Discourses on the Seasons

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Abstract

The task in learning science is not just to acquire specific facts, nor even to refine a complex mental model. In addition, one must learn the practices and the discourse of science. We focus here on a particular content domain in a study of the teaching of a unit on seasonal change to fourth-graders in an urban, multiethnic school. We see different ways of talking science, which have implications both for how students learn and for how they are perceived. We examine these discourses in light of a similar examination of the school text these students read and discussed.

There is a significant mismatch between the assumptions built into typical curricula and teaching approaches and those brought to school by students. This mismatch results in inadequate learning for all students, but especially those whose beliefs, values, and discourse differ from the mainstream patterns. The research we describe here is based upon a study of the classroom as a unit in an attempt to better understand the classroom "literacy system" as a whole, i.e., the ways in which the teachers' beliefs and practices interact with those of students' and the consequences for their learning. Through this work, we are beginning to identify patterns of reasoning, and ways of organizing and presenting knowledge which contribute to the problems students encounter in school. We also hope to understand better the assumptions about literacy held by students and the assumptions embodied in school practices.

In the study reported here, we focused on the teaching and learning of a unit on seasonal change in an urban, fourth-grade classroom. Early in the study we realized that the central issue for us was not whether particular students did or did not acquire particular facts, nor even, as many have suggested, how their mental models differed, or developed over time. Instead, we saw children trying to become little scientists by adopting the practices of science as they interpreted them being manifested in their teacher's discourse and actions, and in the discourse and diagrams of their textbook. Thus, we decided to look in detail at the ways students, the teacher, the textbook, scientists, and we ourselves talked when we engaged in scientific discourse. We learned that acquiring scientific discourse requires much more than learning scientific terms or even understanding causal mechanisms.

Classroom Literacy Systems

Our research derives from recent work on the interaction of classroom texts, tasks, and talk in the social construction of literacy (Heath, 1983; Cook-Gumperz, 1986; Cazden, 1988). This work, looking at a range of settings and problems, has led to the development of analytic techniques for integrating ethnographic, textual, and conversational analysis in the assessment of classroom-based learning processes and outcomes.

For example, one three-year study of classroom contexts for writing (Bruce & Michaels, 1988; Watson-Gegeo, Cohen, Strucker, & Craig, 1989), examined the impact of microcomputers used for writing on classroom life, teacher/student and peer/peer interaction, and student writing. That study, conducted in two urban, sixth-grade classrooms, documented the critical role of the teacher--both in integrating word processing technology into the writing program, and in creating the learning environment in which writing instruction and practice occurs (Michaels, 1985, 1986; Michaels, Cazden, & Bruce, 1985; also see Rubin & Bruce, 1986). The study used the analytic construct of the classroom writing system (see also Bruce, Michaels, & Watson-Gegeo, 1985), meaning the day-to-day practice of a curriculum, shaped largely by the teracher, but partly by the students, and partly by outside forces, such as standardized testing, social organization of the school, and the linguistic and cultural backgrounds of the students.

We have since extended the notion of a writing system to that of a classroom literacy system; by which we mean *the activities, norms, rights and obligations for speaking and acting, including uses of technology, which influence and constrain student reading and writing in the classroom.* Studies of classroom literacy systems integrate analyses of three aspects of learning:

(1) Students' and teachers' folk theories and models of phenomena.

(2) Social interaction among teachers and students.

(3) Classroom discourse, including spoken language and the production and interpretation of written texts.

Figure 1 shows an idealized model for this type of research. It represents neither a recipe to be followed rigidly, nor necessary elements to include in the research, but rather, a sketch of the types of data and analyses that might make up a literacy systems study. In a "Context" phase, researchers observe existing classroom interaction in order to develop some understanding of the teachers' and students' learning styles. This work relies heavily upon ethnographic techniques. They also interview students to elicit their folk theories of the phenomena in question. In addition, where appropriate, they interview content area experts about the domain students are studying. In an "As is" phase, researchers look at the teaching and learning of content in a focal "curriculum unit." They analyze student texts and any teacher materials. They observe large and small group classroom discussion, and interview teachers and students about what was learned. In an "Intervention" phase, researchers work with the teacher to design new approaches to teaching. The goal is not simply to develop better methods, but rather to open a new window on literacy development by attempting to foster learning in new ways. In this phase there would again be observations of classroom activities, analyses of texts, problem solving protocols and interviews with teachers and students.

