engle & Conant, 2002; Hatano & Inagaki, 1991; Osborne, Erduran, & Simon, 2004), tested and refined by Ms. B's class in 2005 and implemented again in Mr. S's class. In the following sections we briefly describe these design strategies.

### Design Strategy 1: Make the Epistemic Criteria Explicit

In a synthesis of design literature, Quintana et al. (2004) identified common strategies for facilitating student participation in scientific practices. One such strategy was to create supports that make the expectations for how to participate explicit. In terms of scientific argumentation, this strategy calls for clearly identifying the components of an argument. For example, Osborne et al. (2004) supported students by giving them sentence stems that identified the components of a complete argument.

The epistemic criteria for constructing and evaluating arguments were made explicit in the IQWST curriculum through the "evidence-based scientific explanation" instructional framework (McNeill et al., 2006). These "scientific explanations" were the students' argumentative product; they were recordings of their final arguments. The IQWST instructional framework drew on Toulmin's (1958) argumentation model to make explicit the importance of justification when communicating scientific explanations. This framework contained three components: a claim or answer to the question, evidence or information that supports the claim, and reasoning or a justification connecting the evidence and the claim. A detailed description of the components in this framework can be found in the study of McNeill et al. (2006). Students in Ms. B's class worked with this framework extensively by writing scientific explanations that incorporated the three components and practicing evaluating these products throughout their unit enactment. Owing to time constraints, students in Mr. S's class received much less practice using this framework. Instead, they defined the term evidence early in their unit enactment and occasionally revisited that definition throughout.

### Design Strategy 2: Create a Need for Students to Connect Claims and Evidence

Fostering argumentation requires that the use of evidence is sensible—that it serves a purpose in the discussion. The IQWST team built on the Learning-For-Use (Edelson, 2001) approach to educational design by "creating a need" (L. Kuhn, Kenyon, & Reiser, 2006) for students to use evidence. We did this by designing data-rich investigations for which multiple claims could be investigated and supported. For example, one of the many discussions designed with this strategy in mind asked students to construct scientific explanations regarding whether microscopic things that they observed were living things. To answer this question, students had to synthesize their observations of the microscopic things. As designers, we expected different claims to emerge as a result of the students' different interpretations of their observations and different tacit definitions for what would define a living thing. We expected these conflicts to focus students' attention on what they had been taking for granted that needed to be resolved to make progress (Reiser, 2004) and that this would help them clarify both the underlying argument for what makes a living thing and evaluate the specific evidence they used to support their claims.

### Design Strategy 3: Create a Need for Students to Value One Another's Ideas

While a rich question may create a need for students to use data when constructing their claims, it does not create a context in which students have a reason to overcome their traditional ways of interacting by attending to one another's ideas. As stated by Jiménez-Aleixandre, ". . . learning environments designed to prompt argumentation should engage students in knowledge evaluation practices" (2008, p. 97). In other words, learning environments need to support students in questioning and challenging the ideas being discussed. To do this, students must be accountable to more than just their teacher; they must be accountable to one other as well (Brown & Campione, 1996; Engle & Conant, 2002; Sohmer & Michaels, 2005). This goal goes beyond the typical classroom activity of inviting students to simply discuss one another's ideas. Instead, being accountable to one another entails that each student needs to be explicit about how his or her idea builds on or conflicts with what peers have already contributed. Thus, we need to design situations that motivate and empower students to engage explicitly with one another's ideas. In the IQWST unit, we addressed this goal by designing activities that make the goal of consensus building explicit to the students. We placed students in situations in which their disagreements were highlighted and structured the activity so they needed to work together to resolve those disputes. For example, we designed an "argument jigsaw" activity in which pairs of students construct a preliminary answer and then join another pair to form a group of four with the goal constructing a joint explanation that they all endorse.

It is important to recognize that these design strategies rely on one another: Without activity structures that motivate student-to-student interactions, the explicit epistemic criteria become unnecessary because students have no need to evaluate one another. Similarly, without shared criteria, students may have difficulty engaging in the richer questions and responding to one another's ideas because they might be using differing criteria. Finally, without a complex problem context, the activity structures are unnecessary because the question will not motivate argumentation.

In the following section, we illustrate these design strategies by describing one lesson that used all three of these design strategies to foster student participation in scientific argumentation. Because this lesson was designed to explicitly foster argumentative discourse and was enacted by both participating classes, it is the context of the argumentation analyzed for this study.

### Example of a Lesson Designed to Foster Argumentation in the Ecosystems Unit

The invasive species lesson is the argumentative lesson that we explore in this paper. This lesson was the last lesson of Mr. S's enactment, and it occurred about halfway through Ms. B's enactment. In both cases, it was the first time that students engaged in a lesson that utilized all three of the argument support strategies described above. However, Ms. B's students had been introduced to the evidence-based scientific explanations previously. The purpose of the lesson was for students to explore interactions between organisms in a food web with particular emphases on the idea of competition for resources. Students did this by working with a computer model of a simple ecosystem (using the NetLogo environment; Wilensky, 1999). In the beginning of the students' work with this simulated ecosystem, it contained three organisms: foxes, rabbits, and grass. These organisms existed in a simple food chain: The foxes ate the rabbits and the rabbits ate the grass. In this system, as in a real food web, changes to one population affected another. For example, if the rabbit population increased, the fox population was able to increase because it had more food. A higher fox population caused the rabbits to decrease because they had more predators. Reduced rabbits caused the fox population to decline, thereby allowing the rabbits to increase again. A similar cycle is evident between the grass and rabbits. Under appropriate conditions (i.e, sufficient grass and appropriate rates of reproduction), the stable cyclical relationships can continue indefinitely. However, if the fox population grew too large they could consume so many of the rabbits that the rabbit population would no longer be sustainable and both species would die out. Figure 1 depicts these cyclical relationships in a typical run of the ecosystem.

Once the students were able to reliably create model runs in which these stable relationships emerged and explain the population fluctuations therein, the students introduced an unknown organism into their ecosystem. The students were then challenged to use the new population fluctuations that resulted to identify what the "invasive species" ate.

