Scientific Discourse in Three Urban Classrooms: The Role of the Teacher in Engaging High School Students in Argumentation

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ABSTRACT: Argumentation is a core practice of science and has recently been advocated as an essential goal of science education. Our research focuses on the discourse in urban high school science classrooms in which the teachers used the same global climate change curriculum. We analyzed transcripts from three teachers' classrooms examining both the argument structure as well the dialogic interactions between students. Between 19% and 35% of the discourse focused on scientific argumentation in that students were using evidence and reasoning to justify their claims. Yet in terms of dialogic interactions, only one teacher's classroom was characterized by student-to-student interactions and students explicitly supporting or refuting the ideas presented by their peers. This teacher's use of open questions appeared to encourage students to construct and justify their claims using both their scientific and everyday knowledge. Furthermore, her explicit connections to previous students' comments appeared to encourage students to consider multiple views, reflect on their thinking and reflect on the thinking of their classmates. This study suggests that a teacher's use of open-ended questions may play a key role in supporting students in argumentation in terms of both providing evidence and reasoning for students' claims and encouraging dialogic interactions between students. © 2009 Wiley Periodicals, Inc. *Sci Ed* **94:**203–229, 2010

INTRODUCTION

Argumentation has become increasingly prevalent as an essential goal for science education in which students need to support claims using appropriate evidence and reasoning

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as well as consider and be critical of alternative explanations (Duschl, Schweingruber, & Shouse, 2007). Yet incorporating argumentation into classroom science is challenging and can be a long-term process for both teachers and students (Osborne, Erduran, & Simon, 2004). Our research focuses on the discourse in three urban high school science classrooms in which the teachers used the same global climate change curriculum. We are interested in whether or not the students engaged in argumentative discourse as well as the teacher's role in supporting that discourse. Specifically, we ask the following research questions: What are the patterns in classroom discourse in three urban science classrooms? What is the role of the teacher in promoting argumentation in terms of both the argument structure and dialogic interactions in classroom discourse?

THEORETICAL BACKGROUND

Discourse in Science Classrooms

The linguistic practices in science classrooms define science through the ways that science is spoken and written in different contexts (Kelly, 2005). Traditionally, the discourse in science classrooms has been dominated by teacher talk (T. Crawford, 2005). Frequently, full class discussion follows a triadic pattern in which the teacher *initiates* discussion by asking a question, a student *responds* to the question, and the teacher then *evaluates* the student's response (i.e., IRE) with minimal student-to-student interaction. Herrenkohl and her colleagues (1999) talk about the "mistake stigma" in science classrooms where the objective of schooling is to get the correct answer, and mistakes are viewed as bad. The IRE pattern can reinforce that stigma in that it suggests the teacher is only looking for correct responses and is the sole knowledge authority in the classroom. Authoritative classroom interactions in which the teacher focuses the discussion on one meaning or one point of view most frequently occur through an IRE pattern (Scott, Mortimer, & Aguiar, 2006). This traditional pattern of discussion in science classrooms places teachers in a position of power in which they control the topic, the direction of the conversation, who participates in the conversation and what contributions count as legitimate (Lemke, 1990). This type of traditional IRE discourse focuses on conveying the correct answer and having students repeat back to teachers content they previously learned.

Traditional science discourse patterns, such as IRE, are not appropriate as the sole discourse pattern in inquiry-oriented classrooms, because they are based on teacher-driven instruction and known answer questions (Polman & Pea, 2001). If the goal is to engage students in a more open form of instruction with greater student involvement, a different type of discourse needs to be supported in classroom discussion. Science is a practice that requires the use of both scientific ways of thinking and reasoning as well as conceptual understandings (Lehrer & Schauble, 2006). Viewing science as a practice that students need to experience and be enculturated into shifts the traditional image of science classrooms. Learning science means that students are able to talk science, which requires students' participation and practice in talking science (Lemke, 1990). This suggests that science classrooms should include opportunities for students to engage in classroom discussions in which students practice talking science, challenge each other's ideas, and influence the direction of the discourse.

Science education needs to demystify science so it is no longer represented as a static body of facts, but rather a social endeavor where culture and discourse play prominent roles (Yerrick & Roth, 2005). Students need to participate in and develop an understanding of how knowledge claims are constructed in science. Science is a social process in which scientists debate knowledge claims and continuously refine and revise knowledge based on evidence (Driver, Newton, & Osborne, 2000). Yet classroom science often portrays science as a static set of facts rather than the social construction of knowledge (Lemke, 1990). To be proficient in science, students need to be able to generate and evaluate scientific evidence and explanations as well as participate productively in scientific discourse (Duschl et al., 2007). Consequently, it is important not only for students to actively have a voice in science classrooms, but that their participation enculturates them into essential scientific practices such as argumentation. Participating in dialogic interaction in which claims and evidence play a dominant role may help shift students' views of science. Viewing science as alive and changing is important for developing student epistemologies of science and encouraging student interest in becoming part of this dynamic process (Herrenkohl et al., 1999). Shifting the type of discussion in classrooms requires examining the roles of the teacher and students as well as instructional strategies that can be used to alter discourse norms (Kuhn & Reiser, 2006).

Argumentation in Science Classrooms

Argumentation can play an important role in both the written and oral discourse practices in science classrooms helping to promote students' scientific reasoning and conceptual understandings (Zohar & Nemet, 2002) as well as support students enculturation into the practices of scientific culture (Jiménez-Aleixandre & Erduran, 2008). Argumentation is a core practice of science in that scientists construct and justify knowledge claims, and it is essential for students to also experience science in this manner (Driver et al., 2000).

Similar to Jiménez-Aleixandre and Erduran (2008), we define argumentation in terms of both an individual or structural meaning and a social or dialogic meaning. The individual or *structural* aspect refers to argument as the justification of knowledge claims through the use of evidence and reasoning, which can occur either internally within one individual or externally in writing or talk. A single individual can construct a scientific argument as he or she weighs evidence and considers relevant scientific theories to form a conclusion about a problem. The key aspect of the structural meaning is the product. The structural definition can be thought of as an argument or product in contrast to argumentation or the process of arguing (Jiménez-Aleixandre & Erduran, 2008). Sampson and Clark (2008) reviewed the diversity of analytic frameworks that science education researchers use to examine the structure of students' written and spoken arguments. These analytic frameworks offer different perspectives on students' arguments such as a focus on the components of the argument (Bell & Linn, 2000), the epistemic levels of the claims (Kelly & Takao, 2002), the coherence of the explanation (Sandoval, 2003), and the rhetorical features of arguments (Kelly, Regev, & Prothero, 2008). The various frameworks have different constraints and affordances offering a range of insights into student work (Sampson & Clark, 2008). Similar to a number of other science education researchers (Bell & Linn, 2000; Driver, et al., 2000; Jiménez-Aleixandre, Bugallo Rodríguez, & Duschl, 2000; Erduran, Simon, & Osborne, 2004), we adapted Toulmin's (1958) framework of claim, data, warrant and backings to examine the structure of students' arguments. The data, warrant, and backing are all different ways to justify a claim or conclusion about a problem. An individual can determine the validity of a claim by constructing an argument that considers the data, warrant, and backing both for and against the claim.

Both the construction and critique of claims are essential to scientific practice. Although an argument can be constructed by a lone individual, it can also be constructed and critiqued in a social or dialogic process with other individuals (Jiménez-Aleixandre & Erduran, 2008). The *dialogic* component refers to argumentation as persuasion or the interactions that occur between individuals when they try to persuade or convince an audience about the validity of their knowledge claims. In science, critique is important because knowledge claims are constructed within a community of scientific peers and individual success is often determined by one's ability to anticipate the potential critiques of the community (Ford, 2008). Furthermore, rebuttals are a complex and important aspect of argumentation, because they require the examination of multiple perspectives (Osborne et al., 2004). Yet students often do not see persuasion as a goal of science, but instead can see the goal of science as to know the "right answer" (Berland & Reiser, 2009). In science classrooms, it is important not only for students to be able to make sense of data to construct claims, but they also need to be able to consider alternative claims as well as critique the claims and justifications provided by other individuals in the context of dialogic interactions. The social or dialogic aspect of argumentation focuses on the relationships between individuals and whether or not students' contributions are linked (either in support or against) to previous ideas contributed by the classroom community.

We view both the structural and dialogic aspects of argumentation as essential for classroom practice, because they promote students' abilities to reason and justify claims as well as interact with their teacher and peers in terms of both building off and critiquing their ideas. Consequently, we examined the patterns in the classroom discourse from both perspectives of argumentation as well as the role of the teacher in supporting both the structural and dialogic aspects of scientific argumentation.