"Context Phase"

Observations of class discussions and activities (field notes; audio- and video tapes)

Interviews with students (audio-taped) to elicit folk theories within a given domain

Interviews with content experts

Text analyses

student textbooks

teacher's guide

"As is Phase"

Observations of class discussions and activities around a focal curriculum "unit"

Text analyses

textbook unit

teacher-prepared materials

student products: texts, charts, posters, computer output, etc.

Interviews:

students-on what was learned and experienced in the unit

teacher-critiquing student work, curriculum materials and practices

"Intervention Phase"

Production of new materials and design of new activities

Text analyses

new materials

student products

Interviews

students

teachers

designers of new activities and materials

Figure 1. A literacy systems analysis of classroom learning

The work is thus based on ethnographic data, writing samples, and interviews with students and teachers in multiethnic, urban classrooms. It has three distinguishing characteristics. First, it integrates analyses of phenomena that have traditionally been separated in research. In particular, it examines the interactions among cognitive development, social interactions, and the texts students encounter and produce. Second, it studies processes over extended time periods. It seeks to understand the possibilities for change, not just to characterize static relationships. Third, the research involves teachers and researchers working together to devise new approaches to teaching and learning.

The Literacy System in a Fourth-Grade Classroom

The data for this particular study were gathered from long-term participant observation, audio- and video-recording in a fairly typical urban, multiethnic fourth-grade classroom. These observations were supplemented by analyses of textbooks, student writing, interviews with students and the teacher, and analyses of problem-solving protocols.

Using the literacy systems approach, looking at a wide range of tasks, lesson formats, and subject areas, we found that classroom reading, writing, and problem solving were constrained by several key assumptions students held. Among these were the following:

(1) It doesn't have to make sense;
(2) "It doesn't have to be perfect--we're only in fourth grade";
(2a) A finished product is finished, even if it's not perfect;
(2b) Getting it done is more important than getting it done right;
(3) The teacher (or, by extension, the textbook) is always right.

Collaborating with the teacher, we studied how these assumptions affected students' reading of school texts, their participation in classroom activities, and ultimately what they learned. We also worked closely with the teacher to develop school activities that would challenge these assumptions and promote more effective learning.

One focus of the work was on the teaching and learning of a unit on seasonal change (commonly taught in fourth grade in science or social studies). With Paul Horwitz, we carried out an interpretive analysis of the textbook chapter on seasons and comparable texts used throughout the elementary and scondary school curriculum. We found that numerous relevant terms were taught ("axis," "equator," "direct and indirect rays"), but that the actual scientific explanation was so reduced and misleading that it was impossible to learn from the text alone. Horwitz (1988) contains a detailed analysis of a similar text and an alternative to the standard textbook approach.

In addition, we collected data on students' "folk theories" of the seasons, their discourse patterns, their assumptions about the meaning of science, and their ways of interpreting text and school tasks. In this classroom, after reading the text and having a lengthy discussion and demonstration by the teacher, not a single sutdent learned the correct explanation of what causes the seasons to change. Nevertheless, their ways of discussing what they knew revealed interesting patterns in their approach to science and in our own interpretive practices.

Textbook Discourse on the Seasons

Students in this class all read a section from their social studies text, which presents a simple four-page account of the earth's motions and the reasons for seasonal changes. An analysis of how the students talked about seasonal change needs to be done in the context of a critical look at the text they read.

How the Earth Turns and Travels

It is easy to find fault with any book, especially an elementary school textbook. So many constraints must be addressed that the final product is often disjointed, inaccurate, and hard to read, exactly the opposite of what students most need. Thus, our purpose here is not to indict the text at hand, but rather, to look closely at the discourse of the text, and to consider how its ways of talking science may relate to those of the students.

The text begins by making an analogy between the earth and a spaceship:

> The earth is like a huge spaceship in flight. It never stands still as you might suppose. In fact, it moves in two different ways at the same time.

