The Tension Between Authoritative and Dialogic Discourse: A Fundamental Characteristic of Meaning Making Interactions in High School Science Lessons

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ABSTRACT: In this paper, we draw upon a framework for analyzing the discursive interactions of science classrooms (Mortimer & Scott, 2003, *Meaning Making in Secondary Science Classrooms*, Maidenhead, UK: Open University Press), to probe the movement between authoritative and dialogic discourse in a Brazilian high school science class. More specifically, we argue the point that such shifts between communicative approaches are an inevitable part of teaching whose purpose is to support meaningful learning of scientific knowledge. We suggest that a necessary tension therefore exists between authoritative and dialogic approaches as dialogic exchanges are followed by authoritative interventions (to develop the canonical scientific view), and the authoritative introduction of new ideas is followed by the opportunity for dialogic application and exploration of those ideas. In these ways, one communicative approach follows from the other, authoritativeness acting as a seed for dialogicity and vice versa. We discuss how this analysis, in terms of shifts in communicative approach, offers a new and complementary perspective on supporting "productive disciplinary engagement" (Engle & Conant, 2002, *Cognition and Instruction,*

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20, 399–484) in the classroom. Finally we consider some methodological issues arising from this study. *Sci Ed* **90:**605–631, 2006

INTRODUCTION

In recent years, there has been a gradual development of interest in studies of how meanings are developed through language and other modes of communication in the science classroom. Different studies have highlighted, from various points of view, the importance of investigating classroom discourse and other rhetorical devices in science education (see, e.g., Candela, 1999; Halliday & Martin, 1993; Kelly & Brown, 2003; Kress, Jewitt, Ogborn, & Tsatsarelis 2001; Lemke, 1990; Mortimer, 1998; Mortimer & Scott, 2003; Ogborn, Kress, Martins, & McGillicuddy, 1996; Roychoudhury & Roth, 1996; Scott, 1998; Sutton, 1992). This "new direction" for science education research (Duit & Treagust, 1998) signals a move away from studies focusing on individual student understandings of specific phenomena toward research into the ways in which understandings are developed in the social context of the science classroom.

The importance of language for learning has also been recognized in a number of curriculum development initiatives. For example, in the UK, the Qualifications and Curriculum Authority (QCA, 2003) strongly identifies "dialogic teaching" with effective whole-class instructional approaches, drawing on the comparative, cross-cultural research of Alexander (2001) as a basis for doing so. In North America, there is a powerful movement toward "inquiry-based" science lessons, in which the students work collaboratively on open-ended activities and are encouraged to talk their way to solving problems (see, e.g., Kelly & Brown, 2003; Roychoudhury & Roth, 1996). On both sides of the Atlantic, moves are being made to engage students in the patterns of talk, or modes of "argumentation," which are characteristic of science (see, e.g., Driver, Newton, & Osborne, 2000; Duschl & Osborne, 2002; Kelly, Brown, & Crawford, 2000).

The notion of dialogic discourse seems to be a central part of all of these initiatives. Duschl and Osborne (2002), for example, claim that argumentation must be dialogic as it "requires the opportunity to consider plural theoretical accounts and the opportunity to construct and evaluate arguments relating ideas and their evidence" (p. 52). Kelly, Crawford and Green (2001) show the potential importance of dissenting voices in the discursive construction of physics explanations by students working in small groups. Ritchie and Tobin (2001, p. 295) suggest that genuine consensus in science can only be achieved through dialogic discourse.

Despite this widespread interest in dialogic discourse, the fact of the matter is that dialogic interactions are notably absent from science classrooms around the world (Alexander, 2001; Fischer, Reyer, Wirz, Bos, & Hollrich 2002; Wells, 1999). In the book *Meaning Making in Secondary Science Classrooms*, we (Mortimer & Scott, 2003) developed a framework for characterizing different kinds of discursive classroom interactions and present examples (rare as they may be) of dialogic discourse, as played out in real classrooms, contrasting these with more authoritative passages.

The purpose of this paper is to extend those kinds of analyses and to develop the argument, with exemplification, that any sequence of science lessons, which has as its learning goal the meaningful understanding of scientific conceptual knowledge, must entail *both* authoritative and dialogic passages of interaction. Indeed, from the perspective that we take, we see a *tension* between authoritative and dialogic approaches as being an inevitable characteristic of meaning making interactions in science classrooms. In order to explore this tension between authoritative and dialogic discourse, we have collected and analyzed data from a series of high school science lessons taught in Brazil. In addition, we discuss some methodological issues which emerge from that analysis, setting out the range of criteria to be used in identifying authoritative and dialogic approaches.

The general theme of extending the range of interactions in science classrooms is one which has been explored in various studies over recent years. A common issue in these studies is that the participant structures (Phillips, 1972) of science classrooms should change so as to "overcome the barriers of traditional classroom participant structures wherein the teacher does most of the talking and students participate by responding to teacher questions and receiving evaluation of their responses" (Cornelius & Herrenkohl, 2004). The aim of the proposed new participant structures is to produce what Engle and Conant (2002) call "productive disciplinary engagement." Engle and Conant give a list of features of students' discourse that can be considered as evidence of their greater disciplinary engagement: more students make substantive contributions to the topic under discussion; these contributions are in coordination with each other; few students are involved in "off-task" activities; students express passionate involvement and they re-engage and continue to be engaged in the topic over a long period of time (Engle & Conant, 2002, p. 402). By disciplinary engagement, the authors mean "that there is some contact between what students are doing and the issues and practices of a discipline's discourse" (p. 402). Productive disciplinary engagement sees the students making intellectual progress that can be inferred by, amongst other things, an improvement in the quality and sophistication of arguments and the development of new ideas and disciplinary understandings.

Engle and Conant advance four principles for fostering productive disciplinary engagement: problematizing content, giving students authority, holding students accountable to others and to disciplinary norms, and providing relevant resources. Problematizing content involves the teacher in encouraging student questions, proposals, and challenges rather than just expecting answers and assimilation of facts and procedures. Giving students authority means encouraging students "to be authors and producers of knowledge, with ownership over it, rather than mere consumers of it" (Engle & Conant, 2002, p. 404). Holding students accountable to others and to disciplinary norms involves students in considering the points of view of others, not necessarily to accept them but to be responsive to them. The students are expected to consult others in constructing their understanding in a domain and to respect disciplinary norms, as for example in giving evidence for their claims. All of these points resonate with Resnick's (1999) notion of "accountable talk" in the classroom. The authors situate the fourth principle at a different level in that it supports the embodiment of the other principles. "Resources supporting productive disciplinary engagement may be as fundamental as having sufficient time to pursue a problem in depth or having access to sources of information relevant to it" (Engle & Conant, 2002, p. 405). These resources might include books and Internet sites but also things such as students' questions and their familiar ways of discussing them. According to Warren, Ballenger, Ogonowski, Rosebery, and Hudicourt-Barnes (2001), these familiar ways of thinking "constitute invaluable intellectual resources which can support children as they think about and learn to explain the world around them scientifically" (p. 548).

Framed in terms of fostering the communication of physics principles, Van Zee and Minstrell's (1997) notion of "reflective discourse" is highly relevant to the achievement of productive disciplinary engagement. Van Zee and Minstrell contrast reflective classroom discourse with the discourse of traditional classrooms in which the authority of the teacher is central and define reflective discourse as classroom discussions in which three conditions are frequently met. These conditions are that (i) students express their own thoughts, comments, and questions; (ii) the teacher and individual students engage in an extended series of questioning exchanges that help students better articulate their beliefs and conceptions; (iii) student/student exchanges involve one student trying to understand the thinking of another (Van Zee & Minstrell, 1997, p. 209).

Central to all of these studies is the goal of engaging students with disciplinary ways of thinking and doing so without ignoring their existing or everyday ways of thinking which are considered to be a fundamental resource in this enterprise. This goal is also central to the dialogic/authoritative tension that we see underpinning meaningful learning and as such there are considerable overlaps to be explored between the present study and the literature outlined above. For example, Van Zee and Minstrell's conceptualization of "reflective discourse" maps directly onto what Bakhtin refers to as "internally persuasive" discourse, which we redefined as dialogic discourse. Cornelius and Herrenkohl (2004) explicitly consider the Bakhtinian notion of persuasive discourse as one of the fundamental tools for empowering students and fostering their productive disciplinary engagement in science classrooms. In suggesting that an effective balance between authority and accountability should be maintained in science classrooms, Engle and Conant (2002) get very close to our intention of exploring how a suitable balance between authoritative and dialogic discourse can contribute to students' meaning making of scientific concepts.