Student work with this simulated ecosystem concluded with a whole class debate in which students with opposing claims presented and discussed their arguments to determine, as a class, the best explanation for what the invader ate. This process was designed to *create a*

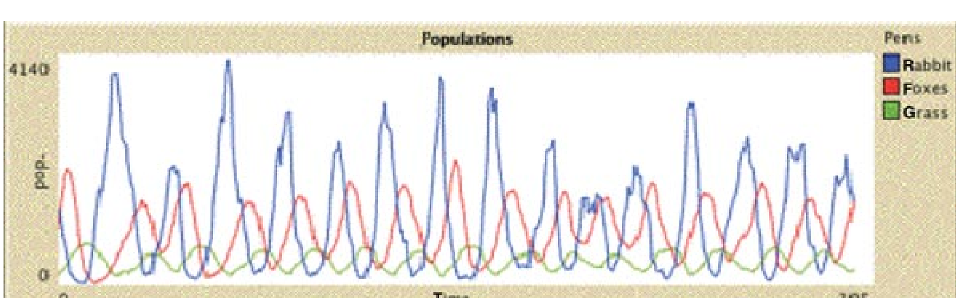


**Figure 1.** Example graph of population fluctuations in the NetLogo simulation. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

*need for students to use evidence* by providing them with a complex data set that supported multiple claims. In addition, the debate *created a need for students to value one another's ideas* by making the explicit goal of the activity one of consensus building, which can only be accomplished when students attend and respond to one another's competing claims and evidence. In addition, the curricular materials *made the epistemic criteria explicit*. In Ms. B's class, this occurred when she reminded her students of the IQWST instructional framework and provided them with prompts to guide their decision-making process as they debated their different interpretations of the data. In Mr. S's class, this explicitness took the form of a brief discussion in which they (re)defined the term evidence. We will use this debate to explore the different ways that two classes took up the goals of scientific argumentation.

### Participating Classes

To explore the different ways that classroom communities make sense of the practice of scientific argumentation, we observed four classes as they enacted the IQWST ecosystems unit. For this paper, we focus on two of the classes, those of Mr. S and Ms. B, because they reveal students actively engaging in scientific argumentation in a common context. A third class did not enact a lesson that utilized all three of the above argumentation strategies, and in the fourth class, students enacted the invasive species lesson but presented their arguments in a formal way without engaging in much debate.

All of these classes were in a large, Midwestern, urban school district. The teachers and/or school administrators volunteered to enact the curriculum and participate in the study. For all classes we collected videotaped observations of two or three class periods a week for the duration of the unit enactment; teacher preinterviews regarding their teaching experience and beliefs about inquiry instruction, group work, and scientific argumentation; pre-, during-, and postinterviews of eight students per class regarding their content understandings, criteria for evaluating arguments, classroom norms, and the purpose of the activities being enacted; and all student written work. Our exploration of the ways that classroom communities took up this practice focuses on the videotaped observations of Ms. B and Mr. S's respective enactments of the invasive species lesson.

### Mr. S's Class

Mr. S's class was a self-contained sixth-grade classroom in a K-6 charter school. The class had 16 students. The school was in the middle of a rundown neighborhood known for gang presence and drug use. At the time of the study, 94% of the students in the school were African American and 89% participated in the free or reduced lunch program. This school advertised that they had the most improved test scores in the city. Inexperience with science instruction and difficulties acquiring equipment meant that this class did not complete the unit before the school year ended. Instead, this class did portions of the first and second halves of the unit, concluding with the invasive species lesson described above.

### Ms. B's Class

Ms. B taught in a Grade 7–12 magnet school located a few blocks from a private university in a neighborhood that was home to an affluent African American population. Entry into this school was based on test scores in reading and mathematics. About 95% of the middle school students (Grades 7 and 8) in this school were African American, and about 62% were on the free or reduced lunch program. Unlike Mr. S's self-contained classroom, Ms. B's students moved to different classes and teachers for each subject. There were 15 seventh graders in this participating class, many of whom took honors classes in domains other than science.

In 2005, the first author worked with Ms. B and a postdoctoral fellow to redesign a precursor to the ecosystems unit. This redesign served as a pilot test of the curriculum used by the classes in 2006 and was focused on implementing the design strategies discussed above. Throughout this enactment, the postdoctoral fellow, Ms. B, and the first author met weekly to discuss the previous week's lessons and to revise the upcoming lessons in response to the students' and teacher's needs.

These two classes took up the practice of scientific argumentation in very different ways. Thus, we use them to explore the different ways that classroom communities adapt this practice. We begin by introducing the analytical methods we used to characterize and compare the argumentative discourse that emerged in each class.

## ANALYTICAL METHODS

We analyzed the ways each of the participating classes adopted and adapted argumentation and the challenges they faced by analyzing videotaped observations of the invasive species debate that was explicitly designed to foster argumentative discourse. Throughout these analyses, we focused on the discourse moves that are most relevant to scientific argumentation. We identified these moves by drawing on descriptions of classrooms in which students are engaged in collaborative sensemaking (Brown & Campione, 1996; de Vries et al., 2002; Hogan & Corey, 2001; Naylor, Keogh, & Downing, 2007; Scardamalia & Bereiter, 1994) and on Toulmin's (1958) structural analysis of final form arguments. Through this process, we identified five discourse characteristics as being key to scientific argumentation. In argumentative discourse, students

- *construct* claims,
- *defend* their own and other's claims,
- attend and respond to one another's claims and defense by *questioning* them,
- attend and respond to one another's claims and defense by *evaluating and critiquing* them, and
- *revise* their own and other's claims.

The italicized words indicate the key actions of each discourse move. These discourse moves clarify the goals of sensemaking and persuasion by describing various ways that classroom discourse can engage in them. For example, there are two discourse moves that relate directly to the goal of persuasion: defending a claim and evaluating and critiquing arguments. Both of these discourse moves involve engagement in persuasion because they are used to demonstrate why one claim is more persuasive than another. In addition, the goal of sensemaking involves three discourse moves: constructing a claim, questioning the claims and defense, and revising claims. Figure 2 summarizes this relationship. Note that, in the diagram, "attend to others" is shared by both sensemaking and persuasive goals—one can attend to other ideas in service of either of these goals. However, this attention involves different discourse moves depending on the goal of the interaction: When focused on sensemaking one will question another's ideas, whereas persuasion is related more to evaluation and critique of ideas.

Identifying these component elements enabled us to examine the ways that classroom communities adapt the practice of scientific argumentation by differentially engaging with the goals of persuasion and sensemaking.