Teachers' Roles in Supporting Argumentation

A shift in discourse patterns places new demands on teachers that require an understanding of current classroom cultural norms around discussion and utilizing instructional strategies that set up new rules for classroom discourse (Polman & Pea, 2001; Tabak & Baumgartner, 2004). Teachers take on new roles in inquiry science classrooms including that of guide in which teachers support students in the learning process yet students still take an active role in that process (B. A. Crawford, 2000). This can be a shift from teachers' traditional roles in that they are not the sole authoritative voice in classroom discourse, rather they guide and support students to play an active role in the discussion. Furthermore, a classroom culture needs to be created in which student-to-student interactions is not only permitted but also encouraged. Student-to-student interactions may require explicit social supports, because this type of interaction is not the norm in most science classrooms (Herrenkohl et al., 1999). Students may wait for the teacher to evaluate a previous student's contribution instead of responding directly to that student. Furthermore, it may be unclear to students what is considered appropriate in terms of a response to another student particularly if it involves critique. Teachers also need to take on the role of critiquer in the classroom community in which they model how to question claims and the justifications for those claims in a manner similar to what they are expecting of their students (Ford, 2008). Students may be unfamiliar with critiquing scientific argumentation so the teacher can play an important role in modeling those practices. Consequently, to shift the discourse practices, teachers may need to take on a variety of roles that are unfamiliar to them or not a part of traditional science classrooms.

Related to taking on new roles, supporting students in scientific argumentation may also entail the teachers' use of different instructional strategies. Simon and her colleagues (2006) identified a number of pedagogical practices used by teachers that may help support students in argumentation discourse. For example, teachers defined argument, provided examples of arguments, prompted students to justify their ideas with evidence, encouraged debate and counterarguments, and promoted student reflection to facilitate argumentation in their science classrooms. Martin and Hand (2009) found that in studying the discourse practices of one science teacher over 2 years that the teacher's questioning strategies appeared to shift and align with increased student voice and participation in classroom discussion. At the beginning of the study, the teacher used more closed or factual recall questions while later the teacher used more open questions with multiple potential responses. When the teacher used more open questions, a greater percentage of the discussion consisted of student voice and argument discourse in which students provided evidence for claims and offered rebuttals.

Other research has investigated teachers' questioning strategies in supporting classroom discourse, though without a particular focus on scientific argumentation. Teacher questions provide an avenue to open up classroom discourse beyond the traditional lecture format of teaching by telling. Questions have the potential to bring students into the conversation and increase student talk, but the type of teacher question impacts how it affects student participation. Traditionally, teachers' questioning strategies have focused on evaluation, but they can serve a very different role in classroom discussion (Chin, 2007). For example, van Zee and Minstrell (1997) found that when the teacher asked open questions and acknowledged student contributions in a neutral way, that these questioning strategies encouraged greater student participation, elicited student thinking, and supported student reflection during class discussions. This type of open and reflective environment may be important for encouraging argumentation discourse in which students engage in dialogic interactions where they support or refute the ideas of their peers. We are interested in how different types of questions impact argumentation discourse in the classroom. Blosser (1973) developed a system for classifying teacher questions that initially used four categories: open questions, closed questions, rhetorical questions, and managerial questions. *Open questions* ask students to express their opinions and explain their reasoning. Because of this, the answers to such questions are not easily classified as being right or wrong and there are a large number of acceptable student answers. *Closed questions*, however, have a limited number of correct answers associated with them. These questions tend to ask that students recall previous facts or explain concepts within imposed limits established by the teacher and the subject matter. *Rhetorical questions* are asked by the teacher, but no response by the students is expected or solicited. *Managerial questions* focus on classroom management, and they are not associated with the subject being taught. As we will discuss in more detail in the methods, we adapted Blosser's coding scheme to evaluate the types of questions being used in the classroom discourse and the relationship between the question types and the argument structure and dialogic interactions occurring in the classrooms.

METHODS

Instructional Context

This study took place during a standards-based high school urban ecology curriculum, *Urban EcoLab: How do we develop healthy and sustainable cities?* (Strauss, McNeill, Barnett, & Reece, 2007). Urban ecology is the study of cities as the interactions among biological, chemical, physical, and social forces, which focuses on the science of the system, but also considers the human component (Pickett, Burch, Dalton, Foresman, Grove, & Rowntree, 1997). For the 70% of students who live in urban areas, urban ecology provides local problems, resources, and opportunities for teaching and learning (Hollweg, Pea, & Berkowitz, 2002). We designed the curriculum with a team of educators and scientists as a capstone course for 11th- and 12th-grade students to engage urban youth in locally relevant interdisciplinary science. The curriculum consists of eight modules each of which is designed to last between 2 and 4 weeks of instructional time. This study took place during the 2007–2008 school year when four of the eight modules were being piloted. Specifically, the study occurred during Module 2, which focused on global climate change.

We selected Module 2 because of the socioscientific context and potentially contentious nature of the topic of climate change. Socioscientific contexts can provide a richer context for argumentation, because students can draw from their own life experiences in providing justifications for claims (Osborne et al., 2004). The climate change module consisted of 11 lessons, which we estimated would take teachers between 16 and 19 class periods (approximately 45 minutes each) to enact. Lesson 1 focused on eliciting students' ideas about climate change and engaging them in this science topic. Lessons 2–7 supported students in developing an understanding of both the causes (e.g., greenhouse effect, greenhouse gases, and human use of carbon-based resources) and consequences (e.g., changing weather patterns, coastal flooding, severe storms) of climate change through the use of in-class investigations, games, simulations, presentations, and discussions. Lessons 8 and 9 included a field study component in which students investigated the trees near their school and determined their ecological and economic role in terms of climate change. Lessons 10 and 11 focused on human behaviors and actions in terms of choices that can be made at the personal, school, and city level to reduce energy consumption.

Specifically, we focused on the first lesson, because we designed the lesson to provide an opportunity for interactive classroom discourse in which the students played an active role. The lesson was explicitly developed to create a context to support scientific argumentation in which students would debate different claims and their justifications for those claims with their peers. During the 2007–2008 school year, the other lessons in the module did not include the same focus on classroom discourse, though we have since revised the curriculum to make the goal more prevalent both throughout this module and in the other modules in the curriculum. The lesson began with students observing two short video clips, each between 1 and 2 minutes long, which provided different perspectives on climate change. The video clips came from YouTube and were selected because they represented videos students might see in mass media, such as a commercial on television or a video on the Internet. Both clips relied heavily on music and flashy images to convince the audience, though they also included some information as well. The quality of the information in the videos varied in terms of the scientific accuracy. One video clip argued that the climate is changing and provided evidence including that the 10 hottest years on record have all occurred in the last 25 years and that glaciers are melting across the world. The other video clip argued that the climate is not changing and justified this claim by stating that Greenland's glaciers are growing, not melting and that carbon dioxide is naturally occurring in the atmosphere, not the result of human industrialization. Neither video provided a strong model of a scientific argument for climate change. Rather they were selected as a way to engage students at the beginning of this new module and to encourage students to reflect on their own ideas about climate change and their justifications for those ideas. The lesson included specific strategies for the teacher to encourage his or her students to think about the credibility of the videos and how to be critical consumers of media. One of the main goals of the lesson was to encourage students to consider what counts as credible evidence for climate change.

After observing the videos, an investigation sheet directed students to "Write an argument for whether or not the earth's climate is changing. Is global warming occurring? Provide evidence for your claim and provide your reasoning for why that evidence supports the claim." This writing prompt was designed for students to support their claims with appropriate evidence and reasoning to encourage them to reflect on their own justifications for their ideas. Each student completed the writing task independently. The lesson then asked the teacher to lead a discussion in which students shared their arguments. Although it was our intent that this activity would encourage dialogic interactions in which the students

TABLE 1
School Context

Teacher	Number of Students in Focus Class	Number of Students in School	Student Ethnicity	School Statistics
Ms. Baker	14	289	46.7% Black 33.9% Hispanic 15.9% White 3.1% Asian 0.3% Native American	21.2% mobility 4.6% annual dropout rate 44.4% graduate in 4 years
Mr. Dodson	26	261	61.7% Black 32.6% Hispanic 2.7% White 2.3% Asian 0.8% Native American	4.9% student mobility 7.1% annual dropout rate 57.6% graduate in 4 years
Ms. Steven	28	305	60.7% Black 33.8% Hispanic 3.9% White 0.3% Asian 1.3% Native American	32.5% student mobility 15.2% annual dropout rate 26.8% graduate in 4 years

would share and critique each other's argument, this goal was not explicitly included in the curriculum nor did the curriculum provide specific strategies for the teachers in leading the discussion. After the discussion, the rest of the 1-day lesson consisted of the class reading a narrative about climate change and then analyzing temperature data from the National Oceanic and Atmospheric Administration for the past 1,000 years.