It assumes, quite properly, that the student may have little knowledge of the topic ("It never stands still <u>as you might suppose</u>"), but abandons this assumption later on. Next, the analogized concept abruptly switches to being a top:

> The earth spins around like a top. Every 24 hours, the earth makes one complete turn, That turning, called rotation (ro ta shen), gives us day and night.

Notice that a new term ("rotation") is introduced, in italics, with its pronunciation made explicit. This emphasis on terminology continues throughout, with 12 new terms being introduced in 1060 words. The text tells us that "rotation gives us day and night". But, of course, rotation alone doesn't give us day and night. It is the rotation of the earth coupled with such facts as: the primary source of daylight is the sun, light travels in straight lines, and the sun maintains a fixed position with respect to the earth, that gives us the day/night variation. Unless we presume that the students, who "might suppose" that the earth "stands still", nevertheless possess accurate models of the earth/sun geometry, failure to mention the sun and its role in making day and night leads to an overly elliptic passage. It might even leave the impression that learning the word, *rotation*, is the most important part of the scientific process in the study of this familiar cycle.

Next, the text expands its description of the turning motion. In the process it introduces three new technical terms:

> The earth spins around an imaginary line called an *axis* (ak'ses). The axis goes through the center of the earth, from the *North Pole* to the *South Pole.* Look at the earth on these pages. The map maker has drawn each earth with an axis.

The text fails to explain what it means that the "earth spins around an imaginary line", or to define the North Pole and South Pole. These omissions would not be a problem for a reader who already knew the subject, but for students who are encountering it for the first time, they could lead to confusions. (We discovered in interviews later that many students could not locate the equator or the poles on a globe even after reading the text and discussing it in class.)

In the next paragraph, the text introduces the notion of a tilted axis:

> Notice that the earth's axis is tilted. The earth is always tilted on its axis. It is always tilted the same amount. And it is always tilted in the same direction.

This apparently straightforward description is also problematic. The notion of tilt makes sense only if a reference plane has been established, in this case, the plane of the orbit of the earth's revolution about the sun. But the revolution movement is not introduced until three paragraphs later. Again, a phenomenon is described without the appropriate background being established. Thus, students are forced to accept a perhaps surprising concept (the tilt of the axis) as a proclamation from authority, and one which has no connection to other concepts they are reading about.

Four substantive points are made in the paragraph, each of which depends upon a clear understanding of the geometry of the system. Without such an understanding, the statements are ambiguous at best. For instance, what does "same direction" in "it is always tilted in the same direction" mean? Given what fourth-graders are assumed to know and what the text has presented thus far, it could mean "always towards the sun" or "always displayed in a diagram pointing to the upper right". In fact, it is the latter interpretation that might seem most plausible, since nine pictures of the tilted earth are shown in the first three pages. Unfortunately, the last picture in the section shows an untilted earth, without any explanation for the change.

In the next paragraph, students encounter a shift in speech acts that is unique to textbooks:

> Study the globes at the right. Is the earth rotating from west to east? Or is it rotating from east to west? What is the name of the imaginary line around which the earth spins? Is the earth straight or tilted on this line?

The first sentence directs the student to study the diagrams. Then there are questions. Ordinarily, questions in a text are used rhetorically, to stress a point, or to identify truly unresolved issues. In the school text, the questions serve other functions. Some are designed to get students thinking, such as: "Is the earth rotating from west to east?" Others are designed to have students check their knowledge, such as "What is the name of the imaginary line around which the earth spins?" The answer to this particular question is of course given just two paragraphs earlier. Having such an infelicitous response/question pair must reinforce for the students the belief that the purpose in reading the text is neither to become excited about a new domain of knowledge, nor to stretch their knowledge by solving problems, but rather to accumulate without question a set of vocabulary items. The last question is particularly confusing. What could it mean to be straight on a line versus tilted? Our guess is that we should say the earth is straight on the line, but that the line is tilted (although we're still not certain at this point in the text what that means).

The next paragraph continues this questioning process (In all, 18/93 sentences are questions, 9/93 are imperatives):

> How long does it take the earth to rotate one full turn? Think about the hours when your part of earth is turned toward the sun. What do we call that time?