We shall return to these links with the existing literature in the final part of this paper and review them in the light of the data and arguments which we present. In the following sections, we shall first of all outline the framework which we have used in analyzing the classroom discourse. We then present the analysis of data, focusing on the movement between authoritative and dialogic communicative approaches.

THE FRAMEWORK

Following Vygotskian principles, we consider that science teaching entails a kind of "public performance" on the social plane of the classroom. This performance is directed by the teacher who has planned the "script" for the performance and takes the lead in "staging" (Leach & Scott, 2002) the various activities of the science lessons. Central to the teaching performance is the job of developing the "scientific story" on the social plane of the classroom (Ogborn et al., 1996) and the support given to students in internalizing the new scientific ideas which are being introduced. Of course, the teacher cannot exert absolute control over the ways in which the interactions are played out with students in the classroom (Candela, 1999; Erickson, 1982), and as such the teaching and learning performance may develop along unexpected pathways.

The framework which we outline here was developed to analyze the speech genre (Bakhtin, 1986) of science classrooms and, in particular, the ways in which the teacher acts to guide meaning making interactions on the social plane of high school science classrooms. The framework is the product of an ongoing research program conducted over a number of years (see, Mortimer, 1998; Mortimer & Scott, 2000; Scott, 1998) and a detailed description of its development is set out elsewhere (Mortimer & Scott, 2003). Suffice it to say, for the purposes of this article, that the framework is based on a sociocultural perspective on teaching and learning (Mortimer & Scott, 2003) and has been developed through a series of detailed case studies. The case studies focus on the interactions and activities of sequences of high school science lessons in England and Brazil, in which conceptually demanding science topics (such as "air pressure," "energy," and "the particulate theory of matter") were taught to students aged 12–16 years. From the analyses of these data and from the insights gained from various aspects of sociocultural theory, the framework was developed through an iterative process of application and refinement.

The analytical framework (Mortimer & Scott, 2003) is based on five linked aspects, which focus on the role of the teacher, and are grouped in terms of teaching focus, approach, and action (see Table 1).

Central to the framework is the concept of "communicative approach" which was first developed by Mortimer and Scott (2003), and provides a perspective on *how* the teacher

TABLE 1
The Analytical Framework: A Tool for Analyzing Meaning Making Interactions in Science Classrooms

	Aspect of Analysis	
(i) Focus	*1. Teaching Purposes*	*2. Content*
(ii) Approach	*3. Communicative approach*	
(iii) Action	*4. Teacher interventions*	*5. Patterns of interaction*

works with students to develop ideas in the classroom. The different classes of communicative approach (see next section) are defined in terms of whether the classroom discourse is authoritative or dialogic in nature and whether it is interactive or noninteractive (Mortimer & Scott, 2003, p. 33). The different communicative approaches are put into action through specific patterns of interaction and teacher interventions. A common pattern of interaction (p. 40) is the triadic I-R-E form (see next section), whilst a common form of teacher intervention (p. 42) involves marking key ideas, possibly by use of repetition. The different communicative approaches are also linked to specific teaching purposes (p. 28), such as developing the scientific story, and to the nature of the thematic content (p. 28) which is the focus of the teaching. The content might be everyday or scientific; descriptive, explanatory, or generalized; empirical or theoretical, in nature.

In this paper, we shall focus our attention on just three aspects of the framework. These are the communicative approach, teaching purposes, and patterns of interaction and we say a little more about each of these in the following sections.

COMMUNICATIVE APPROACH

The communicative approach focuses on questions such as whether or not the teacher interacts with students (either taking turns in the discourse or simply presenting material), and whether the students' ideas are taken into account as the lessons proceed. In developing this aspect of analysis, we have identified four fundamental classes of communicative approach, which are defined by characterizing the talk between teacher and students along each of two dimensions, *dialogic–authoritative* and *interactive–noninteractive*.

The Dialogic—Authoritative Dimension

The distinction between authoritative and dialogic functions has been discussed by Wertsch (1991), and was used by Mortimer (1998) in analyzing discourse from a Brazilian classroom. It is based on the notions of authoritative and internally persuasive discourse, as outlined by Bakhtin (1981), and on the functional dualism of texts introduced by Lotman (1988) (quoted by Wertsch, 1991, pp. 73–74).

According to Vice (1997), Bakhtin uses "dialogism" in two different senses. In a broader sense, dialogism is a universal property of language where *any* discourse is dialogic because every word or utterance responds to previous utterances and anticipates the responses of others. "Utterances are not indifferent to one another, and are not self-sufficient; they are aware of and mutually reflect one another" (Bakhtin, 1986, p. 91). In addition, any true understanding, or meaning making, is dialogic in nature because we lay down a set of our own answering words for each word of the utterance we are in process of understanding (Voloshinov, 1929/1973, p. 102).

The other sense of dialogism in Bakhtin's work is a more restricted concept, related to the historical and cultural environments in which language is shaped. In this case, the author makes a distinction between *authoritative* and *internally persuasive discourse* (Bakhtin,

1981) and it is this distinction which we draw upon in defining the concept of communicative approach.

We certainly agree that when a teacher makes an authoritative presentation, then the meaning making process must be *dialogic* in nature as the students try to make sense of what is being said by laying down a set of their "own answering words" to the words of the teacher. At the same time, and according to our own definition, we are clear that in authoritative discourse the teacher's *purpose* is to focus the students' full attention on just *one* meaning. It is in this sense that we have chosen to use the word "authoritative" (whilst acknowledging the underlying dialogic nature of the interaction). Additionally, we have chosen the word "dialogic" to contrast with an authoritative communicative approach, in order that we can draw upon the dialogic meaning of recognizing others' points of view. Thus, according to our definition, we are clear that in dialogic discourse the teacher recognizes and attempts to take into account a range of students', and others', ideas.

Following on from these perspectives, we define dialogic discourse as being that which is open to different points of view. At different points in a sequence of science lessons, dialogic talk inevitably takes on a different character. Thus at the start of a lesson sequence, the science teacher might elicit students' everyday views about a particular phenomenon. Later on in the sequence, the teacher might encourage students to discuss how to apply a newly learned scientific idea in a novel context.

In the first situation the dialogic discourse involves collecting students' everyday views. A fundamentally important point here is that this kind of dialogic interaction can be played out with different levels of *interanimation* of ideas (Bakhtin, 1981). At one extreme the teacher might simply ask for the students' points of view and list them on the board. Here the discourse is open to different points of view, but there is no attempt to work on those views through comparing and contrasting. The teacher's approach involves a low level of interanimation of ideas. On the other hand, the teacher might adopt an approach which involves trying to establish how the ideas relate to one another (*John thinks that this might be the case, but Susan seems to be suggesting something different. Nancy what do you think?*). Both of these approaches are dialogic in the sense of allowing the space for different ideas to be represented, but the second approach clearly involves a higher level of interanimation of ideas. It might be the case that the teacher simply collects ideas at the start of a teaching sequence (low interanimation) and then, later in the sequence, compares and contrasts these ideas with the school science point of view (high interanimation).

In the second situation, the dialogic discourse might involve the students in working together to apply a new (to them) scientific idea to construct an explanation for a novel problem. Here we might imagine the students agreeing on some points and disagreeing on others, but working together to understand any points of difference (*Oh! I see what you mean!*) as they develop their explanation. The agreeing and disagreeing on points of view constitutes an ongoing, dialogic interanimation of ideas.

In *general* terms we can say that dialogic discourse is open to different perspectives. There is always the attempt to acknowledge the views of others, and through dialogic discourse the teacher attends to the students' points of view as well as to the school science view. Within dialogic discourse, there is the possibility of different levels of interanimation of ideas, as in Table 2.

By way of contrast, *authoritative* discourse does not allow the bringing together and exploration of ideas. Here the teacher focuses attention on the school science point of view. If ideas or questions, which do not contribute to the development of the school science story, are raised by students, they are likely to be reshaped or ignored by the teacher. Alternatively, if a student idea is perceived by the teacher as being helpful to the development of the scientific story, it is likely to be seized upon and used. In these ways, authoritative discourse

TABLE 2
Dialogic Discourse and Interanimation of Ideas

DIALOGIC discourse	LOW level of interanimation of ideas	Different ideas are made available on the social plane. For example: teacher lists student ideas on the board.
	HIGH level of interanimation of ideas	Different ideas are explored and worked on by comparing, contrasting, developing.

is *closed* to the points of view of others, with its direction having been set in advance by the teacher. More than one voice may be heard, through the contributions of different students, but there is no exploration of different perspectives, and no explicit interanimation of ideas, since the student contributions are not taken into account by the teacher unless they are consistent with the developing school science account.