Participants

The participants in this study included three teachers and their students all from the same large urban school district in New England who used the curriculum materials in the fall of 2007. Each teacher taught in a different high school in the same school district. Table 1 provides the demographics for the three different high schools. As the number of students in each school indicates, all three teachers taught in "small" high schools. The large urban district recently divided the larger high schools into small schools though the physical high school buildings in the city remain large. Consequently, there are multiple schools in the same building. For these three teachers, each taught in a different physical building that consisted of two, three, or four different schools. All three high schools were ethnically diverse with the majority of students identifying themselves as either Black or Hispanic. Similar to other urban districts, the mobility between schools is high and percentage of high school students that graduate within 4 years is low. For all three teachers, the urban ecology class was a capstone class including students in both 11th and 12th grade.

Data Sources and Data Analyses

We selected Lesson 1 as the focus of this study, because it was the only lesson in the module with an explicit focus on classroom discourse and argumentation. Consequently, we videotaped all three teachers' initial lesson. The full classroom discussion emerged as the lesson segment with the greatest potential for argumentative discourse to allow us to investigate this phenomenon. After the students observed the two video clips and wrote individual arguments, all three teachers conducted full classroom discussions about climate change that lasted between 9 and 15 minutes. At the end of the classroom discussion, the activity structure shifted to the class reading a narrative about climate change. Because of our research interest in classroom discourse, we focused our analysis on the full classroom discussion. This moment of instruction in the three classrooms offered value in characterizing the discourse practices of the students and the potential role of the teacher in supporting argumentation. All three teachers' classroom discussions were transcribed, and each transcription was broken into utterances, in which an utterance represented a unique idea or contribution to the discussion. An individual's talk could consist of one utterance or multiple utterances depending on how many ideas were included in one segment of talk. The tables for the three coding schemes (Tables 2–4) and the tables in the results with the longer segments of transcript (see Tables 6 and 7 later in the paper) provide examples of utterances. Ms. Baker's discussion, which lasted 15 minutes, consisted of 304 utterances, Mr. Dodson's discussion, which lasted 14 minutes, consisted of 235 utterances, and Ms. Steven's discussion, which lasted 9 minutes, consisted of 121 utterances. Utterances were counted, and patterns were examined for the interactions between students and teacher to determine whether the discussion was dominated by teacher talk. Each utterance was also coded using three different coding schemes: argument structure, dialogic interactions, and types of teacher questions. The three coding schemes were developed from both the theoretical framework and an iterative analysis of the transcriptions (Miles & Huberman, 1994). All teacher and student utterances during the classroom discussion were used to calculate percentages and to look for trends in the patterns of argumentative discourse and the role of the teacher in supporting that discourse.

The coding scheme for argument structure adapted Toulmin's model of argumentation building off of our previous research examining student writing (McNeill & Krajcik, 2007; McNeill, Lizotte, Krajcik, & Marx, 2006) as well as the work of other science education researchers for both writing (Bell & Linn, 2000) and talk (Erduran et al., 2004; Jiménez-Aleixandre et al., 2000). Table 2 presents a description of the argument structure coding scheme as well as examples for the different codes from the classroom transcripts. We were specifically interested in students' ability to construct arguments around global warming in terms of what components did they rely on to either support or refute their claims. Although Toulmin's argument pattern is often used as a domain-general analytic framework (Sampson & Clark, 2008), we specifically defined the codes for claim, evidence, and reasoning in terms of the content around global warming. Consequently, similar to other work we have conducted looking at students' writing (McNeill, 2009; McNeill et al., 2006; McNeill & Krajcik, 2007), we adapted Toulmin's argumentation pattern to develop a domain-specific framework. We were interested in whether students used evidence and reasoning related to the claim that the climate was or was not changing, not if they were engaged in other arguments during the course of the discussion or provided evidence or reasoning that was unrelated to the claim.

In order for an utterance to be classified as a *claim*, individuals needed to offer a conclusion about whether or not they believed the climate is changing. For *evidence*, an utterance needed to include data or information that the student was using to argue for whether or not the climate was changing. We then classified the data as *scientific evidence*, *personal evidence*, or *other evidence* to further capture the nature of the data students used. Scientific evidence was any data that scientists use to investigate this phenomenon, such as glaciers melting, sea levels, air temperature, water temperature, or species disturbance. Data were categorized as scientific evidence regardless of whether students obtained the information from one of the two videos or from another outside source such as a previous science class

TABLE 2
Coding Scheme for Argument Structure

Code	Description	Example
Claim	Conclusion about whether climate change is occurring.	"I would say that global warming is occurring." Student "I don't think it's occurring." Student
Evidence	Data either in support or against climate change. The evidence was further classified as (1) *Scientific evidence*, data used by scientists such as glaciers melting, sea levels rising, species disturbance (Evid–Sci), (2) *Personal evidence*, information such as personal experiences with weather or flooding (Evid–Per), or (3) *Other evidence*, information such as heard about it from someone else (Evid–Other).	"I was going to say that, um, the waters have risen." (*Evid–Sci)* Student "Right now we've reached 77 degrees, 80 degrees toward the end of October. Usually by this time it would only be 50s or 60s." (*Evid–Per)* Student "You must be talking about the year with no summer. I heard about that." (*Evid–Other)* Student
Reasoning	Justification for why the evidence supports the claim. A theory (either personal or scientific) that suggests the climate is changing or is not changing.	"Because we use so much um gas and stuff and cities, like cities that use a lot of carbon dioxide their atmosphere is open and bigger." Student "Well maybe right before an ice age happens, the planet gets warm and then like it cools back down just to cure itself and everything that's been going on." Student
Question	Question about the discussion.	"What was some of the evidence presented?" Teacher "Can the sun get ready, get ready to explode?" Student
Other	All other utterances not included in the four previous codes for argument structure and question. These comments were typically either around the management of the discussion, not directly focused on the question of whether the climate is changing or an incomplete statement that did not fit the other codes.	"So let's start with Sylvia." Teacher "I wrote something like what Carlos wrote." Student "My brother used to make a lot of money when it snowed." Student "American people are spoiled." Student

or a news program. Personal evidence was information from students' everyday lives, such as comments about weather patterns during their lifetime. Other evidence was information or data that were not data scientists would use nor was it a personal experience of the student, such as discussing nonscientific information from the media. The *reasoning* component consisted of a combination of Toulmin's warrant and backing. For reasoning, we looked for students to provide either a justification for why their evidence supported their claim or a theory or mechanism for why global warming is or is not occurring. If another argument was pursued during the discussion, such as whether or not "American people are spoiled" this discussion was coded as *other*. We were only interested in classifying utterances as evidence and reasoning if they were related to a claim about climate change. Finally, we also decided to separately classify *questions*, because they appeared to have a unique role in the discussion in terms of how the teacher used them to facilitate classroom discourse. We will return to this idea of questions again later. Because we focused on classroom discussion and the urban high school students had relatively little content knowledge about this science topic as well as experience with scientific argumentation, we did not expect to find arguments as complex as those one might observe in high school students' writing (Sandoval, 2003) or undergraduate students' writing (Kelly et al., 2008) who had spent a longer period of time studying a science topic. Consequently, instead of focusing on the types of relationships between the various components, we examined the presence of the components to determine whether students were even using evidence or reasoning to justify their claims about global warming. Each utterance was classified as one of the five-argument structure codes to investigate what percentage of the discussion focused on argument and whether some components of argument were more prevalent than others.

Besides the structural aspects of argument in the classroom discussion, we were also interested in the interactions between members of the classroom. Specifically, we were interested in whether students engaged in dialogic interactions in that they were responding to ideas previously offered by other members of the classroom. As students discussed whether or not they believed the climate is changing, did they offer support or try to refute previous ideas? Or in contrast, did individuals present independent ideas that were

TABLE 3
Coding Scheme for Dialogic Interactions

Code	Description	Example
Independent	Not linked to a previous idea offered in the discussion. It is still considered independent if the utterance is in response to a question, as long as that question is not linked to any previous ideas.	"What other evidence was there, uh, /that the climate is changing? Robert?" Teacher *(Independent)* "The separate dates. The hottest days recorded in the separate years." Robert (*Independent)*
Connected	Dialogic interactions that support, refute, restate, or ask a clarifying question about a previous idea.	"It's like in Europe like John said. Like/ there's no global warming/ because they don't use carbon dioxide. So their atmosphere is closed." Student
Dismissal	Explicitly or implicitly suggests that a previous contribution is not important or relevant for the discussion.	"Okay. So let's try to limit our conversation just to evidence from the video." Teacher
Acknowledgment	Recognize a statement, but not to the extent of supporting, refuting, restating, or clarifying.	"Oh. Okay. So that's an interesting idea."

not connected to previous contributions in the classroom? Table 3 presents the coding scheme that we developed to capture the dialogic interactions that were occurring in the classroom.