Interestingly, these questions are not answered in the text, but instead presuppose pre-existing student knowledge. Yet like the question about the axis, they are asked either to activate or verify knowledge, functions typically found only in school texts. One question refers to the time when the earth is turned toward the sun. This is the first mention of the sun in the text. A reasonable inference at this point could be that the ambiguity about the direction of the tilt might be resolvable. Maybe tilting and turning are the same process.

The next paragraph introduces the concept of the earth's annual movement around the sun:

> The earth has another way of moving besides rotation. Each year, it takes a trip around the sun. It speeds along at 66,600 miles (106,560 kilometers) an hour. As it travels, it also keeps on spinning. It also stays tilted on its axis.

Here, we see a curious transition from the informal, qualitative style to a precise. quantitative statement about speed ("66,600 miles (106,560 kilometers) an hour"). The degree of precision is inappropriate in several respects. First, knowing the exact speed is irrelevant to understanding the basic principles of planetary motions. Putting the figures here (in two measuring systems, and to five significant digits) can only suggest the wrong place for students and teachers to put the emphasis in learning. Second, without more discussion, the figures are probably meaningless to most students at this stage of learning. A better approach would have been to say "very fast" or "faster than a rocket". Third, the assertion of a precise figure is simply wrong because it suggests a constancy that doesn't exist. The speed given is at best an <u>average</u> speed (other texts give 66,000 or 67,000 miles per hour), since the velocity changes during the orbit. Even the average rate is in fact decreasing slowly. Thus, stress is placed on a fact that has little meaning for the students, that seemingly comes from nowhere, that is not connected to anything else they are learning, that few scientists could recall, and that, as stated, is not true.

In the next paragraph, we get the term for this annual movement, and our first description of the orbit:

> The tilted ride of Spaceship Earth around the sun is called *revolution* (rev e lu'shon). The earth revolves in a path shaped like a stretched-out circle.

This paragraph tells us the path of the earth is "shaped like a stretched-out circle". An idea made graphic in Figure 2:

[diagram with an elongated oval, emphasizing the stretched-out circle idea]

Figure 2. A diagram from the school text showing "our earth at four different times of the year".

A key explanatory principle in many folk theories about the seasons is the assumption that distance from the sun accounts for temperature change--the earth is closer to the sun in summer and farther from the sun in winter. In fact, distance is irrelevant; it is the tilt of the earth, the earth's revolution about the sun, and the resultant changes in the angle of radiation that causes the seasonal variation. And yet, the intuitive "distance theory", a reasonable inference from everyday phenomenal experiences with heat sources, may be reinforced by the textual reference to the "stretched-out circle" and diagrams such as Figure 2. The diagram represents the earth's orbit as an exaggerated ellipse (when in fact it is close to being a circle), in which a reasonable inference is that variations in temperature are caused by variations in the distance from the earth to the sun. Terms in the text like "direct" and "indirect" rays, which are introduced later in the text may also reinforce the "distance" theory. They are often interpreted as "shorter" and "longer" rays, respectively.

The distorted scale in the figure presents the sun as smaller than the earth (when in fact the sun has 100 times the diameter of the earth). It also shows the earth/sun distance as less than one earth diameter, when in fact it should be 100 times the diameter of the sun. These representations may contribute to the misconception that variations in energy received between the poles and the equator are due to differences in distance to the sun.

An analysis of the remainder of the textbook portions that address questions about the seasons reveals similar textual problems. We should remember that for many of the students, the text may be the only formal presentation of scientific easoning about the saesons that they have encountered.

Purpose of the Text

Curiously, these four pages, part of a section entitled "Introduction to Maps and Globes", are redundant with later sections of the textbook, which also discuss earth-sun relationships and the reasons for seasonal variation. For example, Unit 1: "The World in Which We Live", contains three pages on topics like, "Why we have day and night", "The earth's motion aroung the sun", and "The sun's rays". Unit 2: "Hot, Wet Lands and Cold Lands" discusses seasonal variation under topics like, "The Antarctic Circle".