The Interactive—Noninteractive Dimension

An important feature of the distinction between dialogic and authoritative approaches is that a sequence of talk can be dialogic or authoritative in nature, independent of whether it is uttered individually or between people. What makes talk functionally dialogic is the fact that different ideas are acknowledged, rather than whether it is produced by a group of people or by a solitary individual. This point leads us to the second dimension to consider in thinking about the communicative approach: that the talk can be *interactive* in the sense of allowing for the participation of more than one person, or *noninteractive* in the sense of excluding the participation of other people.

Four Classes of Communicative Approach

Combining the two dimensions, any episode of classroom talk can be identified as being either *interactive* or *noninteractive* on the one hand, and *dialogic* or *authoritative* on the other. We can represent this combining of the two dimensions in Table 3.

The four classes, as they appear in the classroom, can be exemplified as follows:

a. *Interactive/dialogic*: Teacher and students consider a range of ideas. If the level of interanimation is high, they pose genuine questions as they explore and work on different points of view. If the level of interanimation is low, the different ideas are simply made available.
b. *Noninteractive/dialogic*: Teacher revisits and summarizes different points of view, either simply listing them (low interanimation) or exploring similarities and differences (high interanimation).

TABLE 3
Four Classes of Communicative Approach

	Interactive	Noninteractive
Dialogic	*A. Interactive/Dialogic*	*B. Noninteractive/Dialogic*
Authoritative	*C. Interactive/Authoritative*	*D. Noninteractive/Authoritative*

c. *Interactive/authoritative*: Teacher focuses on one specific point of view and leads students through a question and answer routine with the aim of establishing and consolidating that point of view.
d. *Noninteractive/authoritative*: Teacher presents a specific point of view.

Although these aspects were developed in relation to the teacher's role and actions, they can also be used to characterize student–student interactions in the classroom. We shall return to this point in the final section of the paper.

PATTERNS OF INTERACTION

This second aspect of analysis which we shall consider relates to the structure of the interactions between teacher and students in the classroom. The most distinctive pattern of interaction reported in the literature is the three-part exchange structure which Lemke (1990) refers to as triadic dialogue. This pattern was first described as IRF (Sinclair & Coulthard, 1975) or as IRE (Mehan, 1979). For both authors, *I* stands for "*I*nitiation" (normally through a question from the teacher) and *R* stands for "*R*esponse" (normally from the student). In relation to the third move, Sinclair and Coulthard (1975) refer to "*F*ollow-up," while Mehan (1979) and others refer to "*E*valuation." Wells (1999) stresses the point that the third move from the teacher can serve different functions. In some contexts, it has a dominant evaluative function, in others "the third move functions much more as an opportunity to extend the student's answer, to draw out its significance, or to make connections with other parts of the students' total experience during the unit" (Wells, 1999, p. 200). An important contribution of Wells is to show that triadic dialogue is neither intrinsically good nor bad. "Its merits—or demerits—depend upon the purpose it is used to serve on particular occasions and upon the larger goals by which those purposes are informed" (p. 169).

In the following paragraphs, we take an approach similar to that of Wells, by distinguishing between *triadic* IRE patterns and *chains* of interaction which are generated when the third move of the interaction is made to prompt elaboration of the student's point of view.

The *I-R-E* Pattern

As outlined above, this pattern of interaction is played out in "patterns of three" with utterances from teacher–student–teacher and is referred to here as a *triadic* "*I-R-E*" interaction (Mehan, 1979). This pattern of initiation–response–evaluation is distinctive and very common in high school classrooms. As we shall see, most *authoritative* interactions are played out through an I-R-E pattern.

The *Open* and *Closed Chain* Patterns

An alternative form of interaction occurs when, instead of making an evaluation of a student's response, the teacher feeds-back the response to the student, in order to *prompt* further elaboration of their point of view (*that's interesting, tell me a little more*...) and thereby to sustain the interaction. In this way the student is supported in elaborating and making explicit their ideas.

This alternative pattern of interaction normally generates interaction chains which take an *I-R-P-R-P-R-* form (where *P* stands for *P*rompt). Here the prompt move by the teacher is followed by a further response from the student [R] and so on. Some chains of interaction are *closed* by a final *evaluation* from the teacher (*I-R-P-R-P-R-E*), whilst others remain *open* without any final evaluation (*I-R-P-R-P-R-*). As we shall see, some teacher prompts involve only single words taken from the student's response, whilst others involve further elaboration by the teacher.

There are other ways in which nontriadic patterns might appear in the classroom. For example, students (rather than the teacher) can initiate a sequence by posing a question. Alternatively, different students can answer the same question from the teacher, generating an $I\text{-}Rs_1\text{-}Rs_2\text{-}Rs_3-$ form, where Rs_n indicates a response from a particular student. In this latter pattern, the response from student 3 (for example) might not necessarily address the initial question posed by the teacher; it might be a comment on a previous student's response. In such cases, the pattern of interactions can become relatively complex.

TEACHING PURPOSES

The third aspect of analysis which we shall consider relates to the teaching purposes. It is clear that as a sequence of teaching progresses, different purposes are addressed by the teacher with each purpose relating to a particular phase of a lesson within an overall lesson sequence. The teaching purposes which we have identified (Mortimer & Scott, 2003) are as follows:

1. Opening up the problem;
2. Exploring and probing students' views;
3. Introducing and developing the scientific story;
4. Guiding students to work with scientific ideas and supporting internalization;
5. Guiding students to apply, and expand on the use of, the scientific view and handing-over responsibility for its use;
6. Maintaining the development of the scientific story.

This list of purposes was developed both from our observations of science lessons in which there were significant and substantive interactions between teacher and students, and from the basic tenets of the Vygotskyan perspective on teaching and learning (see Mortimer & Scott, 2003).

ANALYSIS OF TEACHING EPISODES

As outlined earlier, the aim of the analysis presented in this paper is to explore how shifts between authoritative and dialogic approaches might evolve as a teaching sequence proceeds. In the following sections, we therefore present four teaching and learning episodes taken from a teaching sequence in a Brazilian school with students aged 14–15 years, along with an analysis of each in terms of communicative approach, patterns of interaction, and teaching purposes.

These episodes were part of a sequence of lessons to introduce some basic concepts of thermal physics. The teaching sequence content was organized around the topic of the thermal regulation of living beings. It included the study of heat, temperature, thermal equilibrium, and the balance of energy in organisms. The students in the target class had been introduced previously to the kinetic particle model of matter through an approach based on the interpretation of phenomena such as gaseous diffusion and changes in the physical states of matter.

The lessons involved a combination of work carried out in small groups followed by whole-class discussions led by the teacher. In the small group work the students performed experiments and discussed their observations and findings. The teacher introduced each experiment with a preliminary presentation whose purpose was to contextualize the problem and to locate it within the developing teaching and learning story. In the subsequent whole-class discussion, the teacher and students talked through the ideas and explanations that the students had proposed.

In presenting the episodes, we decided to refine the original transcripts by leaving out the technical marks and adding punctuation for the pauses and interrogative intonations. We have also left out some turns of speech which were not relevant to the theme under discussion, since they referred to issues of classroom organization and maintenance of discipline. The most delicate step in the "reconstruction" of classroom interactions was the translation of the Brazilian transcripts from Portuguese to English.

Episode 1—You Must Justify Your Ideas

This episode took place during the *first* lesson of the teaching sequence. An initial activity involved students immersing one hand in cold water and the other in warm water before plunging them both into a tank of water at room temperature. The purpose of the activity was to show the limitations of the senses in monitoring temperature. During the group work the teacher noticed that students were talking about what was happening in various different ways. In the subsequent whole-class discussion the teacher encouraged the students to explain what they meant by "heat" and "temperature" in the context of this activity.

1. Teacher: So, how do you explain it? What happens when we feel hot and cold?
2. Student 2: Maybe the temperature of the water passes to your hand when you put it in the water.
3. Teacher: What passes to your hand?
4. Student 2: The temperature.
5. Teacher: The temperature? Do you agree with that?
6. Student 5: There was a heat change.
7. Teacher: Heat change. What's that? Can you explain please?
8. Student 3: There was a kind of diffusion. The temperature of the water passes to your hand and from your hand to the water.
9. Student 6: One swops heat with the other Miss.
10. Student?: I think that it's a change of temperature.
11. Student 6: The heat warms the cold water until a point at which the temperature will transfer neither cold nor hot.