Extended transcripts that more clearly illustrate the relationships between statements can also be found later in Tables 6 and 7. Utterances were coded as *independent* if they were not linked to a previous idea presented during the classroom discussion. An utterance was coded as *connected* if it either supported, refuted, restated, or asked for clarification about another idea that either a student or teacher offered during discussion. On a couple of occasions, we observed *dismissals* during the discussion. Although a dismissal is connected to a previous idea, its role is to shut down that idea or direction of discussion. Consequently, we classified it as distinct from the role of the connected code, which served to expand or continue the discussion in a direction offered by one of the participants. Finally, the last type of interaction that regularly occurred in the discussion was *acknowledgments* that recognized a previous statement, but did not serve to either extend it or shut it down. Acknowledgments were most frequently offered by teachers with comments such as "Okay," "Uh huh," or "Great" in response to a student contribution.

The final coding scheme that we developed focused on classifying teachers' questions, because of the potential unique role of the questions in impacting the direction of the classroom discourse. In the argument structure coding scheme, we classified utterances as questions. We found that during the discussion Ms. Baker asked 42 questions, Mr. Dodson asked 46 questions, and Ms. Steven asked 33 questions. The teachers' questions coding scheme returned to all of the teacher questions and further classified them into four different types of questions based on Blosser's (1973) classification scheme (see Table 4). A teacher's question was coded as *open* if there were many possible answers and if it could potentially elicit a variety of student responses. A question was considered *closed* if there were a limited number of correct answers to the question. When teachers asked a question and continued talking, not waiting for a student response, the question was classified as *rhetorical* regardless of whether the question was open or closed. Finally, *managerial* questions were noncontent questions that focused instead on the organization or management of the class. Similar to the rhetorical code, questions were coded as managerial regardless of whether they were open or closed. We were interested in examining whether the three teachers used different types of questions and whether or not there was a relationship between the question types and the discourse patterns in their classrooms. Consequently, we focus the results on the teacher questions and not the student-generated questions.

TABLE 4
Coding Scheme for Teachers' Questions

Code	Description	Example
Open	A content question with many possible answers where the teacher is not looking for a specific response.	"So what do you think that has to do with global warming?"
Closed	A content question with limited correct answer(s).	"What kind of evidence is that? Direct or indirect?"
Rhetorical	A question for which an answer is not solicited identified by continuous talk by the teacher.	"Right?," "Okay?"
Managerial	A noncontent question that is used to organize or manage the class.	"Can I see a show of hands first?"

The two authors coded together the first 8 minutes of Mr. Dodson's class to develop and refine the argument structure and dialogic interaction coding schemes. The remainder of Mr. Dodson's transcript, Ms. Steven's transcript, and Ms. Baker's transcript were coded independently by both raters. For the three teachers, 494 independent codes were assigned for both the argument structure and dialogic-coding schemes. Interrater reliability was calculated by percent agreement. The percent agreement was 78% for the structure codes and 78% for the dialogic codes. All disagreements were resolved through discussion. In using the two argument-coding schemes, the role of teacher questioning emerged as being important for the nature of the classroom discussion. Consequently, we developed the third coding scheme that focused on the types of questions asked by the teachers. For the three teachers, all teacher questions were coded independently by the two authors. The percent agreement was 75%, and again all disagreements were resolved through discussion.

In presenting the results, we report the utterances for the different coding schemes as percentage of total utterances for each teacher during the classroom discussion. We present them as percentages, to focus on what was emphasized in each class in terms of the relative amount of time spent on the different discourse features and teacher questioning strategies.

RESULTS

In this section, we provide the results from our analysis of the classroom discourse. Our analysis addresses two research questions: (1) What are the patterns in classroom discourse in three urban science classrooms? (2) What is the role of the teacher in promoting argumentation in terms of both the argument structure and dialogic interactions in classroom discourse? First, we discuss the percentages and the interaction patterns for teacher and student talk in the three classrooms. Then we discuss two specific examples of classroom transcripts, which illustrate a number of the patterns that emerged from the argumentation and teacher questioning codes. Next, we present the percentages for those patterns in terms of the argument structure, types of evidence, and dialogic interactions to demonstrate the differences in scientific argumentation across the three classrooms. Finally, we present the percentages for types of teacher questions to offer one potential cause for those differences in classroom discourse.

Teacher and Student Utterances

The first pattern that emerged was whether the classroom talk was dominated by the teacher or consisted of an interactive pattern that included a more active role for the students. Figure 1 displays the percentage of utterances that were either teacher or student talk during the classroom discussion.

In Ms. Baker's classroom, her students contributed 61% of the utterances. For both Mr. Dodson's and Ms. Steven's discussion, their classroom discourse was similar to traditional discourse in that the teacher contributed the majority of the utterances. In Mr. Dodson's class 31% of the utterances were contributed by his students, whereas in Ms. Steven's class only 28% of the utterances were contributed by students. Just examining the percentage of student and teacher talk in these classrooms does not provide a complete picture of the discourse patterns in terms of the interactions between the teacher and students. A teacher may contribute a larger percentage of the utterances because of time spent framing the argumentative discussion or wrapping up the discussion at the end, whereas the students play a dominant role during the actual argument about global climate change.

We also looked at the order of teacher and student contributions to examine whether the teacher was always the main driver of the discourse in a traditional IRE pattern that

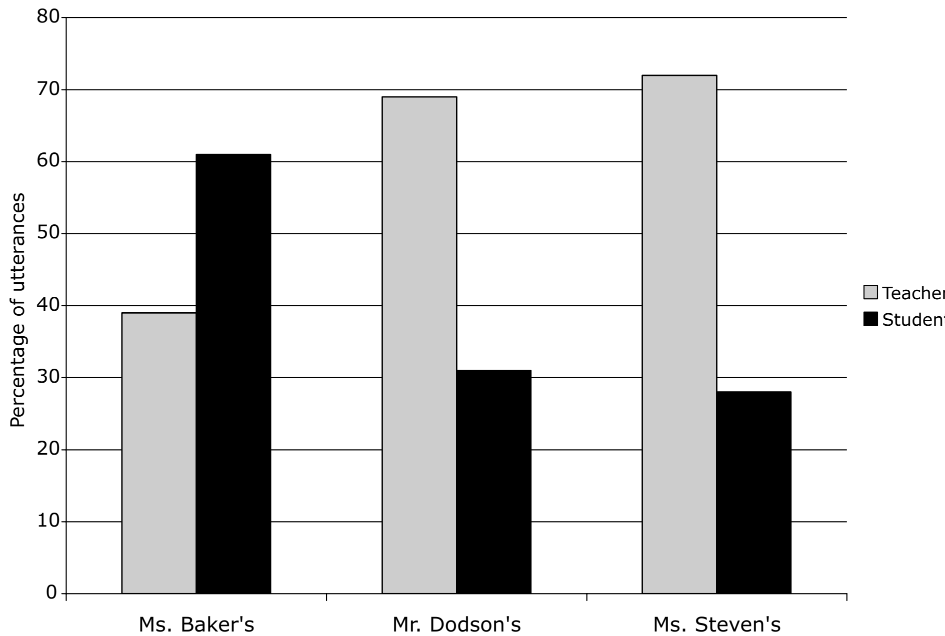

Figure 1. Percentage of teacher and student utterances.

alternated teacher, student, teacher (i.e., TS), or whether the students were more likely to directly respond to each other in an interactive pattern such as teacher, student, student, teacher (i.e., TSS). Table 5 presents the result from this analysis. Again, Ms. Baker's classroom discourse had a distinct pattern compared to the other two teachers' classrooms. Ms. Baker's students were more likely to directly respond to each other with one instance in which 11 contributions were made by students before Ms. Baker interjected with a clarifying question. In Mr. Dodson's and Ms. Steven's classrooms, the majority of student contributions were followed by a teacher question or comment.

In Mr. Dodson's and Ms. Steven's classrooms, the conversation was dominated by teacher talk and driven by the questions and comments of the teacher. Ms. Baker's discussion differed in that her students played a more active role in the discussion in terms of both the percentage of time as well as students more frequently directly responded to each other. This provides an overarching pattern of the teacher and student utterances to bear in mind as we examine the substance of the conversations that emerged from the three coding schemes.