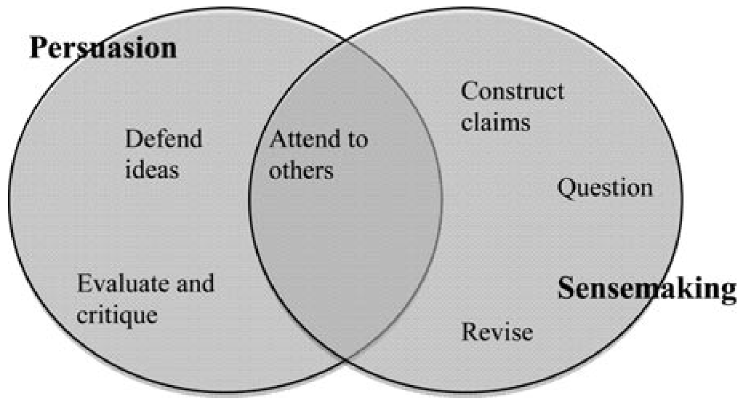


**Figure 2.** Relating the discourse moves of scientific argumentation to the goals of persuasion and sensemaking.

We examined classroom discussions for each of the argumentative discourse moves through a multistep approach, developed through a combination of theory and data-driven methods. Each step is outlined in Table 1 including the codes used in each step (codes are described in more detail in Berland, 2008). We exemplify the codes when discussing our findings, in the following sections.

Table 2 shows how we used the steps in the coding scheme (shown in the right-hand column) to determine whether and how students were engaging with the various instructional goals of scientific argumentation (shown in the left-hand column).

This table belies the complexity of this analysis. For example, this table indicates that if students defend their ideas, then their discourse will indicate that they are attending to that aspect of persuasion. This raises the question: How frequently do they have to defend their ideas for this to be true? Does every idea have to be justified or just 50% of them? As there are no empirical or theoretical measures of how frequently each of these codes must appear to demonstrate that the discourse reflects these moves, we use cross-class comparisons and relative frequencies to identify differences in how each class adapted this practice. For example, in the following analyses, we demonstrate that Ms. B's students were slightly more likely to question one another's ideas than they were to evaluate them. As a unique data point, this comparison is not very informative. However, in contrast to Mr. S's class, in which students made evaluative statements twice as often as they asked questions, this comparison reveals differences in how the classroom communities were engaging in scientific argumentation. Thus these cross-class comparisons elucidate differences in how students in each class took up the practice of scientific argumentation and their varied attention to the goals of sensemaking and persuading.

## RESULTS

Before presenting our analysis of the argumentative discourse that emerged in the participating classes, we provide summary descriptions of how students in each class engaged in the argumentative lesson analyzed. These descriptions serve to highlight key ways that the classes' argumentative discourse differed and, as such, they become the base upon which our more detailed analysis builds. We then present our detailed analysis of the ways in which each classroom communities engaged with the moves of scientific argumentation (i.e., defending ideas, evaluating and critiquing, and so on) and how these moves reflected student engagement with the goals of persuasion and sensemaking.

**TABLE 1**
**Coding Process for Argumentative Discourse**

| Step | Process | Codes |
|---|---|---|
| 1. Identify *knowledge-construction chunks* | Identify those sections of the discourse that were relevant, on task and entailed substantive discussion of topic (eliminating logistical conversations, review of previous material and off-topic discussion). Only the knowledge-construction periods were analyzed further. | • Knowledge construction<br>• Not knowledge construction |
| 2. Code for *utterance functions* | Identify the argumentative function of each utterance (e.g., contributing a claim, defending a claim, and so on). | • Claim<br>• Defense<br>• Evaluation<br>• Question<br>• Nonargumentative |
| 3. Recombine utterances to examine *defense patterns* | Differentiate between those ideas (ideas can be expressed as claims, questions and evaluations) that are and are not defended. | • Defended idea<br>• Nondefended idea |
| 4. Recombine utterances to examine *interaction patterns* | Group utterances into interactions and code for who is making the utterance and how it was elicited. | • Student to student<br>• Student to teacher<br>• Teacher to student<br>• Spontaneous student<br>• Spontaneous teacher |
| 5. Combine interactions into *episodes* and identify the conclusion of the oppositional episodes | Group interactions together to identify episodes, based on interaction patterns; focusing on the episodes in which individuals challenge one another, code for how these episodes are resolved. | • No resolution<br>• Teacher resolved<br>• Discrepancy acknowledged<br>• Claim revised<br>• Neutral answer |

### Summarizing the Argumentation in Mr. S's Class

On the day of the debate, Mr. S began by having the students identify their personal claims and to sit next to students with whom they agreed. At the conclusion of this shuffling, there were three large groups of students: one for each of the claims represented in the class. These claims identified the invader's food as grass; rabbits; or foxes, rabbits, and grass. After the groups were formed, Mr. S projected a graph from the NetLogo model and told his students that they should use it as evidence to support their claims regarding the invader's food. He then selected one student from each large group to present their argument, gave the presenting student a yardstick with which to point to the projected graph, and sat in the back of the room. He told the students that they would be trying to reach consensus on one of these claims, saying, "Alright, now what we have to do you guys, what we have to do is come to consensus."

While the lesson was originally designed for an amalgamated group of two pairs to construct and present a single argument, Mr. S's students had not worked in their large

**TABLE 2**
**Summarizing the Ways in Which the Coding Scheme Indicates Discourse Moves That Demonstrate Attention to Each of the Instructional Goals of Scientific Argumentation**

| Instructional Goal | Discourse Move | Indicators in the Discourse | Coding Step That Reveals This |
|---|---|---|---|
| Persuasion | Defense of ideas | Students defending their ideas | Step 3: Examine defense patterns |
| | Evaluating and critiquing one another's ideas | Students responding directly to one another's ideas (as much or more than they respond to a teacher prompt) by evaluating them | Step 2: Code for utterance functions (to look for evaluative statements)<br>Step 4: Examine interaction patterns (to look for student-to-student interactions) |
| Sensemaking | Constructing claims | Students contributing claims | Step 2: Code for utterance functions |
| | Questioning one another's ideas | Students responding directly to one another's ideas (as much or more than they respond to a teacher prompt) by questioning them | Step 2: Code for utterance functions (to look for questioning)<br>Step 4: Examine interaction patterns (to look for student-to-student interactions) |
| | Revision | Students revising their ideas in light of a challenge | Step 5: Examine the conclusion of the oppositional episodes |

groups before the debate. Thus, Mr. S had his students move through multiple rotations such that one student from each large group presented an argument in each rotation and each large group was represented multiple times. In these presentations, the students defended their group's claim with their data from their prior experiences with the simulated ecosystem and the projected data. During and between presentations, students in the audience called out responses to their classmate's ideas. This resulted in a heated exchange of ideas in which the students spoke directly to one another, identifying evidence and counterevidence for one another's claims while Mr. S sat at the back of the room. For example, at the conclusion of Tyler's presentation, Isaac said, "you claim that the invader eats rabbits, right? Well, at the end of the graph when the rabbits are dead, how do the invader keep going up?" This debate lasted approximately 36 minutes.