Here, Student 2 (turn 2) uses the idea of *temperature* in a way which is closer to the school science concept of *heat*. Students 5 and 6, on the other hand, refer to a "heat change." In turn 11, Student 6 refers to some kind of equilibrium being achieved and in his explanation temperature is something which is able to transfer either hot or cold (probably both). In this way, a range of ideas are presented for consideration. The teacher does not evaluate, or correct, these ideas but simply asks for further clarification and prompts others to position themselves in the debate.

12. Teacher: I don't understand what you're saying. I want to know what changes between the water and hand. . . temperature or heat?
13. Students: Temperature.
14. Student ?: It's heat, a heat change.
15. Teacher: Well, you must justify your ideas.
16. Student ?: It's because the temperature is made by heat.
17. Teacher: Hmm. . . .

Some confusion now arises in the class as one of the students, Student 4, provides a long description of the activity and other students conclude that the hand absorbs heat from the water. To keep the transcription as simple as possible, we decided not to present this part of the talk, which consists of 11 turns. The teacher, after Student 4's intervention, asks whether anybody thinks differently.

29. Student 1: I think there is a heat change because our body is always around the same constant temperature.
30. Teacher: Hmm. . . .
31. Student 1: So, if you put your hand in a bowl of warm water your temperature remains more or less the same, it doesn't change. There is a change of heat. Heat relates to what you feel, so there is a heat change and not a change of temperature.
32. Student 7: That's it. And heat can be cold or hot. It can be a cold or hot heat.
33. Teacher: Do you agree with that? Movement of cold heat and hot heat?
34. Student ?: No.
35. Student ?: Temperature is only a measure.
36. Teacher: But she is saying that. Please Student 7, explain again, because when you were saying hot and cold heat I saw someone looking surprised.
37. Student 7: I think that heat, when we talk about heat it does not mean just a hot heat, it can be cold, cold heat. For instance, in cold water we have cold heat and we felt it cold.

Communicative Approach and Teaching Purpose. Throughout this episode, the teacher adopts a neutral stance in not offering evaluative comments. She prompts the students to present their ideas and asks for elaboration and justification of points of view. She also helps the students to recognize the existence of different possible interpretations of the phenomenon. For example, in turn 36 the teacher gives special attention to Student 7's explanation which is based on the existence of two kinds of heat. Although Student 7's explanation is not fully explored at this point in the sequence, the teacher returns to it later (as we shall see in the next episode). In this way an interactive/dialogic communicative approach is developed by the teacher and the "two kinds of heat" idea, is foregrounded as a theme to be returned to.

With regard to teaching purpose, the interactive–dialogic approach is consistent with the purpose of *exploring and probing students' views* of heat and temperature, prior to any teaching on this topic.

Pattern of Interaction. The teacher starts with a question: "How do you explain this? What happens when we feel hot and cold?" [Initiation] Student 2's reply "Maybe the temperature of water passes to the hand when we put in the water" [Response] is followed by a request for elaboration by the teacher, "What passes to your hand?" [Prompt]. Student 2 restates her idea, and the teacher foregrounds the answer by repeating it, "The temperature?" and opens up debate by asking the whole class "Do you agree with that?"

Up to this point, it is not possible to decide whether by repeating the answer ("The temperature?"), in this way, the teacher is evaluating it negatively or whether he is just making a prompt move to elicit other interpretations. Looking ahead through the episode, we see the teacher making similar responses to all of the ideas proposed by the students, and each response has the same kind of neutral intonation. We can therefore conclude that the function of his questioning was to *prompt* students' elaboration and justification of their ideas rather than to evaluate those ideas. Since the students do not modify their answers when the teacher responds with these questions, we can assume that they have also interpreted the teacher's questioning as a prompt rather than an evaluation.

In fact the teacher makes successive prompt moves, with requests for elaboration (turns 7, 12, 15, 33 and 36), and without (turns 17 and 30), to encourage the students to engage in the debate. In some of these interventions the teacher simply "bounces-back" the student's words: "Heat change. What's that? Can you explain please?" (turn 7). In this way he encourages the student to continue and thereby acts to sustain the interaction. At other points, the teacher stresses the existence of different accounts for the same phenomenon and the consequent need to justify personal ideas: "Please Student 7, explain again, because when you were saying hot and cold heat I saw someone looking surprised" (turn 36). At the beginning of this episode, the contributions from the students are relatively short and strongly connected to the teacher's feedback, but then become longer after turn 14. This change provides evidence of the increasing engagement of the students in the construction of the arguments as the lesson proceeds. We also observe the I-Rs_1-Rs_2-Rs_3- pattern, referred to earlier, in this episode. For example, in turn 7, the teacher's question, "Heat change. What's that? Can you explain please," generates four answers from different students.

In this way the teacher uses *open chains of interaction* (generally with no evaluative feedback) to support an *interactive–dialogic* communicative approach, with a clear purpose of *exploring and probing students' views*. By adopting an interactive–dialogic communicative approach, the teacher sets an appropriate climate for "productive disciplinary engagement" (Engle & Conant, 2002), which becomes apparent as a significant proportion of the class become involved in making substantive (and passionate!) contributions to the discussion (thereby addressing the teaching purpose of *opening up the problem*). Such is the level of involvement that the teacher is eventually forced to intervene and to call the discussion to a close.

Of course in opening up the discourse in this kind of way the teacher is left with the challenge of what to do next; how to move toward the orthodoxy of the scientific point of view. In this way a *tension* is created for the teacher. This tension exists between developing the dialogic approach of encouraging students to make their views explicit on the one hand, and focusing more authoritatively on the accepted scientific point of view, on the other. We shall see how the teacher begins to address this tension in the next episode.

Episode 2: Examining Ideas of Cold and Hot Heat

This episode took place during the next lesson of the teaching sequence. In this lesson the teacher had organized a small-group activity to address explicitly the idea, from the first lesson, that there are two kinds of heat. The activity entitled "Can cold be hot?" involved preparing a system (ice chips with salt) which is colder than melting ice and observing what happens to the reading of a thermometer when it is moved from a beaker containing ice and salt to one with melting ice. The reading of the thermometer actually goes up as it is placed in the melting ice. The episode starts (on completion of the activity) with a whole-class review of the question that had arisen in the previous discussions:

1. Teacher: Now let's return to our question. Last week some groups were talking about there being two kinds of heat. . . hot and cold heat. In fact, this is not a new idea. In the history of science it's been around for a long time.

   Also, we often think about heat in terms of our sense of touch and we have distinct senses of hot and of cold. So, we naturally tend to accept that there are two opposite and separate things—hot heat, which warm objects have and cold heat, which cool objects have.

But, we have to examine these ideas to see whether they can help us understand the notion of heat or not. So, there are two things. The first relates to what we call "cold," or "the cold." There is nothing which is absolutely cold is there? For example, melting ice. . . we think it is really cold, but is it compared to ice plus salt? Is it cold?

2. Student?: No.
3. Teacher: No, it's warm. It's a source of heat. If you put both in contact, pure melting ice will pass heat to the ice with salt. What *is* cold? I can say that it is less hot and the opposite is also true, hot is less cold. Cold and hot are relative ideas, aren't they? It's a matter of comparing things. So, does it help to think about two kinds of heat, one associated with hot objects and the other with cold? There is a second point, an important one. . . .

Communicative Approach and Teaching Purpose. Here the teacher returns to the idea, introduced by Student 7 in Episode 1, that it is possible to have two kinds of heat, both hot and cold. The teacher starts by referring to the historical origins of this idea and makes the link to the students' commonsense ideas. She then refers to the findings of the earlier practical activity and challenges the "two kinds of heat view," giving support to the scientific perspective that "cold and hot are relative ideas."

Hence, initially, the teacher adopts a noninteractive/dialogic communicative approach as she reminds the class of the ideas from the first lesson, comparing and contrasting points of view. The teacher's discourse takes the form of a rhetorical presentation (Billig, 1996), as she brings together different sides of an issue to be debated and thereby reminds the students of the "state of play" of the ongoing classroom talk. However, once the teacher acknowledges and positively appraises the "two kinds of heat" point of view (by making a link to historical perspectives and to the physical sensations of hot and cold) she introduces the scientific perspective. In other words, there is a clear movement toward the authoritative pole of the dialogic/authoritative dimension.