TABLE 5
Patterns of Teacher–Student Interactions

	Ms. Baker	Mr. Dodson	Ms. Steven
TS (1)	38	62	23
TSS (2)	14	4	1
TSSS (3)	3		2
TSSSS (4)	4		1
TSSSSS (5)	5		
TSSSSSSS (7)	2		
TSSSSSSSSSSS (11)	1		

Examples of Classroom Discourse

In this section, we provide two examples to demonstrate the difference in the role of teacher talk in Mr. Dodson's and Ms. Steven's discussions compared to Ms. Baker's discussion as well as to illustrate the patterns in argument structure and dialogic interactions, which we will continue to discuss in more detail in the following sections. Table 6 includes an example from the classroom transcript in Mr. Dodson's class. This example is from the

TABLE 6
Excerpt With the Teacher as Driver and Fewer Dialogic Interactions

Classroom Transcript		Structure	Dialogic	Question
Mr. Dodson:	Why?/You say no it's not changing and/can you provide evidence from the—let' look at the video?	Question Claim Question	Connected Connected Connected	Rhetorical Closed
Rasheed:	I can sum it up for a lot of people in here./A lot of us lived in New England for our whole lives. And New England has the funniest weather in the United States./So you really can't say that the climate's changing/if you've only been here, basically if you can only remember weather patterns for ten years. You have to judge it by like that somewhat. And most of us are seventeen and eighteen. So you really can't say that the weather's changing if you haven't been here to see it that long.	Other Evid–Per Claim Reasoning	Independent Independent Independent Independent	
Mr. Dodson:	Well, let's, let's./What was the evidence that was presented in the video? / Let's. For ah. Donna, /What was some of the evidence presented?	Other Question Other Question	Independent Dismissal Independent Independent	 Rhetorical Closed
Donna:	It had examples of areas that was	Other	Independent	
Mr. Dodson:	Sorry. Which, which video are you talking about?	Question	Connected	Closed
Donna:	The first video./It had examples of areas that were like all ice. At one point, like um they were gone. The ice was gone. And then on, and then it showed the after picture and it was either all gone or all (inaudible).	Other Evid–Sci	Independent Independent	
Mr. Dodson:	Right./It was showing all these, uh, glaciers and, and uh, so ice melting./They showed that in the first video./Right?/They showed uh, uh, Kilimanjaro./Marcus.	Other/ Evid–Sci Other Question Evid–Sci/ Other	Connected Connected Connected Independent Connected Independent	 Rhetorical

beginning of the discussion in which Mr. Dodson just asked the class to raise their hands in response to whether they believe the climate is changing, is not changing, or they are not sure. After the students raised their hands, he began the conversation by calling on Rasheed who had indicated that he believed the climate was not changing.

One pattern in the discussion is that the contributions alternate between teacher, student, and teacher in a typical IRE pattern. As shown in Table 5, this pattern was characteristic of both Mr. Dodson's and Ms. Steven's classrooms in that the students rarely responded directly to each other. Instead, the teacher asked a question and called on a student, the student responded to the question, and the teacher then evaluated the response. The initial contribution by Rasheed is uncharacteristic of the rest of the discussion in Mr. Dodson's class in that it was the longest contribution any student offered, it used personal experience as evidence and it provided reasoning. We include this excerpt from the transcript to show Mr. Dodson's response in which he dismissed Rasheed's comment and instead redirected the conversation to focus on evidence from the video. Throughout the discussion, Mr. Dodson encouraged students to draw solely on evidence from the videos and not to use personal experience or other evidence. The interaction between Mr. Dodson and Donna is characteristic of the discussion in his classroom in that: (1) the teacher drove the discussion, (2) the teacher offered more utterances than the student, and (3) the students' contributions were independent or not connected to any previous contributions by other students in the class. These three characteristics were also typical in the discussion in Ms. Steven's classroom. This example also illustrates that Mr. Dodson predominately used closed or rhetorical questions and rarely asked open questions. This is one area in which Mr. Dodson and Ms. Steven differed in that she was more likely to include open questions though not as frequently as Ms. Baker.

The next transcript (Table 7) comes from Ms. Baker's classroom in which the students played a larger role in driving the discussion, more reasoning was included for claims, and both teacher and student utterances were more likely to be connected to previous contributions. The excerpt (see Table 7) was approximately 5 minutes into the full class discussion, and the students were trying to explain why they believed the climate is changing. After one student commented that the sun is so hot, another student (Dan) asked about whether the sun could explode, which shifted the focus of the conversation to the role of the sun in climate change.

This example is characteristic of Ms. Baker's classroom in that she asked open questions based on students' prior ideas that encouraged students to elaborate on their ideas. In this example, she asked Jamar to clarify his statement about the sun being too old. Ms. Baker was also more likely to connect to previous students' ideas, like her comment about Sam's contribution. The transcript also illustrates how the students were more likely to respond and build off of previous comments from other members of the classroom in that the dialogic-coding scheme was more likely to be coded as connected, and the discussion pattern frequently consisted of students directly responding to other students. Instead of being driven solely by the teacher, the discussion was driven by students' ideas and questions about global climate change. Students debated and built off of each other's justifications for why they believed climate change was or was not occurring.

Argument Structure

As these examples illustrate, the argument structure was present in all three teachers' classroom discussions in that the students offered claims about whether or not the climate was changing and provided evidence and reasoning for their claims. Yet there were distinct patterns in the teachers' classrooms in terms of the percentage of time students spent

TABLE 7
Excerpt With Students as Drivers and Dialogic Interactions

Classroom Transcript		Structure	Dialogic	Question
Dan:	So, Miss, I mean./Can the sun get ready, get ready to explode?	Other Question	Independent Independent	 Open
Teacher:	Can the sun get ready to explode?	Question	Connected	Open
Alesha:	No it's the atmosphere, the atmosphere is over (inaudible)	Other	Independent	
Jamar:	Maybe the sun is too old.	Reasoning	Connected	
Ms. Baker:	Maybe the sun is too old?/You think that has to do with global climate change?	Question Question	Connected Connected	Open Open
Jamar:	It's like dying out.	Reasoning	Connected	
Ms. Baker:	But Sam is saying that in places it's actually not warm it's colder. Or in other in some places too warm in other places it's too cold.	Evid–Other	Connected	
Jamar:	It's colder cuz it's dying out.	Reasoning	Connected	
Maria:	It's probably, it's probably the way it's tilting.	Reasoning	Connected	
Alesha:	Yeah, that's why it's tilting like it's in different places.	Reasoning	Connected	
Maria:	Or maybe because it's more um environmentally friendly. That, like that part. Like they say that they get holes in the atmosphere/so maybe where the holes are is above cities that are not so environmentally friendly?	Reasoning Question	Independent Independent	

justifying those claims. As we previously illustrated, Ms. Baker's students were more likely to justify their claims about climate change particularly in terms of providing their reasoning. Figure 2 displays the percentage of the classroom discussion that consisted of claims about climate change as well as the evidence and reasoning to support those claims for the three teachers.

The percentage of utterances coded as claim, evidence, and reasoning for climate change ranged from 19% in Ms. Steven's class, 21% in Mr. Dodson's class, and 35% in Ms. Baker's class. The rest of the utterances were either coded as *questions* or *other*. The *other* code was typically given either for comments around the management of the discussion, like calling on a student, or not directly focused on the question of whether climate change is occurring. Furthermore, during the middle of all three classroom discussions the focus diverged from arguing whether the climate is changing to a related topic. Each instance of divergence lasted less than 1 minute. In Mr. Dodson's class they discussed Tony Blair who was shown in one of the videos, in Ms. Steven's class they discussed the difference between direct and indirect evidence, and in Ms. Baker's class they discussed whether people were spoiled and would ever change their environmental actions. In all three classrooms, the teacher refocused the conversation on the question of climate change. For example, Mr. Dodson asked, "Were there any arguments from the second video that we don't have

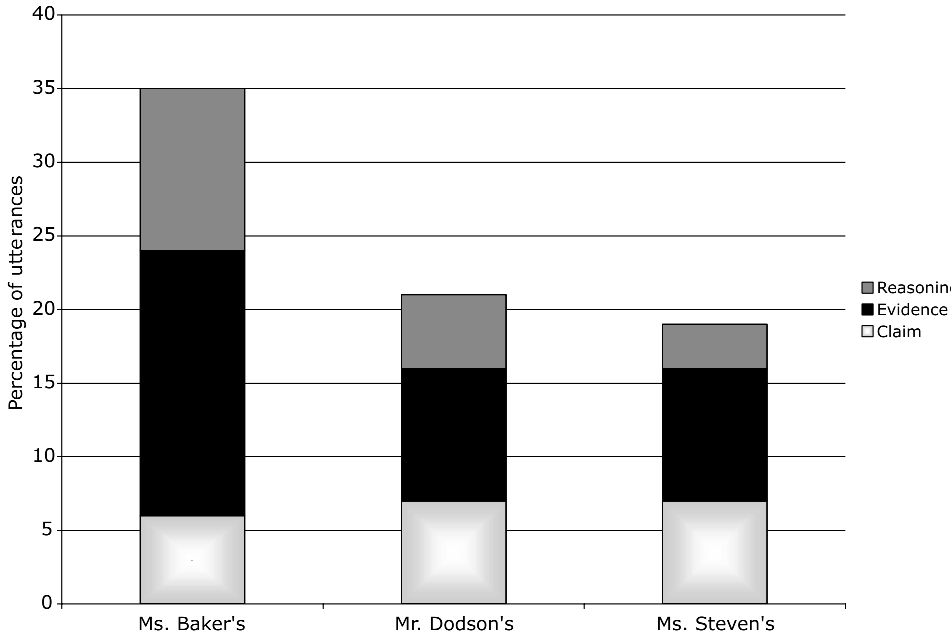

Figure 2. Argument structure of discourse.

up here?" Using our coding scheme, it is not possible for a discussion to be coded as 100% for argument structure, because there will always be questions and acknowledgments even if the discussion remains on topic. Of the three classrooms, Ms. Baker's most closely resembled our ideal in terms of the argument structure of the discourse, because of the greater prevalence of argument, particularly in terms of the inclusion of evidence and reasoning. The higher percentage of argument discourse in her classroom was not because she or her students were providing more claims about climate change; rather, they were more likely to justify their claims with evidence and reasoning specifically related to their claim.