### Summarizing the Argumentation in Ms. B's Class

Ms. B's students' argumentative discourse differed from the argumentation seen in Mr. S's room: It was much more structured. For example, unlike Mr. S's class, in which large groups were created moments before the debate began and consisted of about a third of the class, large groups in Ms. B's class were groups of four that were formed from two pairs before the debate. In addition, before the argument began, the class discussed appropriate questions to ask one another. Furthermore, Ms. B gave students roles to guide their participation during the debate: During each presentation, the groups-of-four were told that they were *presenting* their argument, *questioning* the presenters, or silently *observing*. The groups rotated through each role so that all students performed all roles. Thus, the debate was a series of four students presenting, four students questioning the presenters, and eight students quietly observing.

This structure was apparent throughout the debate, in which students only spoke when it was their responsibility—or role—to do so (i.e., to present an argument or question an argument). In addition, in contrast to the heated interactions observed in Mr. S's class, Ms. B's students engaged in something more akin to a student-led IRE exchange (Mehan, 1979). In these exchanges, student-questioners would ask a question, presenters would answer it, questioners would acknowledge the answer, and then the conversation moved on to another question or another presentation. Unlike Mr. S's class, these students rarely stated whether they agreed with the ideas presented or responses to their questions.

The debate ended when all four groups had presented their arguments. At this point, these students explained the differences in their data by (incorrectly) interpreting the random variation of runs of the simulation as evidence that each group-of-four was working with a unique computer model with a different definition for the invader. As Toby said, ". . . does everybody think that they have the same invader or do they think that they have a different invader from everybody else's. . . ." This debate lasted approximately 24 minutes.

In the following sections, we investigate these apparent differences by presenting a detailed analysis of the argumentative discourse that emerged in each of the classes. In particular, we use the indicators seen in Table 2 to explore how the argumentative discourse that emerged in each class provides evidence of students engaging with the moves of argumentative discourse and therefore reflected the goals of persuasion and sensemaking.

## Students Constructing Claims

Constructing claims is the first argumentative discourse move that we examine. This move shows that students have engaged with the sensemaking goal of argumentation because the act of constructing a claim requires that one make sense of the data and phenomenon under study. The functional analysis of the students' utterances (Step 2 of the coding process) reveals that 20% (41 claims of 172 utterances) of the students' utterances in Mr. S's class were claims and 13% (20 of 155) were claims in Ms. B's class. Thus, the students in both classes were providing explicit evidence of having constructed a claim—they were stating that claim relatively frequently. For example, a student in Ms. B's class made the claim "We think it eats rabbits," whereas a student in Mr. S's class made the claim "It was an omnivore." We therefore conclude that students in both classes were constructing claims.

## Students Defending Ideas

As shown in Figure 2, defending ideas is one part of engaging with the goal of persuasion: To persuade an audience of your ideas, you must defend them. Moreover, the importance of defense is seen in other literature that evaluates the quality of students' arguments partly in terms of whether and how the claims are defended (as reviewed in Sampson & Clark, 2008). To determine whether the students were defending their ideas, we focused on the defense patterns, Step 3 in the coding scheme. We examined the discourse surrounding each idea—each claim, evaluation, or question that expressed an idea that was new to the discussion—to determine whether it was defended. We then collapsed across turns of talk and speakers to focus on the ratio of defended ideas to nondefended ideas. That is, regardless of the length of time a single idea is discussed, this analysis coded it as a single "defended idea." For example, if a student presented a complete argument and was then

**TABLE 3**
**Transcript Illustrating Student Discourse During the NetLogo Debate in Mr. S's Class**

| | Speaker | Quote | Utterance Function | Defense Pattern |
|---|---|---|---|---|
| 1 | Student | Maybe it ate off grass | Claiming | Nondefended idea |
| 2 | Students | Calling out | Uncodable | |
| 3 | Tyler | It don't eat grass | Evaluating | Justified (in line 7) idea |
| 4 | Teacher | Shh | Nonargumentative | |
| 5 | Student | Ahh Tyler, you ain't got NUTHIN | Evaluating | |
| 6 | Tyler | It probably might eat foxes but grass, | Claiming | Nondefended idea |
| 7 | Tyler | See look all the way straight across, you see how it keep going like that, right. See when it [invader] come up, Still the same [the grass].. Still the same. . . still the same. . . ..[a] | Defending | |

[a]Tyler successfully constructed a counterargument to challenge the idea that the invader ate grass—if the invader ate grass, one might expect the grass population to drop when the invader entered, but it did not. However, he ignored the issue in the later part of the graph pointed out by Isaac—after the rabbits died, if the invader did not eat grass, the grass population should have increased.

questioned on his or her argument, the ensuing discussion was not coded as an additional "defended idea." Instead, the ensuing discussion was viewed as an extension of the student's argument. In addition, if multiple students defended a single claim it was coded as a single defended idea. Thus, we were looking at the collaborative argument that was being built, rather than the arguments of individual students. Our intent was to detect whether an idea was picked up and defended by the students, regardless of whether it was defended by the original proposer of the idea. This approach reflects our goal of analyzing how classroom communities engaged in argumentative discourse.

For example, Table 3 presents a segment of the argumentative discussion in Mr. S's class. This exchange began at the conclusion of Tyler's presentation that defended his claim that the invasive species ate rabbits. In response to this presentation, Isaac asked Tyler to explain an anomalous data point, saying, "Well, at the end of the graph when the rabbits are dead, how do they [the invasive species] keep going up?" The transcript picks up as unidentified students entered the conversation by contributing hypotheses to answer Isaac's question (lines 1 and 2). Tyler disagreed with these alternatives and claimed that the invader ate foxes and rabbits. In line 7, Tyler supported his conclusion with evidence that the invader did not eat grass.