Episode 2 thus constitutes *one* turning point in the flow of discourse of this lesson sequence as the teacher brings together everyday and scientific views and makes an authoritative case for the scientific view that there are *not* two kinds of heat. The teacher has developed the case by engaging the students in an activity ("Can cold be hot?") which offers a vivid example of a "cold object" (melting ice) actually being "warm" in relation to another object (ice plus salt), and the noninteractive/authoritative argument that the teacher develops is based on the shared outcomes of this activity. At this point, the teacher is doing all of the talking and it would certainly be wrong to assume that all of the students in the class have taken on the scientific view. Nevertheless, in subsequent small group and whole-class discussions, there are many opportunities for students to articulate their developing ideas about heat, and the two kinds of heat idea is not raised again, by teacher or students.

An important point to recognize is that the sequencing of approaches taken in Episodes 1 and 2 enabled the direct juxtaposition of everyday and scientific views, and we believe that this is of fundamental importance in supporting *meaningful* learning by students. Thus the students have the opportunity to position the authoritative discourse of the disciplinary knowledge in relation to their everyday views and in so-doing we believe that they are better placed to appropriate this discourse and to make it their own. In simple terms, the students are better placed to see how the different ideas fit together. Drawing on the ideas of Engle and Conant (2002), the teaching approach taken here requires that the students are accountable to the views of others and to disciplinary norms and encourages students to take ownership of the scientific point of view, thereby encouraging productive disciplinary engagement.

Episode 3: What's Going on Between the Ice and Thermometer?

This episode took place during the same whole-class review of Episode 2, staged after the small-group activity "Can cold be hot?" During the activity, the teacher had talked with the groups of students, emphasizing amongst other things that a process of "heat transfer' (one way) rather than "heat exchange" (two ways) was taking place. The students had already been introduced to the particulate theory of matter, but not in the context of thermal phenomena. In the whole-class discussion, the teacher starts by asking the different groups to explain why the thermometer reading goes up when it is moved from one beaker to the other.

1. Teacher: What ideas do the different groups have? Is it right to say that the ice water transfers heat to the thermometer and that's the reason for the mercury going up?
2. Student 1: I don't think that the water transfers heat but that the thermometer measured the heat and the result was the temperature.
3. Teacher: Why not?
4. Student 1: The water doesn't transfer heat, not to the thermometer. The thermometer is just there to measure the temperature of the water.
5. Teacher: Who agrees with Student 1? Who has a different explanation?
6. Student 2: I think there is a transfer of heat because when you put the thermometer into the salt water it was at a lower temperature, than when you move it into the beaker with pure ice the temperature rises, so it is taking heat that is provided by the ice.
7. Teacher: And where does this heat come from?
8. Student 2: From the melting ice.
9. Teacher: Student 3, what did you come up with?
10. Student 3: That there is a heat change.
11. Teacher: Why?
12. Student 3: Because the thermometer measures temperatures and so it must have a heat change. The thermometer has to take in heat to get the temperature of the material which is being measured otherwise it would not measure the temperature.
13. Teacher: Student 4, what did you think?
14. Student 4: I think there is a change.
15. Teacher: Why?
16. Student 4: I think that the thermometer is measuring the temperature but besides this the water is giving heat to the thermometer.

Communicative Approach and Teaching Purpose. The purpose of this whole-class review was for the teacher to guide the students to work with scientific ideas and to support internalization as they considered the process of heat transfer from the ice–water mix to the thermometer, after the thermometer was switched between beakers. During the practical activity itself the teacher had been able to carry out a significant amount of instruction with the individual groups and this is reflected in the responses from individual students. Interestingly, the first response from Student 1, "The water doesn't transfer heat, not to the thermometer" is contrary to the school science view. Although the teacher makes no evaluative comment, she ignored this alternative response and asked for a "different explanation" (turn 5), probably expecting that other students would offer the correct response, which is what actually happened.

Consistent with the teaching purpose for this phase of the lesson, the students were not being asked to present their own ideas or beliefs about a phenomenon but to articulate the scientific point of view with support and guidance from the teacher. Furthermore it is clear from the students' responses that they understood what was being asked of them. In this way the episode sees the teacher checking student understandings and the discourse is firmly (and authoritatively) centered on the school science point of view. There is no interanimation of ideas here as the one contrary view (expressed by Student 1) is ignored. This episode is thereby played out through an interactive/authoritative communicative approach as the teacher addresses her purpose of guiding students to work with scientific ideas and supporting internalization, by probing the students' understandings of the taught school science point of view. There is clear evidence that the students are in process of making the authoritative scientific point of view their own, as they offer complete utterances in explaining that there is heat transfer between the melting ice and the thermometer (Student 2 in turn 6, Student 3 in turn 12, and Student 4 in turn 16).

Pattern of Interaction. Short, closed chains of interaction I-R-P-R-(E) are repeated strikingly throughout the episode within turns 1–5, 5–8, 9–12, and 13–16. The interesting point here is that within these chains the final evaluation (E) from the teacher appears to be missing.

Although there was no *direct* evaluation from the teacher throughout the episode, we can infer from a set of contextualization cues visible in the video that evaluation and confirmation of the science point of view *were* taking place. These contextualization cues include kinesic shifts (related to body movement), proxemic shifts (related to the interpersonal distance between speakers), prosodic shifts (changes in voice, intonation and pitch), and register shifts (Green & Wallat, 1979; Gumperz, 1992). It is also evident, from the video, that the students were absolutely clear that the responses from Students 2–4 were being positively evaluated by the teacher.

A further important point which arises here is that the analysis in terms of communicative approach and patterns of interaction is consistent with what we know about the teaching purpose for this episode. The teacher's intention was to check the students' understandings of the school science point of view. The "understated" evaluation responses from the teacher are consistent with the students providing acceptable responses. Indeed, it is inevitable that the evaluative response would have been quite different (pointing out any shortcomings) if the students' answers had not been acceptable. The interactions of this episode are therefore not to be mistaken for an interactive–dialogic communicative approach where the absence of evaluation by the teacher points toward a teaching purpose of exploring the students' own ideas.

A general methodological point which follows from this is that we should examine how all three aspects of the framework (teaching purpose, communicative approach, and patterns of interaction) articulate with one another in analyzing a particular episode.

Episode 4—What's Happening in the Thermometer?

This episode took place in a whole-class format, in the same sequence of talk as Episode 3, and illustrates how authoritative discourse can develop into dialogic discourse whilst still focusing on school science content. The numbering of turns follows on from Episode 3, thus between the end of Episode 3 and the beginning of Episode 4, 21 turns of speech are not presented.

38. Teacher: Now, what happens to the thermometer when its temperature goes up? What's happening in the thermometer? Does some kind of change take place?

39. Student 3: I think so, because the mercury in the thermometer only goes up and down, expands or contracts according to the temperature. It expands when the temperature is higher. It must have a heat change to go up and down.
40. Student 6: I think that the stuff in the thermometer is made of a material that doesn't take much heat to make it change. That's its property and that's why it's used in a thermometer. It's sensitive to whatever's being measured.
41. Teacher: A good thermometer mustn't take too much heat otherwise it would lower the temperature of the object to be measured, OK?
42. Student 6: There is heat transfer, but the mercury doesn't take much. That's why it's used in thermometers, to measure the energy from the particles.
43. Teacher: There is a small amount of energy [transferred to the thermometer/mercury] but if there was no energy, would it be possible for the mercury to expand?
44. Student?: No, I don't think it would.
45. Teacher: And there *was* an expansion of the mercury, wasn't there?
46. Student 8: Any change in heat, due to its sensitivity, changes its temperature. When you get this thermometer and put it in the surroundings, then it's at 25°. When you put it in ice the temperature decreases so fast because the heat from the ice is higher and the mercury is sensitive to it and so it goes lower.
47. Student 6: And I think that the energy of the mercury will be equal to that of the ice that is moving faster and will make the mercury go up or down.
48. Teacher: Let's consider this situation you have mentioned. It was at 25° and then you put it in the ice and then the temperature decreased. And you are saying that the ice, in this situation, has more heat than the thermometer? Is there any heat transfer in this case? What is the direction of this heat change; heat transfer in this case?

Communicative Approach and Teaching Purpose. This episode starts with the teacher asking, "what's happening in the thermometer?" This prompts a response from Student 3 which is framed tentatively "I think so. . . ," and she goes on to explain what happens to the thermometer in a scientifically correct way. Student 6 builds upon this point, taking the talk in a new direction, by independently commenting on the need for the thermometer to be sensitive. The teacher feeds-back Student 6's idea "mustn't take too much heat" and provides some elaboration by stating, "otherwise it would lower the temperature of the object to be measured, OK?" At this point Student 6 specifically refers to the "mercury" inside the thermometer and introduces the idea of particles for the first time. In this way we see the students working on and developing the original theme of "what happens in the thermometer."