We were also interested in what types of evidence students used to justify whether or not they believed that climate change was occurring. As we mentioned previously, this was the first lesson in the module focused on global climate change so students were not expected to have extensive scientific knowledge about the topic. As curriculum designers, our goal was for this initial discussion to elicit students' ideas, engage students in dialogic interactions, and interest them in the topic. Consequently, we were interested in whether students would draw their evidence from scientific data, personal experiences, or other sources as they argued about this socioscientific problem. Figure 3 displays the results from this comparison.

There was quite a bit of variation in terms of the types of evidence used in the three classroom discussions. In Mr. Dodson's discussion, the majority of the evidence was scientific with students rarely providing personal evidence or other evidence for whether or not the climate was changing. The example in Table 6 illustrates that Mr. Dodson's discussion focused on asking students to recall what evidence was presented in each video. As we mentioned previously, Rasheed was the first student to participate in the classroom discussion and drew from his own personal experiences. Instead of asking Rasheed to elaborate or asking the rest of the class what they thought of Rasheed's idea, Mr. Dodson dismissed Rasheed's comment and redirected the conversation to focus on the video. For the rest of the discussion, Mr. Dodson continued to focus on the video with questions and

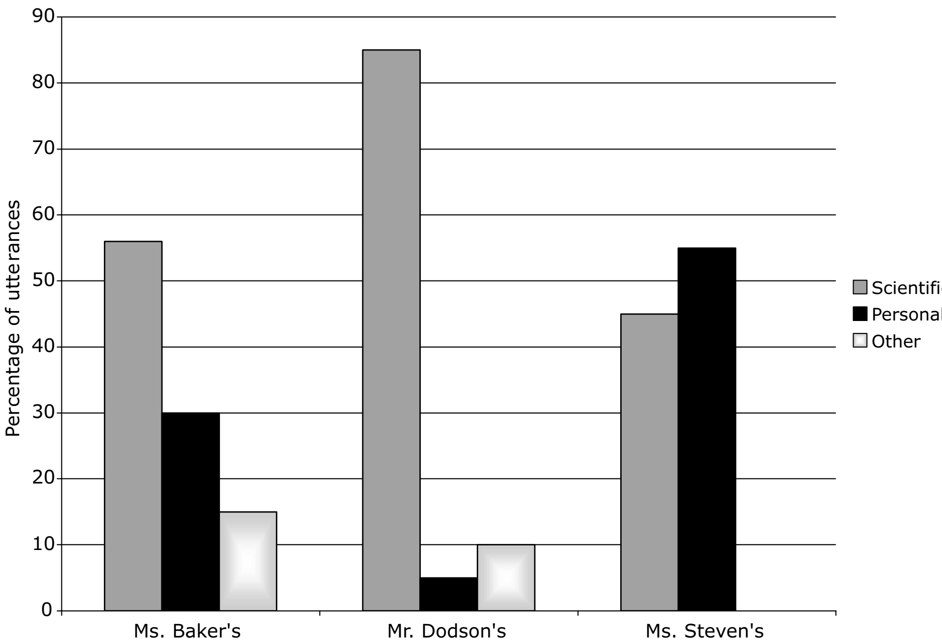

Figure 3. Types of evidence.

comments such as, "What was some of the evidence presented in the video?," "What other evidence was in the videos?," "Was that from the video?," and "So let's, let's try to limit our conversation just to evidence from the video." The focus of his discussion was on having students extract evidence from the two videos. Consequently, it is not surprising that much of the evidence provided by his students was scientific evidence from the videos and did not include personal evidence or other evidence from outside the classroom.

Both Ms. Steven's and Ms. Baker's discussions were more likely to include personal experiences as evidence. For example, in Ms. Steven's class the students talked about how unseasonably hot the fall had been. One of her students argued that the climate was changing, ". . . because summer time it's, it's supposed to be hot and the winter is supposed to be colder. Now it's say the middle of October with like 80 degrees." Ms. Baker's students used the widest range of evidence drawing from all three categories and as we will discuss in more detail later she asked the most open questions. This may suggest that if high school students are not explicitly told to focus on scientific evidence that they use a range of information to determine their own scientific and socioscientific conclusions, particularly in a content area in which they have little science content knowledge.

Dialogic Interactions

In terms of scientific argumentation, we were interested in not only the structure of the argument in terms of whether and what types of evidence and reasoning students used to support their claims, but also in the interactions between students. As curriculum designers, our goal for this lesson was to have students not only share their justifications but listen to, critique, and build off of the claims, evidence, and reasoning offered by other members of the classroom. Consequently, we were interested in whether students' contributions were independent or connected to previous ideas offered during the discussion. Figure 4 presents the results from our analysis of the interactions during the classroom discussions.

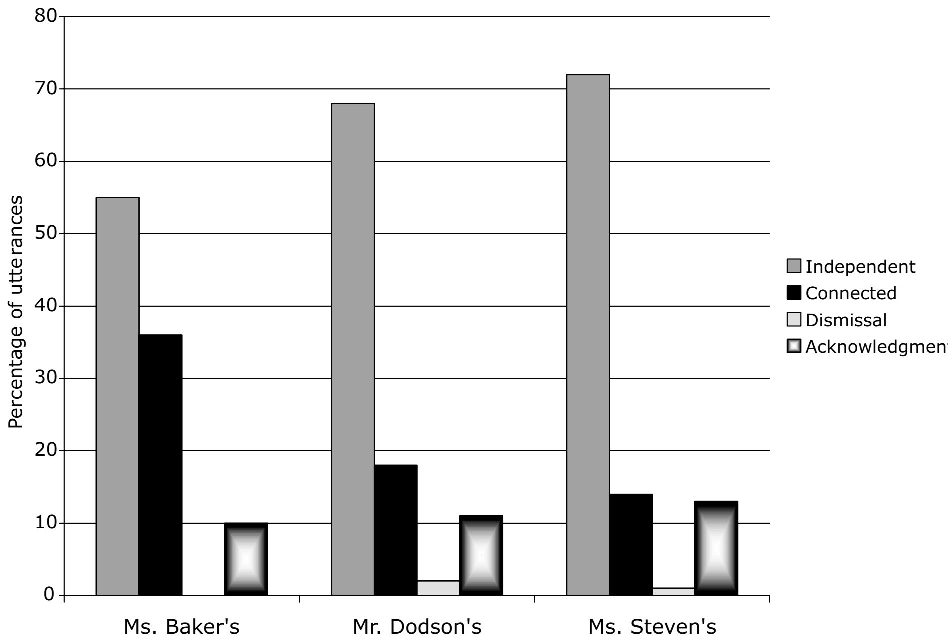

Figure 4. Dialogic interactions during discourse.

Again, Ms. Baker's classroom discourse differed from the other two teachers. In Ms. Baker's classroom, 36% of the utterances during the classroom discussion were connected to a previous contribution in that the comments supported, refuted, restated, or asked a clarifying question about a previous idea. In Mr. Dodson's class only 18% of utterances were connected, whereas in Ms. Steven's class only 14% of utterances were connected. Ms. Baker's students were more likely to connect their ideas to a previous comment in the class. For example, the excerpt in Table 7 illustrates both the teacher and students connecting to and trying to make sense of both Jamar's reasoning about the sun being too old and Sam's evidence that in some areas of the world the climate is actually getting colder and not warmer. Frequently, Ms. Baker would repeat what a previous student had said and link it to the current conversation. Furthermore, her students often immediately replied to what another student had said in contrast to the traditional IRE discourse structure. This differed from Mr. Dodson's and Ms. Steven's classrooms where students would respond to a teacher question, but rarely linked back to what another student said or directly replied to another student's comment.

Types of Teacher Questions

The patterns in student talk, the argument structure, and the dialogic interactions suggest that the nature of the discussion in Ms. Baker's class was different from that of the other two teachers. One potential cause of this difference is the types of questions the teachers used to facilitate the discussion. Figure 5 displays the percentage of questions for each teacher that was open, closed, rhetorical, or managerial during the classroom discussion segment of the lesson.