The introductory unit, whose pages have special numbers of the form "M-1, M-2,..." was apparently added for those teachers who might want a concentrated unit on astronomical relationships, seasons, maps, and climates. In the context of a social studies textbook, such a unit would presumably lay the foundation for discussing cultural differences that were traceable to climactic variation. Thus, Unit 2 tells us about "Hot, Wet Lands and Cold Lands"; Unit 3 tells us about "Dry Lands, High Lands, and Islands".

The four pages these fourth-grade students read thus have an odd status with respect to the textbook as a whole and to what the students are expected to learn. They purport to explain "How the Earth Turns and Travels" and "The Traveling Earth and the Seasons", two complex topics, which would be difficult to explain to educated adults in four short pages (1060 words). There is no acknowledgement in the main text that students might have read the introductory unit. They are told (on p.1 of the main text) that they "will meet" words such as "axis" and "equator". Moreover, "indirect rays" are mysteriously transformed into "slanting" rays without any explanation.

At the same time the text introduces a large set of technical terms: "rotation. "axis", "North Pole". "South Pole", "revolution", "direct rays", "indirect rays", "equator", "Northern Hemisphere", "Tropic of Cancer", "Southern Hemisphere", Tropic of Capricorn", few of which are necessary for explaining seasonal variation or for the later examination of cultural similarities and differences. It is worth noting that the rate of introduction of technical terms is comparable to that found in many dictionaries. Students may well assume that saying scientific terms is the essence of science.

Summary of the Textbook Analysis

Problems such as the ones we see in the first few paragraphs are not unique to the first portion of this text, nor even to school texts on the seasons in general (See Horwitz, 1988, for a more detailed analysis of a similar text.). In fact, throughout the text there are inaccurate statements, irrelevant details, missing connections, ambiguities, and an emphasis on terminology and isolated facts.

We point out these technical problems, not to chastize the textbook writers, but rather to articulate part of the context in which the students were reading and theorizing. In particular, they were given a disjointed text in which explanations are abbreviated to the point that they appear as magical assertions, on-going assessment in the form of check-up questions disrupts the flow, and the emphasis is on correct pronunciation of terms. Although the text is presented to the students as a "science" section within the social studies textbook, its discourse bears only a distant resemblance to standard scientific discourse, and thus may hinder the students' acquisition of scietific discourse. Moreover, the presentation of ideas in the text as isolated facts precludes any meaningful connection between those ideas and students' theories.

It is worth pointing out that we are discussing here the discourse of theorizing, that is, cases in which one articulates a theory of the seasons. We are looking for propositional content of the form "X causes Y by mechanism Z". (Other forms one might find are "X is correlated with Y" or "X and Y influence each other".) These relationships can be encoded in many different ways. One can say "X causes Y", "Y because X", or "because of X,Y" in each case, leaving the mechanism implicit. Alternatively, one could highlight the mechanism (Z) but leave the phenomenon being explained (X and Y) implicit. Or, one could assert observable facts as evidence for the phenomenon and allow both the causal theory and the mechanism to remain implicit. It is thus possible to talk about explanations as being theory-implicit or -explicit and mechanism-implicit or -explicit.

In these terms, the text the students were asked to read is mechanism-implicit and theory-implicit. It states unconnected facts, and when it does assert a relationship, it leaves out the mechanism, thus inviting inaccurate interpretations. Only once is the word "because" used, in the sentence, "But <u>because of</u> the curve [of the earth's surface], not all rays strike the earth as *direct rays*." There are two uses of the "That is why..." construction, and one "that means..." which like "because" can be used in expressing a causal relationship. In general, though, the complex relations involved in forming an adequate model of seasonal change are left implicit. (In the next section we analyze the childrens' discourse using these same constructions.)

Student Discourse on the Seasons

In our attempt to understand more deeply what these fourth-graders had learned about seasonal change from the textbook, we engaged each of them individually in an extended interview probing various aspects of their knowledge related to seasons. This happened several months after they had read the text in class. We sat together outside their classroom, on the floor of a carpeted landing. The conversation was open-ended and relaxed. The kids had known us for months by now as friendly, frequent visitors, Chip and Sarah. However, the framework of the interview was always the same. We began with the intention of asking some version of these questions:

> What makes the days longer in the summer than in the winter?
> What makes it hotter in the summer and colder in the winter?
> If you went south from Cambridge (and then farther and farther), what would happen to the temperature?
> When it's summer in Cambridge, is it summer everywhere in the world?
> What makes night and day happen?
> Where did you learn all this?