In turn 43, the teacher takes back control and checks the students' understandings by posing the question, "if there was no energy, would it be possible for the mercury to expand?" A student responds correctly (turn 44), and the teacher follows up with a further question. At this point, it looks as though the interactions are returning to an authoritative pattern driven by the teacher. Student 8 thinks differently however, and he intervenes by sketching out a "thought experiment" which involves moving a thermometer from the surroundings and putting it into ice. Student 8 also introduces some confusion (as is often the case in classrooms!) by stating that "the heat from the ice is higher." Student 6 takes the ideas further by re-introducing the notion of particles "moving faster" and points to a thermal equilibrium being achieved, "the energy of the mercury will be equal to that of the ice." Finally, the teacher intervenes (turn 48) and invites the students to reconsider the situation which Student 8 has introduced, posing a whole range of questions which probe the key points raised by the students.

So we see an interesting transition from Episode 3 to Episode 4 as the teacher slackens his control and the students (in turns 39, 40, 42, 46, 47) independently offer points of view and there is a genuine interanimation of ideas. Whilst Episode 3 involves an interactive–authoritative communicative approach where the students simply respond to the teacher's questions, Episode 4 sees the development of a dialogic pattern of communication in which the students begin to pose their own questions, problematizing the scientific themes of the teaching sequence for themselves. Here the dialogic communication emerges from a context in which the students were asked to use scientific ideas to explain what happens to the thermometer when its temperature goes up. The students themselves raised a number of relevant points and this created a space for the emergence of dialogic exchanges within the scientific discourse. There is an important difference between the dialogic communicative approaches of Episodes 1 and 4, in that in Episode 1 the students were making their everyday views explicit whilst here the students are trying to use their newly learned scientific ideas to deal with problems posed by themselves.

Furthermore, the movement in Episode 4 is from an authoritative to a dialogic communicative approach, which is in a reverse direction to that of Episode 2. This demonstrates that the tension between dialogic and authoritative discourse can occur in either direction (generating a move from dialogic to authoritative discourse or vice versa).

Pattern of Interaction. The teacher starts with a question, "Does some kind of change take place?" [Initiation] and responses from two students follow, setting-up an (I-Rs_1-Rs_2-) pattern. The teacher (turn 41) elaborates upon Student 6's idea and prompts a further response from Student 6. At this point (turn 43) the teacher poses an instructional question, "if there was no energy, would it be possible for the mercury to expand?" and runs through a form of I-R-E routine. Student 8 does not respond directly to the teacher's question but introduces his "thought experiment" in posing his own problem.

Overall for this episode, the pattern of interaction follows the kind of chains of interactions, with students independently making contributions, which is consistent with an interactive/dialogic communicative approach. Here we see students assuming the role of "knower" (Candela, 1999), as they support their knowledge claims and generate fresh interactions. An interesting point here is that the direction of development of the content of the discourse is not only influenced by the teacher but also by the contributions of the students. In this way, Episode 4 shows evidence of the productive disciplinary engagement (Engle & Conant, 2002) of students. They are able to present substantial arguments not only in answering the teacher's question but also in posing their own questions and their own hypotheses. Turns from the students are longer and much more elaborated than in the initial episodes and here they are made within a scientific discourse.

DISCUSSION

In this section, we first of all return to discuss in more detail the central theme of the paper which is the tension between authoritative and dialogic interactions in the science classroom. We then make links to the existing literature on "productive disciplinary engagement" (Engle & Conant, 2002) in science lessons. Finally, we explore some general methodological implications for the use of the analytical framework and specify criteria to be used in identifying authoritative and dialogic communicative approaches.

The Tension Between Authoritative and Dialogic Interactions in Science Teaching

Shifts in Communicative Approach. The analysis which we have presented in this paper shows a series of shifts in communicative approach from an interactive/dialogic approach in Episode 1, to a noninteractive/dialogic approach in the first half of Episode 2 and to a noninteractive/authoritative approach in the second half of Episode 2. Thus in Episode 1 the teacher provided the opportunity for students to talk through their existing ideas about "what happens when we feel hot and cold." In Episode 2, the teacher first drew attention to the "two kinds of heat" idea before moving on to state authoritatively that cold and hot are relative ideas and that there is only one kind of heat. As the teacher worked with the class to consolidate the scientific idea of heat transfer in Episode 3 the communicative approach was predominantly interactive/authoritative, but in the same sequence of talk we identified a shift to an interactive/dialogic approach (Episode 4), as the teacher followed the lead of the students in discussing the sensitivity of thermometers.

Through this form of analysis we begin to see the ways in which dialogic and authoritative approaches are intimately connected and how a tension thereby exists between the two. Thus, as the teacher, in Episode 1, opens up the interactions relating to hot and cold heat, she simultaneously sows the seeds for the authoritative resolution of this issue. The fact of the matter is that science is an authoritative discourse which offers a structured view of the world and it is not possible to appropriate the tools of scientific reasoning without guidance and assistance. Learning science, as well as training professional scientists, inevitably involves acquiring the tools of "normal science" (Kuhn, 1962), and the canonical ways of reasoning in science (Anderson, Holland, & Palinscar, 1997). For the teacher in this lesson sequence (and any other science teacher), it is not sufficient to engage students in dialogue about their everyday views of phenomena; there is the additional and central responsibility of introducing the science perspective.

A reasonable question to ask at this point might be "why bother with the initial dialogic approaches if the teacher is bound ultimately to introduce the authoritative science view?" The fundamental idea here is that meaningful learning involves making *connections* between ways of thinking and talking, in this case between everyday and scientific views of basic thermal phenomena. The initial dialogic approaches offer the opportunity for students to express their everyday views and then later to see how these views relate to the science perspective. In addition we would argue, based on our experience of teaching and researching in science classrooms, that dialogic engagement is potentially *motivating* of students (as seen in Episode 1), drawing them into the problem at hand, and legitimizing their expression of whatever ways of talking and thinking they possess. In this way, the initial dialogic approaches address the teaching purposes of "opening up the problem" for the students and allowing the teacher to "explore and probe students' views."

Of course, the authoritative presentation of ideas alone cannot ensure meaningful learning. It is important that students have the opportunity both to make explicit their everyday ideas at the start of a teaching sequence (as in Episode 1) *and* to apply and explore newly learned scientific ideas through talk and other action for themselves (as in Episode 4). Within the context of high school science classrooms, where dialogic discourse is universally rare, there is a tendency for it to fade out altogether as the students appropriate the school science point of view (see, e.g., Amaral & Mortimer, 2004). Thus, the paradoxical situation exists where the most fluent exponent of scientific ideas (the teacher) does all of the talking whilst the novices (the students) have little or no opportunity to speak the scientific language for themselves and to make it their own. We would argue strongly that if we expect students to engage in meaningful learning in the science classroom, they should be allowed to play with the "sharply demarcated" (Bakhtin, 1981) authoritative discourse of science in new situations, expanding its possibilities for application, making links to other areas of science, and constructing meanings that are new for them. Students need to engage in the dialogic process of exploring and working on ideas, with a high level of interanimation, within the context of the scientific point of view.

In these ways, we see transitions between dialogic and authoritative interactions as being fundamental to supporting meaningful learning of disciplinary knowledge as different teaching purposes are addressed (Aguiar & Mortimer, 2003). Thus, now the teacher encourages dialogic discourse to probe students' everyday views; later she adopts an authoritative approach to introduce the scientific point of view; then she prompts dialogic discourse as she encourages students to explore and apply the scientific view, and so the shifts in communicative approach continue throughout the sequence of lessons.

The analysis developed here puts special emphasis on the teacher's role in orchestrating the classroom discourse, but we also consider the students' perspectives, as individuals socially engaged in specific cultural settings, with all their inherent diversity and conflict (Caravita & Hallen, 1994). According to Mercer (1995, p. 50): "appreciating the learner's angle on classroom conversations means recognizing that learners have their own interpretations of events and may be following their own agendas." Thus, the communicative approach cannot always be mapped out in advance by the teacher, since the direction of development of lessons must be consequent upon (for the responsive teacher at least) the interests and concerns of the students.

Although we have presented authoritative and dialogic discourses as constituting, in theory, two poles of a dimension, it is important to recognize their intimate dynamic linkage in practice. The *tension* which we refer to in this article develops as dialogic exploration of both everyday and scientific views requires resolution through authoritative guidance by the teacher. Conversely the tension develops as authoritative statements by the teacher demand dialogic exploration by students. So, both dialogicity and authoritativeness contain the seed of their opposite pole in the dimension, and in this way we see the dimension as tensioned and dialectic, rather than as being an exclusive dichotomy. Following these ideas, we see teaching for meaningful learning in terms of a progressive shifting between authoritative and dialogic passages, with each giving rise to the other.