Table 3 shows one justified idea—Tyler justified his claim that the invader did not eat grass by referring to the graph showing that the grass population did not decrease and suggesting that the lack of change meant that nothing was eating the grass. This transcript also shows two nondefended ideas: Neither the unidentified student's claim that the invader ate grass nor Tyler's claim that it ate foxes was justified.

**TABLE 4**
**Interaction Patterns in Both Classes**

| Class | Percentage of Interactions in Which Students Respond to Students | Percentage of Interactions in Which Students Respond to Teacher |
|---|---|---|
| Mr. S | 71 (69 of 97) | 12 (12 of 97) |
| Ms. B | 82 (63 of 77) | 7 (5 of 77) |

Analyses such as the one illustrated by Table 3 differentiated between ideas that were and were not defended. In both classes, 65% of the ideas discussed were defended (24 of the 37 unique ideas in Mr. S's class; 11 of the 17 ideas in Ms. B's class). Thus, students in both classes were equally likely to defend their ideas and they defended their ideas more than they did not. This suggests that students in both of these classes were similarly engaged with this aspect of persuasion—they were defending their ideas. We attribute this success—the students' frequent defense of their ideas—to the activity design. In both classes, the students were enacting an activity that necessitated that they present arguments (claims and their defense) and respond to student questions about those arguments.

## Students Attending to the Ideas of Others

Attention to classmates' ideas is key to argumentation because this attention enables individuals to both contradict and challenge other's ideas and to learn about them. In this way, as seen in Figure 2, one can attend to the ideas of others in the service of both sensemaking and persuasive goals. We explored student attention to one another's ideas by examining the interaction patterns, Step 4 in the coding scheme. The interaction codes enabled us to examine different relative frequencies with which student contributions were made in response to a classmate's or teacher's utterance. Thus, the interaction patterns illuminate whether students were substantively responding to their classmates' contributions. For example, consider Table 3, in which Mr. S's students were spontaneously evaluating and questioning one another's ideas with very little input from Mr. S. Table 4 summarizes the results of this analysis.

As seen in Table 4, students in both Mr. S's and Ms. B's classes responded to one another's ideas much more frequently then they responded to their respective teacher's contributions. This suggests that the students were indeed attending to one another's ideas. As with the defense patterns, we suggest that this high rate of student-to-student interactions is due to the activity structure that led students to be accountable for one another's ideas.

## Students Questioning and Evaluating Ideas

As seen in Figure 2, we differentiate between two ways that students can respond to one another's ideas: They can question and evaluate them. These two discourse moves suggest differential attention to the goals of argumentation. When one questions an idea they are in a position to make sense of it, while evaluating an idea does not necessarily accomplish this. Instead, evaluating an idea suggests an emphasis on persuasion—by making evaluative comments, one is stating whether they are persuaded and whether others should be persuaded of an idea. Thus, for this analysis, we focused on the relative frequencies with which the student contributions performed these two functions. This analysis used Step 2 of the coding scheme in which the function of each utterance was identified.

**TABLE 5**
**Transcript Illustrating Students Responding to One Another by Questioning Each Other's Ideas in Ms. B's NetLogo Debate**

| | Speaker | Quote | Utterance Function |
|---|---|---|---|
| 1 | Questioner 1 | Where did you get your evidence from? | Questioning |
| 2 | Makaili | The computer | Nonargumentative |
| 3 | Chalinda | Netlogo | Nonargumentative |
| 4 | Makaili | The computer, we went on netlogo the computer and we set it up just like the rabbits, like you would do the rabbits | Defending |
| 5 | Questioner 2 | Excuse me, how do you know that your invader is a vegetarian? | Questioning |
| 6 | Makaili | Because they | Uncodable |
| 7 | Chalinda | Because it only ate grass. | Defending |
| 8 | Chalinda | The foxes didn't die at all, only when the invaders died. | Defending |
| 9 | Makaili | And we made sure of that, because we put the invaders and the foxes in there alone with no rabbits to make sure that that is what was going on. | Defending |
| 10 | Questioner 3 | Is there another way to look at this? | Questioning |
| 11 | Makaili | It could be another kind of animal like another rodent, like a rat or raccoon or something like that, | Claiming |
| 12 | Makaili | But it does not eat the foxes. | Evaluating |

For example, compare Table 3 in which Mr. S's students responded to one another's ideas by evaluating them (lines 3 and 5) to the one in Table 5, in which Ms. B's students questioned one another (lines 1, 5, and 10). The exchange shown in Table 5 begins at the conclusion of Makaili and Chalinda's presentation in which they argued that the invasive species was a vegetarian—it ate grass. The students assigned to respond to this presentation—the "Questioners"—did so by asking questions about this argument.

Comparing the transcripts shown in Tables 3 and 5 reveals a stark contrast in how the students interacted with one another across the two classrooms. In both classrooms, we see evidence that the students were attending to one another's ideas. However, in Mr. S's class, students evaluated and critiqued one another's claims, whereas Ms. B's students asked questions in a neutral way. That is, as seen in Table 5, Ms. B's students did not indicate whether they agreed with one another's arguments, instead they asked questions that elicited more information about the arguments. Table 6 compares the relative frequency with which students in each class questioned and evaluated the ideas being discussed. This table suggests that the patterns illustrated in the comparison of the transcripts held across the argumentative discussions in these classes.