Because we were interested in probing to make sure we understood what the students were saying and thinking, we asked frequent follow-up questions ("say more about that", "What makes that happen?") and freely reframed and reworded questions to clarify our intentions and to check on our understanding of their intentions. We talked at length with each student (at least 15 minutes per interview), asking as many as 15 or 20 follow-up questions about a given topic. As a result, each interview is unique; each is a product of the student's and our sensemaking in concert. Because of this uniqueness, each individual interview (and each individual student) is hard to compare, one to the other. However, what the transcribed protocols do provide are extended examples of students' reasoning about seasonal change, prompted and shaped by their interpretations of our questions and our evolving interpretations of their meanings. And in the jointly produced discourse, we can look at the facts that get elicited, juxtaposed, and embedded in explanations, at the students' underlying causal theories in light of our analysis of the school text these students read and discussed, and at the way the students' discourse is organized and accomplished. In short, we get a glimpse of how these students talk science in a particular content domain, and indirectly, what their assumptions are about scientific discourse and what counts as appropriate scientific explanation.

There are thus many angles and many levels from which to look at these interviews. At the level of factual content, the protocols make clear that the students brought with them -- to the interview and to the initial reading of the science text -- different facts about astronomy and geography, and different knowledge of key vocabulary items in this domain. Nicholas, for example, says that it takes 24 hours for the earth to spin around on its axis and a year for it to go around the sun. Felicia, in contrast, says it takes a year for the earth to turn around once on its axis. She defines "equator" saying, "It's an imaginary line. On the top of it's hot and the bottom is cold. Then it gets a little warmer on the bottom and a little colder on top." Tanika, another girl, knows some facts but is missing others. She knows for example that the earth spins around every 24 hours, what the words equator and axis mean but mixes school-based facts with intuitive knowledge. At some point she says, "Well the sun moves the same way as the earth, but it stays around in one spot, so the earth would have to go around the sun, because the sun doesn't move. It just turns around itself, it just stays there and when the sun goes down the moon comes up. The sun is the moon. But when it goes down it comes up as the moon."

But beyond factual knowledge, the transcripts suggest that depending on what exposure the kids have had to scientific information and discussion, at home, from the textbook, from an older brother interested in astrology, or as in some cases, picking up little standard science either at home or at school, they have very different discourse strategies for integrating facts into explanations, deciding what to lexicalize and how to signal a causal explanation of a particular phenomenon, in short, different ways of talking science. In what follows, we give some examples of discourse that differentiates among the kids, exploring the linguistic characteristics of these different ways of engaging in scientific discourse.

Scientific sounding discourse

The first example is taken from our interview with Nicholas. We discover that Nicholas has learned much of what he knows about the seasons from home, from discussions with his mother, books that he read or were read to him at home, and activities at the Museum of Science. When asked what he learned from his social studies text on the seasons, he says, "We didn't really learn very much," admitting that he learned "words" but "always forgets 'em."

At the outset of the interview, we elicit from Nicholas his theory about the fact that the days are longer in the summer than in the winter:

EXAMPLE 1

1 Chip: Uh / what makes it sometimes / what makes the

day be longer in the summer / and shorter in the winter? //

Nicholas: In the summer the sun can stay out longer / because how the
earth is pointed / the sun can stay out longer //

C: What do you mean by pointed? //

N: Like the earth spins / and sometimes we are like real close to
the sun / and sometimes we're far away //

We then ask seven follow-up probes, getting Nicholas to clarify for us his sense of how the earth moves (in order to account for it getting closer and farther away at different times of year). During the dialogue Nicholas constructs and employs a physical model using his hands as the earth and sun. He shows and tells how the earth spins on its axis once every 24 hours as well as revolves around the sun:

EXAMPLE 2

Sarah: What-- what does having / what does being / close to the sun /
have to do with / how lo:ng the day is? //

N: Because like if I'm / wicked like / this close to the sun /
[yeah] the day is going to happen all day //... if I always have
my-- like my face to it [uh huh] / but if I'm like / this far
away from-- the sun it won't / reach me /... oh yeah / you're
right //