The Challenge for the Teacher. Given the arguments set out above, an important question to reflect upon concerns why the extent of dialogic teaching in high school science classes is so small, and why therefore there is little of the shifting between communicative approaches which we have drawn attention to here.

One fundamental response to this question concerns the teacher's views of what is involved in teaching and learning. Quite simply, if the teacher sees their job as providing a robust and accurate account of the scientific perspective, then there is no logical reason why they should engage in dialogic interactions with their students. Our experience is that such "transmissive" views, relating to a "conduit metaphor" (Reddy, 1979) of language, teaching and learning, are common.

A further point concerns the knowledge bases which need to be drawn upon to engage fluently in dialogic interactions with students. Here, it is not just a question of knowing and understanding some science, but the teacher also needs to have insights into the kinds of everyday ways of talking which students are likely to bring to their lesson and, crucially, know how to respond to those everyday ideas in attempting to move along the students' ways of talking and thinking. Such interventions by teachers have been conceptualized in terms of developing "passing theories" (Davidson, 1986, quoted in Roth, 2005, p.158) or reconstructions of students' views and this inevitably must be a spontaneous and situated process (Roth, 2005, p. 159) carried out right on the edge of the teaching and learning. For example, in Episode 1 of the present case, the teacher was able to recognize the everyday view of two kinds of heat, draw attention to it, and then develop an appropriate activity to challenge this everyday view, making more plausible the scientific account. This kind of teaching activity constitutes a highly skilled performance, indicative of a high level of insight and expertise.

However, this kind of teaching activity does not simply rely on utilization of different knowledge bases. There is also the "know-how" of being able to engage students in dialogic interactions and to see how these differ from authoritative interactions. Our experiences of using the communicative approach framework with teachers, in both preservice and in-service professional development contexts, is that very often they confuse dialogic teaching with interactive/authoritative approaches. Thus the teacher engages students in lots of interaction and turn taking but these are authoritative in nature as the teacher focuses attention on the scientific point of view, ignoring contributions from students which are not consistent with that view. We believe that the link which we outlined earlier between communicative approach and patterns of discourse can be helpful in supporting teachers to adopt a wider range of teaching approaches (both authoritative and dialogic). Our experience has been that teachers, once provided with the theoretical tools, are quick to see the links between an authoritative communicative approach and triadic patterns of discourse and furthermore recognize the possibilities of an alternative dialogic approach based on chains of discourse. The crucial first step is to provide the tools which allow teachers to reflect upon and then modify their classroom practices.

A further point of concern for teachers, which is likely to militate against them using dialogic approaches in the classroom, is the question of *time.* A common, and absolutely understandable point of view, is that the teacher cannot afford to spend lots of time in listening to what their students have to say. We believe that the key to dealing with this issue is to identify those parts of the curriculum where dialogic discourse will be important, simply because there are big conceptual gaps between everyday and scientific points of view. The fact is that some parts of the science curriculum make bigger learning demands (Leach & Scott, 2002) than others, and it is in the areas of big demand where time needs to be spent in comparing and contrasting points of view. We saw an example of this in Episode 2 where the everyday notion of "hot and cold heat" was addressed dialogically by the teacher. There will be other situations where differences between everyday and scientific views are small (teaching the concept of "speed" springs to mind here) and the science appears to be "just common sense" to the students. In such cases, it would literally be a waste of time to commit lengthy initial parts of a teaching sequence to detailed dialogic interaction. The general point here is that teaching decisions to open-up or close-down instruction in a dialogic or authoritative way must relate to the content matter being taught, and in particular to the degree of difference between everyday and scientific views.

Finally, there is the key question of whether shifts in communicative approach give rise to enhanced student learning. If the answer to this question is "no," then there is no reason for teachers to take arguments for a broader range of teaching approaches seriously. At present, there is a limited body of evidence to suggest that shifts in communicative approach can have a positive impact on measured student-learning outcomes in relation to science concepts (see Leach, Ametller, Lewis, & Scott, 2005). A more significant body of evidence is provided by the kinds of transcripts which are presented in this paper and which illustrate the quality of engagement of the students and their ability to talk the scientific discourse in the classroom. This final point takes us back to the studies referred to earlier on relating to the theme of productive disciplinary engagement.

Shifts in Communicative Approach and Productive Disciplinary Engagement. In our analysis of the lesson sequence, we have so far drawn attention to the shifts between communicative approaches and have developed the case that this pedagogy has the potential to support meaningful learning of scientific conceptual knowledge. In this respect we see clear links with the developing literature on "productive disciplinary engagement" (Engle & Conant, 2002).

In the teaching sequence, the lessons were designed to encourage student involvement by engaging them in tasks that were mediated by classroom talk with their peers and the teacher. In this sense, the lessons exhibit a participant structure that was intended to assure "productive disciplinary engagement" of the students, although the four principles advanced by Engle and Conant (2002) were articulated in a particular way that resembles more the Japanese hypothesis–experiment–instruction method (Hatano & Inagaki, 1991, quoted in Engle & Conant, 2002) than the American learning through inquiry projects (e.g., the Fostering Communities of Learners (FCL), Brown & Compione, 1994).

As outlined earlier, Engle and Conant suggest four principles for fostering productive disciplinary engagement: problematizing content, giving students authority, holding students accountable to others and to disciplinary norms, and providing relevant resources. How are these principles manifested in the teaching sequence presented here?

In relation to *problematizing* content, the teacher acted during the dialogic phases to encourage student questions, proposals, and challenges rather than just expecting answers and assimilation of facts and procedures. As outlined earlier, these approaches to problematizing content were evident both at the start (Episode 1) of the sequence in exploring everyday views and later on (Episode 4) in working with and applying the scientific point of view. Right from the start of the lesson sequence, the students were given the *authority* to develop their own hypotheses in the context of working in small groups and to report their ideas back to the whole class. In Episode 4, we have a situation where the students were given the space and time to present relatively elaborated arguments not only in responding to the teacher's questions but also in posing their own questions and developing their own ideas. In this way, the students have a degree of agency linked to the expectation that they should provide hypotheses to explain what they observe in practical activities, arguments to support their views, and that they should pose authentic questions. Throughout the lessons there is the expectation that students should *take account* of the views of others and also provide reasons and evidence for their claims (attending to disciplinary norms), as demonstrated in Episode 1 when the teacher declares: "Well, you must justify your ideas." Finally, for these lessons *relevant resources* include the well-designed activities and texts used to facilitate the emergence of the students' ways of thinking about heat and temperature and their subsequent evolution. Time is another important resource, as the students are invited to engage with and talk through several activities developing explanations for the phenomena they observed.

In these ways, the principles for fostering productive disciplinary engagement are demonstrated in this specific teaching and learning example. In more general terms, we believe that the notion of shifting between communicative approaches provides a useful and complementary way of thinking through and identifying what might be involved in productive disciplinary engagement in science classes.

An Approach to Discourse Analysis: Methodological Issues

In this final section, we examine a number of broader methodological and theoretical issues relating to the use of the framework (Table 1) in analyzing the discourse of science classrooms.

Taking an Overview. In making our analyses we, first of all, try to get a sense of the overall flow of discourse through a sequence of lessons. This approach of taking an overview follows from the Bakhtinian principle that "any utterance is a link in the chain of speech communication" (Bakhtin, 1986, p. 84). In this sense any utterance provides a response to previous utterances and anticipates the responses of others. In other words, if we want to develop an understanding of the way in which the discourse develops through a specific teaching sequence then it is essential to have an overview of how the constituent events fit together moving forwards and backwards in time.

For example, to understand the purpose of a specific teaching activity in a sequence of lessons it is necessary to determine how this particular activity fits with the whole sequence. The same is true for the communicative approach. For instance, the significance of the discussions in Episode 1 ("You must justify your ideas") becomes clear as we analyze the flow of ideas in the following lesson (where the teacher explicitly addresses the key everyday ideas raised in this episode). In a similar way, an appreciation of the ideas proposed by the students in Episode 3 ("What's going on between the ice and the thermometer?") emerges from the analysis of the previous group activity (where the teacher had talked with individual groups to raise the school science point of view). In this way, our analysis of the discourse of science lessons involves an iterative process of moving backwards and forwards through time, trying to make sense of the episodes as a linked chain of interactions.