Table 6 reveals that the relative emphasis on questioning versus evaluation differed across the two classrooms. Mr. S's students were twice as likely to evaluate one another's ideas as they were to question them, whereas Ms. B's students questioned and evaluated at more similar rates. This suggests that the students were paying differential attention to the goals of sensemaking and persuasion. By focusing on evaluative statements over more neutral questions, Mr. S's students were in positions to persuade but not necessarily to make sense of one another's arguments. In contrast, Ms. B's students were emphasizing sensemaking

**TABLE 6**
**Percentage of Utterances that were Questions and Evaluations[a]**

| Class | Questioning | Evaluating |
|---|---|---|
| Mr. S | 9% (37 of 172 utterances) | 22% (15 of 172 utterances) |
| Ms. B | 18% (22 of 155 utterances) | 14% (28 of 155 utterances) |
| Examples | Ms. B's student: "How can you prove your hypothesis?"<br>Ms. B's student: "What was the independent and dependent variables in your thing?"<br>Ms. B's student: "Is there another way to look at this?"<br>Mr. S's student: "If it eats all, then how can the animal eat vegetables how can it be a vegetable eater and a meat eater at the same time?" | Mr. S's student: "Boy, you don't know what you're talking about"<br>Mr. S's student 1: "They fed on the foxes"<br>Mr. S's student 2: "no"<br>Mr. S's student 1: "yes"<br>Mr. S's student: "It don't eat grass."<br>Ms. B's student: "We don't think it could [eat grass]. . . " |

[a]These percentages do not add up to 100% because we are highlighting two of the seven argumentative functions for which we coded.

as they asked questions of one another and worked to learn about one another's arguments. However, they rarely made evaluative statements. As a result, they rarely acknowledged that the groups of four disagreed with one another, even though their claims were inconsistent, and they were therefore not in positions to be persuaded by one another.

### Revising Their Own and Other's Claims

Revision of arguments in response to evidence and critique is a key part of the sense-making goal of scientific argumentation. As such, it is the central focus of many studies examining student learning through scientific argumentation (as reviewed by Leitao, 2000). Thus, in this section we focus on whether and how the students revised their arguments in light of new evidence and critiques.

We examined instances in which students revised their arguments in Step 5 of the analysis. This analysis focused on the episodes in which two individuals disagreed and one individual questioned, contradicted or negatively evaluated the idea of the other individual. Following Sampson and Clark (2008) and Osborne, Erduran, and Simon (2004), we called these episodes "oppositional episodes" because they were instances in which ideas were in opposition. However, unlike those authors, in our oppositional episodes the difference of opinion could be either implicit or explicit. In the case of Mr. S's class, in which students were likely to evaluate one another's ideas, the opposition was most often explicit—students stated that they disagreed with one another. In contrast, in Ms. B's class, in which students were likely to question one another, this opposition was often implicit. In these cases, we identified the episode as oppositional when we knew that the students involved disagreed (on the basis of the ideas that they each presented when it was their turn to present an argument).

We focus on these episodes because they are the instances in which there was a need for resolution. Regardless of whether the disagreement was voiced by the students, its presence offered the greatest potential for student revision of ideas. To explore whether students

**TABLE 7**
**Conclusion of the Oppositional Episodes**

| Conclusion Type | Ms. B's class | Mr. S's class | Exemplar |
|---|---|---|---|
| Conflict aborted | 4 (of 19 total oppositional episodes) | 13 (of 20) | Student: "I'm trying to see something!! Mr. S., hold on, let me see something."<br>Mr. S.: "Stop. . . Ok, I kind of get what you're saying. Moving on." |
| Neutral answer accepted, conflict not acknowl-edged | 13 | 3 | Ms. B's Student 1: "How did you alter the data in NetLogo? Like did you put the foxes with the rabbits and then started the invasion, or did you put the rabbits with no foxes . . . ?"<br>Student 2: "We made a stable graph and then we put in the invader."<br>Student 1: "Ok." |
| Claim was revised | 0 | 2 | Mr. S's student 1 believed the invader ate rabbits, after some discussion, he conceded: "So it probably eats rabbits and foxes." |
| Other | 2 | 2 | |

revised their ideas in these oppositional episodes, we analyzed the ways the episodes were concluded. Three different types of episode conclusions emerged: conflict aborted (teacher terminated the conversation, moving to a new topic); a neutral answer was provided and accepted (similar to line 9 of Table 5); and a claim was revised in light of the challenge. Table 7 provides the frequency and examples for each of these types of conclusions.

As seen in Table 7, students in these classes had a similar number of oppositional episodes (19 in Ms. B's class and 20 in Mr. S's), and revision of claims was an infrequent conclusion in both classes: Regardless of whether the opposition or disagreement was made explicit, these students rarely revised their ideas in light of that disagreement. However, there were important differences in how these episodes were concluded. In Mr. S's class, students negatively evaluated and contradicted one another's ideas until Mr. S asked them to move on. This interaction is apparent in Table 3 in which the students went back and forth without resolving their differences or revising their ideas, until Mr. S stepped in (not shown). In Ms. B's class, students presented the arguments constructed by their groups, and questioned those arguments, but never made that disagreement explicit, and the episodes concluded with neutral answers. Their lack of explicit disagreement suggests that each argument was treated as a stand-alone entity such that it would not make sense to revise it. This is seen in Table 5, in which students questioned and answered one another without debating their responses.

### Summarizing the Patterns of Argumentation

Analyses of the two classes reveal both similarities and differences in their enactments of argumentation. Both classes constructed claims, defended their ideas, and attended to their classmates' ideas. It appears that the activity design influenced and supported these argumentative discourse moves: The design contained supports and teacher guidance to elicit claims and evidence and provided both motivation (a "need") and support (epistemic guidance) to attend to one another's ideas. However, we found that disagreements were rarely resolved in either class and that these students rarely revised their original arguments through these discussions.

Even with these similarities, these classes differed in how the students responded to their classmates' ideas. In Ms. B's class, when students disagreed, they asked one another neutral questions while rarely evaluating one another's ideas and explicitly acknowledging their disagreement. Moreover, when disagreement was treated in this implicit way, questions were answered neutrally without addressing the underlying dispute. In contrast, in Mr. S's class, students made their differences explicit through evaluative statements. In response to this, students would further defend their ideas or evaluate and critique the challenger's ideas until Mr. S stopped them and moved the conversation forward. These cross-class differences suggest that the students were engaging with the goals of sensemaking and persuasion differently. We explore these patterns in the discussion section below.

## DISCUSSION

Engaging in the practice of scientific argumentation requires a significant shift from classroom communities' typical practices. Moreover, the complexity of the argumentative practice suggests that, when classrooms engage in scientific argumentation, they may be only partially successful, or they may exhibit an adapted form of the practice. Understanding how to support teachers and students requires understanding the kinds of adaptations that emerge when current classroom practices meet the idealized scientific practice, as presented in curriculum materials.

There are several possible ways classes could adapt the argumentative practice. One possibility is that some aspects of the practice may emerge consistently as more challenging than others, across classes. One might expect, for example, that critiquing peers is more challenging to perform successfully than formulating claims or defending them. Another possibility is that classrooms could pickup selective elements of the practice, such as presenting claims but without the follow-up discussion to question and evaluate those claims. A third possibility is that classrooms might vary in what elements of the practice they emphasize, and engage in different coherent "slices" of the practice.