While 71% of Ms. Baker's questions were open, only 22% of Mr. Dodson's and 33% of Ms. Steven's questions were open. Ms. Baker was much more likely than the other two teachers to ask open questions where she was not looking for a specific response, but rather

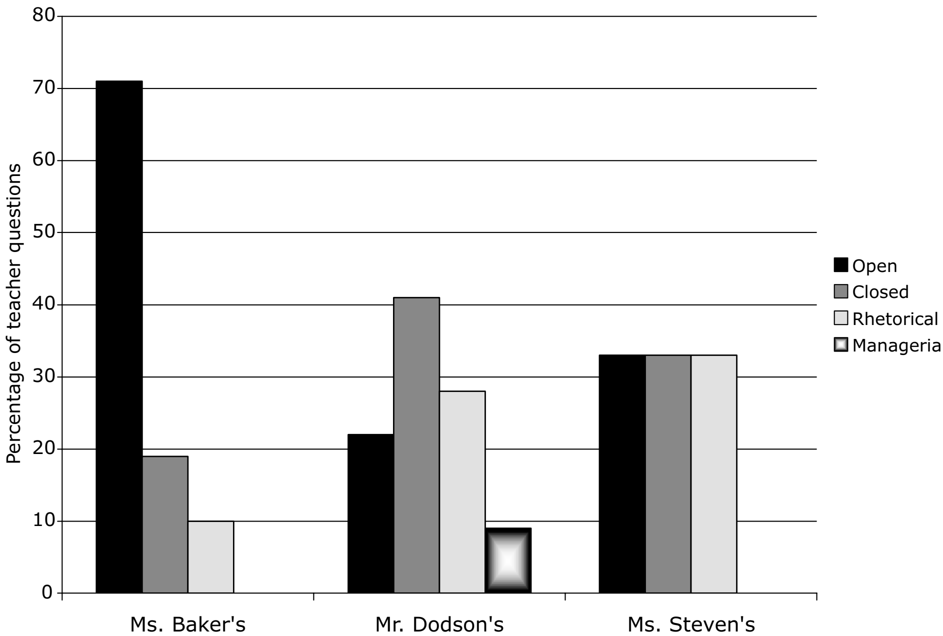

Figure 5. Types of teacher questions.

was encouraging students to share, clarify, or connect their ideas to the ideas of their class members. For example, frequently during the discussion Ms. Baker asked the class as a whole or a specific student, "What do you think?" The other common form of her question was to repeat part of what a student said to ask for clarification. For example, in the excerpt in Table 6 she asks Jamar to clarify what he means by the sun is too old or later in the conversation she asked a student to clarify what she meant by islands disappearing under water, "Okay. So islands might be under water? And why would they be under water?" The openness of Ms. Baker's questions is one potential reason for why her classroom discussion was dominated by student talk, included a greater prevalence of evidence and reasoning, and consisted of more comments connected to previous ideas. Ms. Baker's questions were not looking for a specific response, but rather encouraged students to expand their justifications as well as link to other students' ideas. Her questions were very different from Mr. Dodson's that frequently asked for evidence in the videos. Ms. Steven's class included a variety of questions, but there was not the same openness around just wanting to know what students thought about global warming and why.

Summary of Results

Distinct patterns in the classroom discourse and the teachers' use of questions emerged across the three teachers during the classroom discussions. Table 8 provides a summary of the characteristics of each teacher's discussion. The discussion in Ms. Baker's classroom was dominated by student talk and included many moments of successful argumentation in terms of both the argumentation structure and dialogic interactions. In terms of the structure, Ms. Baker's students used a variety of evidence to support their claims about climate change including scientific, personal, and other evidence, as well as articulated their reasoning for why the evidence supported that the climate either was or was not changing.

TABLE 8
Summary of Characteristics of Classroom Discourse and Teacher Questions by Teacher

	Teacher and Student Talk	Argument Structure	Types of Evidence Used	Dialogic Interactions	Teacher Questions
Ms. Baker	Dominated by student talk	Argument structure was prevalent More focus on evidence and reasoning	Scientific evidence, personal evidence, and other evidence	Dialogic interactions between students are prevalent—more likely to directly respond to their peers and more likely to support or refute the ideas of their peers	Predominately open questions
Mr. Dodson	Dominated by teacher talk	Argument structure was prevalent Less focus on evidence and reasoning	Predominately scientific evidence	Teacher-directed discourse with few dialogic interactions between students	Predominately closed questions
Ms. Steven	Dominated by teacher talk	Argument structure was prevalent Less focus on evidence and reasoning	Scientific evidence and personal evidence	Teacher-directed discourse with few dialogic interactions between students	Equal distribution of open, closed, and rhetorical questions

Ms. Baker's students were also more likely to connect their comments to previous students' ideas through supporting, refuting, restating, or asking for clarification. The prevalence of justifying claims and dialogic interactions in the classroom discourse may have been supported by Ms. Baker's frequent use of open-ended questions to encourage students to share their ideas, clarify their thinking, and connect to the ideas of their peers.

In both Mr. Dodson's and Ms. Steven's classrooms, the classroom discourse was dominated by teacher talk and the students played a less active role in the discussion. The discussions in both of their classes were similar in that the teacher drove the discussion, the discussion included the argument structure (i.e., claim, evidence, and reasoning), and the majority of students' contributions were independent and did not support or refute the comments of their peers. Though the argument structure was prevalent in both Mr. Dodson's and Ms. Steven's classroom, it occupied less of the discourse with smaller percentages for both evidence and reasoning about climate change. Furthermore, the types of evidence varied. Ms. Baker's class contributed all three types of evidence, whereas Mr. Dodson's class predominately contributed scientific evidence and Ms. Steven's class contributed scientific and personal with no other information as evidence. The frequency of open-ended questions was much lower in both Mr. Dodson's and Ms. Steven's classrooms, which is one potential explanation for the differences in discourse patterns.

The classroom discussion patterns in Ms. Baker's class appeared to be different than the other two classrooms. Since we studied only one lesson, we do not know how pervasive these patterns are in the teachers' daily science classroom practice or if they used different strategies at the beginning of the school year to set-up these patterns as norms. Yet in our study there appeared to be a relationship between teachers' use of open-ended questions and the prevalence of student talk and argumentation in the classroom discussions.

DISCUSSION

The most frequent type of question used by teachers in science classrooms is a known answer question in which the teacher is looking for a specific response (Lemke, 1990). This type of question does not encourage students to share different ideas in the discussion or to engage in interactive discourse between students. Similar to Martin and Hand (2009), we found that there was a relationship between teachers' questioning strategies and the argumentation discourse in the science classrooms. There was a relationship between more open-ended questions and increased percentages of student talk, the use of evidence and reasoning to support claims, and dialogic interactions between students.

Argumentative discourse in which students support the claims they are making with appropriate justifications is not the norm in science classrooms (B. A. Crawford, 2005). Osborne and his colleagues (2004) found that when middle school science teachers were supported to develop science lessons with a focus on argumentation that between 15% and 32% of the discourse in those lessons consisted of claims and grounds. They defined grounds as data or warrants, which we refer to as evidence and reasoning in our coding scheme. In our study, between 19% and 35% of the discourse focused on scientific argumentation in terms of the use of claims, evidence, and reasoning, which falls into a similar range. The high school lesson that we studied was designed to encourage argumentation in that the two videos offered different perspectives or different claims, students were asked to write an argument that included evidence and reasoning, and teachers were asked to have students share their arguments in a classroom discussion. In all three classrooms, argumentation discourse did occur with students formulating claims about climate change and justifying those claims with evidence and reasoning. In terms of including the different components of argument, the lesson was successful. However, if we had used a different analytic framework to examine the structure of the argument (Sampson & Clark, 2008), we may have found varying degrees of success such as in the relationships between the different components of the arguments or the coherence of the arguments.

In terms of argumentation as a social or dialogic process, persuasive interactions only occurred regularly in one teacher's classroom. In the other two classes, the students responded to the questions of their teacher, but rarely directly responded to one of their peers in terms of either building on or refuting their claims, evidence, or reasoning. Student-to-student interactions were rare. Instead, the discourse pattern in these two classrooms aligned with the traditional IRE pattern in which the teacher was the main driver and knowledge authority during the discussion.