A further important methodological issue, following from the analyses presented in this paper, concerns the need to consider a whole set of contextualization cues, and not only verbal language, in deciding on the nature of the discursive interactions. In Episode 3, for example, the absence of explicit evaluation renders the I-R-E pattern invisible in the *written* transcripts. It is only through looking closely at the teacher's body movement and her proxemic shifts toward specific students as they answered her questions, that we can conclude that the teacher was evaluating positively their answers. The general message here is that sometimes we must look beyond verbal interactions to identify patterns of discourse, taking the discursive act as a whole and including all contextualization cues. Gee (1999) makes the distinction between analyses of interactions which focus exclusively upon talk (referring to these as "discourse analyses") and those which also take into account other modes of communication (referring to these as "Discourse analyses"). In Episode 3 the importance of considering the "whole act" (the Discourse with the capital D) is clearly apparent.

Units of Analysis. In analyzing classroom data, it is possible to identify several different units or levels of analysis. One "macro" level of analysis is framed by the organization of the school and the way in which it deals with time scales. So, we take video records from *lessons*, which have clear time boundaries. If we move up from this level, these lessons are part of *sequences* that correspond to larger units of the school science curriculum. If we move down, the lessons (at least in the data presented here) are divided into a set of interlinking activities, which is normally planned in advance. These activities themselves are divided into a set of *episodes* which mark out different phases of the lesson. How do we identify episodes? The central idea here is that each episode addresses a specific teaching purpose and, as argued earlier, the teaching purpose is played out with one particular, or a related set of, communicative approaches and underlying patterns of interaction. Thus we identify the boundary between episodes by looking for changes in teaching purpose. For example, in the data presented earlier, there is a change between Episodes 3 and 4, as the teaching purpose and communicative approach/pattern of interaction change.

Our specific research interest focuses on the ways in which meanings are developed in science classrooms within the "micro" context of interactions between people and between people and various objects and events. In this respect, our analyses involve closely examining the individual *utterances* of the teacher and students. Given the point made earlier that any utterance is a link in the chain of speech communication, we cannot classify a single utterance as being dialogic or authoritative. This is a criterion that applies to a number of utterances that constitute an episode of meaning making. In addition, classification of an episode involves examining the broader picture that is being constructed in a sequence of lessons, as different teaching purposes are addressed. This brings us back to the previous point of needing to take an overview of events in mapping the meaning making processes in a sequence of lessons.

Operationalizing the Concepts of Authoritative and Dialogic Discourse. The theoretical concepts of authoritative and dialogic discourse provide a starting point to the analysis of classroom interactions presented in this paper, but it is only through actually applying the concepts and making such analyses that we can begin to understand more fully these ideas in the context of teaching and learning science concepts.

Through applying the framework to the data presented in this paper and to other data sets, we have developed the following comparison (see Table 4) of the key features of authoritative and dialogic discourse, in the context of school science teaching. In presenting the key features of each kind of discourse in this way, we emphasize the importance of bearing in mind (as outlined earlier) that we see the two forms of discourse not in terms of a dichotomy but as a tensioned and dialectic dimension such that one form of discourse gives rise to the other in supporting meaningful learning.

Contexts for Applying the Framework. An important question that emerges in the discussion of any analytical tool concerns the specific contexts in which it can and cannot be applied. In this paper, our focus has been on science concept learning and the evolution in students' reasoning from everyday to scientific views. Furthermore, all four episodes involved teacher-led lessons. This was not by chance. As we stressed earlier, the analytical framework (Mortimer & Scott, 2003) was developed to analyze the speech genre (Bakhtin, 1986) of science classrooms and, in particular, the ways in which the teacher acts to guide meaning making interactions on the social plane of high school science classrooms. The five linked aspects of the framework were created mainly by focusing on the teacher's performance.

Nevertheless, the framework can also be applied to analyze student–student interactions as the students can take on different roles in the classroom, including that of "teacher." As we demonstrated (Mortimer & Scott, 2003) in analyzing a teaching sequence on the particulate theory of matter, "the asymmetry between the teacher's and students' roles, which is reproduced in this interaction between students, seems to be an inherent sociocultural and institutional characteristic of schools that frames the discourse, even when led by students in the absence of a teacher" (p. 86). We have also used the framework to analyze students' questions (Aguiar, Mortimer, & Scott, 2005) and students' engagement in practical activities. Given these studies, we can conclude that the framework can be applied to analyze both teacher-led lessons and student–student interactions, albeit it in lessons in which the participant structure is open enough to allow students to have a real role in the development of the teaching sequence. As might be expected, the framework does not provide many new insights for those classrooms where the teacher talks all of the time and where the students' participation is limited to filling in the gaps left by the teacher in their discourse.

Related to content, our emphasis in the use of the framework continues to be on teaching scientific concepts. Although we recognize the importance of the epistemic dimensions of classroom talk and also of more open participant structure classrooms that emerge in

TABLE 4
Key Features of Authoritative and Dialogic Discourse

	Authoritative Discourse	Dialogic Discourse
Basic definition	• focusing on a single perspective, normally the school science view.	• open to different points of view
Typical features	• direction prescribed in advance	• direction changes as ideas are introduced and explored
	• clear content boundaries	• no content boundaries
	• no interanimation of ideas	• variable (low-high) interanimation of ideas
	• more than one point of view may be represented but only one is focused on	• more than one point of view is represented and considered
Teacher's role	• authority of teacher is clear	• teacher assumes a neutral position, avoiding evaluative comments
	• teacher prescribes direction of discourse	
	• teacher acts as a gatekeeper to points of view	• greater symmetry in teacher–student interactions
Teacher's interventions	• ignores/rejects student ideas	• prompts student contributions
	• reshapes student ideas	• seeks clarification and further elaboration
	• asks instructional questions	• asks genuine questions
	• checks and corrects	• probes student understandings
	• constrains direction of discourse, to avoid dispersion	• compares and contrasts different perspectives
		• encourages initiation of ideas by students
Demands on students	• to follow directions and cues from the teacher	• to present personal points of view
	• to perform the school science language following the teacher's lead	• to listen to others (students and teacher)
	• to accept the school science point of view	• to make sense of others' ideas
		• to build on and apply new ideas through talking with others

inquiry-based learning environments where authentic controversy and opened problem solving take place, we believe that there is still work to be done in developing tools to help us understand more clearly how conceptual understandings develop through language and other modes of communication.

FINAL COMMENTS

In this paper, we have used part of the framework developed in Mortimer and Scott (2003) to explore the notion of a tension between authoritative and dialogic discourse and what might be involved in meaningful learning or productive disciplinary engagement in the science classroom. In reflecting, in more general terms, upon the value of this approach to discourse analysis we are reminded of the criteria which Gee (1999) lists to establish the validity of such analyses. These criteria include the notions of *agreement*, *coverage,* and *linguistic details*.

In relation to "coverage," Gee (1999, p. 95) argues that "the analysis is more valid, the more it can be applied to related sorts of data" and "this includes being able to make sense of what has come before and after the situation being analyzed." We believe that our approach to discourse analysis meets this criterion of coverage in that it has provided valuable insights into all of the science lessons which we, and others (see, e.g., Aguiar & Mortimer, 2003; Amaral & Mortimer, 2004; Tachoua, 2005; Viiri, Saari, & Sormunen, 2003) have applied it to.

In respect to "linguistic details," Gee (1999, p. 95) states that "the analysis is more valid the more it is tightly tied to details of linguistic structure." He further suggests that part of what makes a discourse analysis valid is that "the analyst is able to argue that the communicative functions being uncovered in the analysis are linked to grammatical devices that manifestly can and do serve these functions." We believe that our approach to discourse analysis meets this criterion of validity insofar as we are able to make the link from patterns of interaction to classes of communicative approach and then to teaching purposes.

Finally, according to the concept of "agreement," Gee (1999, p. 95) maintains that the analysis is more valid or convincing, "the more *native speakers* of the social languages in the data and the *members* of the Discourses implicated in the data agree that the analysis reflects how such social languages actually can function in such settings." Once again, we believe that our analysis meets this criterion and have evidence of this through our widespread professional development work (preservice and in-service) with science teachers. In particular, we believe that our analyses are pitched at a level of detail which resonates strongly with the practices and activities of real teachers and students in real classrooms.

In summary, we have made a case for the value of the framework as a research tool for systematically analyzing the interactions of science lessons, drawing attention to fundamental issues such as the tension between authoritative and dialogic approaches. Furthermore we believe that the framework offers a workable set of tools, which can be helpful to teachers in allowing them to reflect upon and to develop their teaching practices in professional development contexts.

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