The two cases in this paper present an interesting example supporting this third possibility: Each class exhibited a unique interpretation of scientific argumentation that was internally coherent. In this section, we examine this coherence and discuss what it suggests for student engagement with the overlapping goals of sensemaking and persuasion in scientific argumentation.

We organized our analysis of classroom adaptations of scientific argumentation around the key goals of sensemaking and persuasion. We analyzed student engagement with these goals by relating argumentative discourse moves to them: Some of these discourse moves are more related to the goal of persuasion (i.e., defending ideas and evaluating/critiquing), whereas others are more aligned with sensemaking (i.e., constructing claims, questioning, and revising). One discourse move (attention to others) is common to both goals.

Our analyses revealed that each classroom engaged with a different coherent configuration of the discourse moves. Thus, we saw that each class engaged with both goals of persuasion and sensemaking (their discourse showed moves related to both goals) but that they did so quite differently. These two different patterns of engagement with the goals of sensemaking and persuasion are shown in Figure 3. For example, once Mr. S's class (Figure 3a) constructed their original claims, they did not seem to return to the goal of

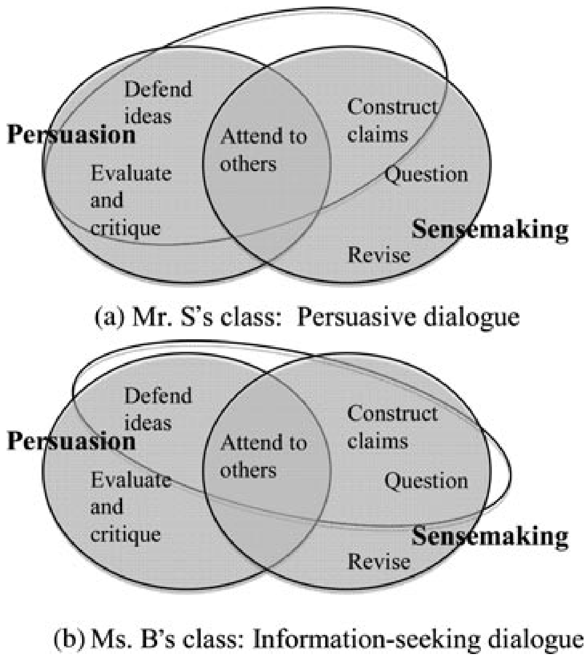


**Figure 3.** Different coherent slices through the argumentative discourse moves.

sensemaking. Instead, they focused on persuading one another of those ideas by defending their own ideas and critiquing and evaluating the ideas of their classmates. In contrast, Ms. B's students (Figure 3b) engaged with the goal of sensemaking by both constructing their initial claims and questioning the ideas of their classmates, but their engagement in persuasion focused on defending ideas with which they agreed without evaluating competing ideas.

In this discussion, we suggest that these different configurations represent overlapping but different interpretations of argumentation. We attempt to explain these different forms of scientific argumentation by exploring what engaging in these discussions accomplished for the students. That is, we examine how these different configurations of discourse moves constitute different coherent interpretations of argumentation. We then discuss the implications of this work with respect to the challenges with engaging students in the argumentative goals of sensemaking and persuasion.

## Characterizing the Argumentative Discourse in Each Class

Our purpose in this paper is to characterize different ways that classroom communities could engage in the practice of scientific argumentation. Our goal is to understand the different forms of argumentation that may emerge as discourse practices. In other work (Berland, under review), we examine the source of the variation (i.e., did the teachers set up the class discussions differently? Do the students have different backgrounds?).

In analyzing for the potential coherence of the different configurations of the argumentative discourse moves, we draw on the work of Walton (1998) who identified different "dialogues" or coherent forms of the practice. Each of his dialogues "has distinctive goals as well as methods that are used by the participants to achieve these goals" (p. 3). In this discussion, we demonstrate that the argumentative discourse that emerged in each classroom reflects one of these dialogues. In addition, we demonstrate that these particular dialogues are present in the argumentation that has emerged in related studies. This consistency across the literature supports our assertion that the argumentation that emerged in this study reflects coherent, or sensible, forms of the practice.

The discourse moves that emerged most frequently in Mr. S's class (i.e., constructing, defending and evaluating/critiquing claims) more closely aligned with the persuasive goal of scientific argumentation than sensemaking. This emphasis on persuasion and the discourse moves associated with it aligns with what Walton (1998) called a "persuasive dialogue" in which participants work "to test the comparative strength or plausibility of arguments on both sides of a controversial or contentious issue" (p. 37). As such, participants in this dialogue type understand and can respond to challenges to their arguments without necessarily reaching consensus. Looking at related studies suggests that this emphasis on persuasion is apparent in the argumentation of other classrooms. For example, it is possible that von Aufschnaiter, Erduran, Osborne, and Simon (2008) witnessed students emphasizing persuasion over sensemaking when they found that

> . . . instead of developing new knowledge (enhanced conceptual understanding), the activity mainly improved the security of students' existing knowledge. In most cases, neither the tasks nor the students' interactions resulted in students' demonstrating an understanding that they had not (almost) attained beforehand. Rather, the students consolidated their ideas and made them more precise. (p. 127)

We suggest that the students in von Aufschnaiter and colleagues' study rarely revised their thinking because, similar to the students in Mr. S's class, they were more focused on the goal of persuasion then sensemaking. That is, they were engaged in a "persuasive dialogue," in which their primary focus was to stand by their original claims without working to improve them.

In contrast, in Ms. B's class, the students asked neutral questions that could extract information from the presenters. As such, the students treated each argument as a stand-alone entity that they could inspect and defend without comparing it to the other arguments—without taking competing arguments into account. Consequently, these students appeared to be less engaged in the persuasive goal of scientific argumentation then the sensemaking goal—they seemed to be working to make sense of one another's arguments while rarely determining whether they were persuaded by them. Thus, it appears that these students were engaged in what Walton (1998) called an "information-seeking" dialogue in which they engaged in a "verbal exchange between two parties, one of whom has specific information that the other party wants or needs" (p. 127). Cavagnetto, Hand, and Norton-Meier (2010) saw a similar constellation of discourse moves in their study of elementary school students arguing. These authors witnessed students that were "able to share their ideas but not to question [in a challenging way] those ideas. . . " (p. 444). We suggest that, similar to Ms. B's students, these students were engaged in an information-seeking form of argumentation: They were emphasizing the sensemaking aspects of scientific argumentation over persuasion.