Ms. Baker's classroom was the exception in that her class discussion included a greater percentage of dialogic interactions. Ms. Baker's students were more likely to directly respond to a previous student as well as explicitly support or refute the ideas presented by their peers. This suggests that while curriculum can help create a context for scientific argumentation to occur, the role of the teacher is essential. Teachers' use of a variety of pedagogical strategies can impact the level of argumentation in classroom discourse (Simon et al., 2006). The characteristics of Ms. Baker's classroom embody what van Zee and Minstrell (1997) refer to as "reflective discourse." Reflective discourse exists when students (1) make their meanings clear, (2) consider multiple views, and (3) reflect on their thinking and those of their classmates. van Zee and Minstrell discuss the importance of open questions for supporting this type of classroom discussion in which the teacher is negotiating multiple meanings instead of looking for a correct answer. This aligns with Ms. Baker's use of open questions such as "What do you think?" that appeared to support students in not only including claims, but justifications for those claims in terms of evidence and reasoning using both their scientific and everyday knowledge and experiences. Furthermore, Ms. Baker's explicit connections to previous students' comments appeared to encourage students to consider multiple views, reflect on their thinking, and reflect on the thinking of their classmates. Her students appeared to consider their ideas in the context of the larger classroom community in terms of whether they supported or refuted previous contributions.

These types of classroom norms around justifying and connecting ideas are not typical in science classrooms. Because of the small sample of teachers in this study, we cannot make a causal link between teachers' use of open-ended questions and argumentation discourse. Furthermore, classrooms are complex environments and student learning is impacted by the use and interaction of multiple teacher, peer, and curricular supports (McNeill & Krajcik, 2009). Yet this study suggests that open-ended questions may play a key role in supporting students in argumentation in terms of both providing evidence and reasoning for students' claims and encouraging dialogic interactions between students. Our findings about the importance of open-ended questions support the results from previous case studies examining classroom discourse in science (Martin & Hand, 2009; van Zee & Minstrell, 1997).

Using Everyday Experiences in Scientific Argumentation

Classroom discourse should engage students in disciplinary ways of thinking and doing without ignoring their everyday ways of thinking and doing (Scott et al., 2006). Our goal in the science classroom is to engage students in argumentative discourse in which they engage in the social process of knowledge construction in which they support their claims with appropriate evidence and reasoning. To be successful, this process needs to draw from and utilize students' everyday knowledge and experiences. Moje and her colleagues (2004) found that the urban youth they followed in and out of the school setting rarely volunteered everyday knowledges in science classrooms, even when their prior experiences were relevant to the current science topic. Science learned in schools is often decontextualized from students' everyday experiences (Aikenhead, 1996). Students constantly engage in border crossing in which they need to navigate different cultures in the context of school, family, peers, and work with often very little assistance in navigating these transitions. Teachers should make clear that different types of knowledges and experiences are welcome in the science classroom to actively construct a third space that helps students navigate different discourses (Moje et al., 2004). Encouraging students to draw from their everyday knowledge and experiences is important to help them connect their different ideas to develop more robust and usable scientific knowledge. The teachers in this study placed different emphasis and support on students' drawing from their own experiences in discussing whether or not climate change is occurring. When teachers were more open to the use of different types of evidence, there was a greater prevalence of everyday experiences (e.g., students' personal experiences with weather) and other evidence (e.g., information students obtained from the media and other people).

Ford and Kniff conducted a study (Ford, 2008) in which they compared how scientists and nonscientists evaluated science-related claims in popular magazines. They found that nonscientists were more likely to draw from personal anecdotal experiences, whereas scientists were more likely to question how the data were collected and analyzed when evaluating these claims. Although it is our goal to have students use scientific evidence and reasoning in supporting their claims, it is important for students to draw from their other experiences to support students in border crossing and making sense of their different experiences. Juxtaposing everyday and scientific views in classroom discussion can support students in engaging in the different discourses and making sense of how the different ideas fit together (Scott et al., 2006).

Osborne and his colleagues (2004) found that socioscientific contexts resulted in higher levels of argumentation discourse than scientific contexts, which they suggest is because in the socioscientific context students can draw from their own life experiences in providing evidence and reasoning. In the case of global warming, we found that students frequently drew from their personal experiences and other experiences outside of science for the evidence they used to support their claims. Controversial socioscientific contexts may be rich areas to engage students both in argumentation as well as support students in border crossing and integrating their various experiences both inside and outside of the classroom. Future work needs to investigate how to best support students to understand how their scientific conceptual understandings as well as their ability to engage in scientific practices, such as argumentation, are relevant to their everyday lives and personal decision making.

Discourse Patterns and Goals of the Science Lesson

The discourse pattern in a classroom depends on a teacher's purpose (Mortimer & Scott, 2003). From analyzing the discourse in the three classrooms, we feel that potentially the teachers had very different goals for the discussion. Mr. Dodson's goal appeared to be to have students provide the evidence both for and against climate change that was presented in the video. When students deviated from this focus, Mr. Dodson directed them back to looking at the video. Ms. Steven's goal appeared to be to have students share their written arguments, but it was not to engage in a dialogic discussion in which the students tried to convince their peers about the strengths of their arguments. The goal of science is often not seen as dialogic interactions or persuasion, but rather as sensemaking and coming up with the "right answer" (Berland & Reiser, 2009). Using the IRE discourse structure places teachers in a position of power in which they can control the topic and direction of the discussion (Lemke, 1990). Consequently, if Mr. Dodson and Ms. Steven were trying to achieve these specific outcomes, which differed from persuasion and dialogic interactions, it is not surprising that they used this traditional discourse structure. Ms. Baker appeared to have a variety of different goals for the discussion, which aligns with the first question she asked her students "So, what do you guys think?" She did not appear to have a particular direction in which she was trying to steer the conversation beyond understanding her students' ideas about global warming and supporting them in listening to and responding to each others' ideas. A dialogic discourse pattern aligned with this more open goal.

The discourse patterns in a classroom should include a range of interactions from dialogic to authoritative (Mortimer & Scott, 2003). Scott and his colleagues (2006) discuss how the appropriate format of classroom discourse is dependent on the goal of the discussion. They argue that it is not that the IRE discourse pattern is inherently “bad,” but rather the communicative approach is explicitly linked to teaching purposes. If the goal of a lesson is to explore and probe students’ ideas, then a more dialogic and interactive discourse pattern may be more effective in meeting this goal. If the goal is to introduce a science concept, then a more traditional authoritative discourse pattern may be more effective. We agree with this perspective in that we do not think that argumentation or dialogic interactions should be the sole discourse pattern in a science classroom. The appropriate discourse pattern depends on the purpose of the particular lesson. Yet argumentation plays an essential role in science and in science classrooms and is frequently missing from classroom norms (Driver et al., 2000). Consequently, if we want students to engage in science as a practice that includes doing, talking, and writing, then students need to have experiences engaging in scientific argumentation in the science classroom. One common finding of studies focused on argumentation in science is that students struggle to engage in this practice and need instructional support (Bell & Linn, 2000; Berland & Reiser, 2009; Jiménez-Aleixandre et al., 2000; McNeill & Krajcik, 2007; Osborne et al., 2004; Sadler, 2004; Sandoval, 2003; Sandoval & Millwood, 2005).

Ford argues (2008) that both the construction and critique of claims is essential for science and for science classrooms. Scientists intuitively appear to recognize and critique scientific claims and to engage in that critique in relation to how data were collected, analyzed, and used as evidence to support the claim in contrast to everyday claims. If we want students to engage in dialogic interactions in which they are connecting, building on and critiquing the claims of their classmates the goal of classroom instruction needs to focus on these social aspects (Berland, 2008). Teachers’ instructional support for scientific argumentation may be influenced by what they see as the goal or purpose of classroom instruction. If teachers do not see argumentation as an essential goal, they may simplify this cognitively demanding inquiry task to make it simpler for students and align more closely with traditional authoritarian classroom practices (McNeill, 2009). The results from this study suggest that having the purpose of a lesson be to explicitly explore and debate students’ ideas as well as using more open-ended questions may promote student talk, dialogic interactions between students, and greater justifications of their claims with appropriate evidence and reasoning.

To better support teachers in argumentation, we need to design educative curriculum that make the rationale behind our design choices explicit for teachers (Davis & Krajcik, 2005) and develop professional development workshops that more effectively support teachers in engaging in this complex practice (Zohar, 2008). Providing teachers with a metalanguage to discuss argumentation with students can provide greater support for argumentation in classroom discourse (Osborne et al., 2004). Consequently, in our revision of the curriculum and work with teachers we have explicitly integrated a framework for argumentation (i.e., claim, evidence, and reasoning) as well as highlighted goals such as promoting student voice and supporting students’ understanding of the social nature of science during classroom discussions. We are also currently working on designing professional development that makes our rationale clearer as well as uses example video and transcripts from previous enactments to illustrate both the goals (i.e., what does argumentation look like) as well as how the use of open-ended questions can impact classroom discourse. Furthermore, we are asking teachers to reflect specifically on their classroom discourse and use of questioning strategies to support those discussions. Future research needs to continue to investigate different strategies for helping teachers support their students in argumentation and dialogic interactions.

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