The apparent consistency with which we see these two forms of argumentative discourse emerging in this study and in related work reveals two challenges underlying the goals of argumentation. First, students rarely revised their ideas in light of the challenges and questions posed. The second challenge uncovered by these commonalities concerns the goals of sensemaking and persuasion: It appears that students struggle with engaging in both goals, simultaneously. We explore these challenges in the following sections.

### Challenge 1: Revising Ideas Through the Argumentative Discourse

Comparing across these classes reveals that students struggled with revising their understandings in light of one another's ideas and evidence. Rather, Mr. S's students stood by their claims in the face of evidence proposed as contradictory, and Ms. B's students did not evaluate their competing claims. Thus, students in these classes struggled with using the argumentative context as an opportunity to refine their own thinking.

Kuhn and colleagues (D. Kuhn, 1989; D. Kuhn, Amsel, & O'Loughlin, 1988; D. Kuhn, Black, Keselman, & Kaplan, 2000) found that students struggle with interpreting evidence in ways that result in revisions. For example, students reinterpret evidence to match erroneous claims, rather than revise their original ideas. This is one possible explanation for the students' lack of revisions in the current study.

However, the data in this study point to the conclusion that the challenge these students experienced with revising their ideas grew more from the version of argumentation in which they were engaged than an inability to revise claims in light of evidence. First, across both classrooms, students consistently aligned claims and evidence as part of their involvement in classroom argumentation (they did so to construct and defend claims as well as when they critiqued competing arguments). Second, the coherence of the argumentative practice seen in each class suggests that the relatively low frequency with which students revised their ideas is connected to their interpretations of the practice. For example, Mr. S's students appeared to focus on the goal of persuasion such that they were successful if they convinced others of the accuracy of their claim, not if their classmate's arguments caused them to revise their own. In fact, revising their own ideas may have implied failure at the overarching goal of persuading others of their ideas. This coherence suggests that the lack of revision seen in these classes could be the result of students' interpretations of the argumentative activity rather than an inability.

### Challenge 2: Simultaneously Persuading and Sensemaking

We began this paper by reviewing literature demonstrating the importance of the persuasive and sensemaking goals of scientific argumentation for constructing knowledge in science: The process of attempting to persuade the scientific community of an idea reveals faults in the argument (i.e., evidence that is unexplained by the idea or misapplication of accepted scientific principles), and identifying these faults creates opportunities for the community to improve upon the ideas being discussed.

However, our analyses of Ms. B's and Mr. S's class arguments suggest that the students may have experienced these two goals as being in tension. Thus, Ms. B's class emphasized individual sensemaking, whereas Mr. S's class emphasized persuasion. Recall that this emphasis is seen most clearly in the students' differential attention to questioning and evaluating one another's ideas: Ms. B's students asked one another neutral questions, whereas Mr. S's students rarely did so. Instead, Mr. S's students frequently made evaluative comments, stating whether or not they agreed with the ideas being discussed. Consistent with this pattern, we also saw that, when students had inconsistent claims, the disagreement was often unstated in Ms. B's class, and episodes were concluded with neutral statements, whereas in Mr. S.'s class disagreements were explicit and these episodes were concluded when the teacher terminated the discussion and initiated a new topic. Moreover, classes in related studies (i.e., Cavagnetto et al., 2010; Kolstø & Ratcliffe, 2008; Mercer, 2000; B. Schwarz, Neuman, Gil, & Ilya, 2003; von Aufschnaiter et al., 2008) reveal similar discourse patterns.

That the argumentative discourse that emerged in each class reflected a coherent, familiar form of the practice (i.e., a "dialogue") suggests that the students' participation was influenced by their interpretation of the argumentative task more then their abilities. That is, it suggests that student participation was influenced by the type of argumentative dialogue that they believed to be appropriate in the current context. For example, we suggest that students in Mr. S's class neither neutrally questioned their classmates nor revised their own claims because those discourse moves were not productive in the context of a persuasive dialogue. Similarly, Ms. B's students did not evaluate ideas or revise their own because those discourse moves were unnecessary in the context of an information-seeking dialogue.

Thus, we suggest that the challenge of engaging in both persuasive and sensemaking goals simultaneously may be related to norms and expectations for engaging in a discussion. In fact, in Walton's (1998) analysis of the different argumentative dialogue types, we see that none appear to emphasize *both* persuasion and sensemaking. This demonstrates the complexity of scientific argumentation: It may be difficult to achieve these two goals of the practice within the confines of the norms that govern typical discussions. Walton addressed this by stating that scientific argumentation borrows methods from both critical and inquiry dialogues. That is, scientific argumentation requires both the careful reasoning of inquiry dialogues in which individual claims are based on premises that cannot be refuted and the processes of persuasive dialogues in which arguments are debated and criticized.

Balancing these goals is made more difficult in the context of classrooms in which participants must shift away from their more traditional interactions. In particular, in scientific argumentation, students are tasked with taking responsibility for constructing knowledge, with guidance, relying on evidence and rationale rather than on an authority to evaluate knowledge claims. Pursuing these interactions appears to require a delicate balance. Focusing on sensemaking, in which claims are synthesized, compared, and combined, may pull students away from the focus on critiquing one another. Similarly, focusing on critique and attempting to persuade peers may lead students to go somewhat "overboard" and focus on "winning" instead of expecting argument and counterargument to converge on consensus.

The tension between these two goals is expected, but important to negotiate. Scientific argumentation necessitates that individuals move between "constructor" and "critiquer" roles as they work to persuade others and construct new knowledge (Ford, 2008). For example, one might ask an apparently neutral question (a discourse move that we identified as being more closely aligned with sensemaking) to learn more about a competing argument so that they could strengthen their critique of it (a discourse move that we identified as being more closely aligned with persuasion). Thus, this paper reveals a possible axis along which student argumentative discourse could progress. In particular, as students' become more facile participants in scientific argumentation, we would expect to see them engaging in discourse moves that align with both goals of sensemaking and persuasion in a single argumentative discussion.

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