S: What do you mean I am right? //

N: B-being far way or close doesn't make a difference / it's the
spinning around part that counts //

S: Say more about that //

N: Like / you know how the earth spins around [uh huh] like this
/ [uh huh] / and goes around the sun [uh huh] it spins around um:/ when it
spins around / it makes the--um night and day / [uh huh]
but when it goes around it makes the differing / temperatures //

S: OK / how--explain how that works //

N: Sorta like when the / when it goes around / sometimes it gets
closer and sometimes it's-- gets further / from the sun? // [uh

19 huh]

Several points are notable about Nicholas' attempts at explanation, illustrating patterns in his discourse that recur throughout the entire transcript.

First of all, note his use of "because" as a connector to explain the cause of a particular phenomenon. In Example 1, line 3, he explains the cause of the sun staying out longer in the summer. In Example 2, line 3, he explains why being close to the sun makes the days long. This causal use of "because" stands in contrast to its use as an evidential connector, or what Schiffrin (1987) calls a "warrant/inference" use. Schiffrin contrasts fact-based causal relations whereby relations of cause and result hold between ideas (as Nicholas uses it), with knowledge-based causal relations which hold when a speaker uses some piece(s) of information as a warrant for an inference (as in "It rained last night because there are puddles on the ground.") Many of the kids use "because" in both ways, as we shall see below, but Nicholas uses "because" as a causal connector 6/6 times. Each time he uses it to explain the underlying cause of a particular phenomenon, invoking as evidence non-experiential knowledge (facts that came from adults or books, such as that the world revolves around the sun).

In addition, his two uses of "because" co-occur with other interesting features in his discourse of explanation. In the first case, Example 1, line 3, he encodes the actual causal mechanism in his because clause, saying "because how the earth is pointed / the sun can stay out longer." In the second case, he creates a model of the earth and the sun, saying "because, like if I am wicked/ like / this close to the sun / the day is going to happen all day / if I always have my like my face to it ". He mentally runs the model, using if/then constructions and halts midway, saying "Oh yeah / you're right." Having run the model of the earth turning on its axis <u>and</u> around the sun, he convinces himself (incorrectly, it turns out) that the length of the day is simply a result of the earth turning around on its axis, not how close it is to the sun, as he originally had asserted.

This second case is an example of a recurring strategy that Nicholas uses to create a model to illustrate and explain the working of a causal mechanism. In half the cases where he uses "because," he spontaneously creates a model, and in all invokes models 15 times during the interview. In building and using a model, he frequently uses the discourse level marker "like" in a non-syntactically constrained way ("If I am like wicked / like / this close"), different from syntactically constrained uses to mean "for example" as in "countries or the otherside like China." "Like" here serves to mark his discourse as an occasion of creating and holding up (metaphorically) a model which can then be run. (We know of no analysis of "like" as a discourse marker of mental or physical model construction. Schiffrin (1987) doesn't even include "like" among the discourse markers she studies). Nicholas uses subordinate conjunctions "when" and "if..." to run the model. He uses "when" 6 times in the interview, not once in a narrative temporal sense, but rather each time in the context of modeling, e.g., "when it [the earth] spins around"; "when it goes around"; "when it's real close"; "when the earth spins".

Nicholas' discourse, punctuated by the causal use of "because" and the discourse marker "like" used to build models to explain the mechanisms underlying seasonal change, tends to be both theory-explicit and mechanism-explicit. His facts are often wrong. (He says there is a 24 hour time difference between the U.S. and Russia.) His underlying causal theory is incorrect. He assumes, as do many educated adults in this society, that distance from the sun is the primary explanatory principle at work. In spite of all this, his discourse sounds scientific.

<u>Personal, narrativizing discourse</u>

An interesting contrast appears in the interview with Cornelius. A street-wise, articulate student who is nevertheless failing in school (and has already been retained twice before), Cornelius is a proficient reader but not at all engaged in typical school tasks. He has, however, learned much about astronomy from his older brother, an eighth grader who has shown him his eighth-grade science books as well as his books on astrology from which he has learned the names and locations of the planets.

We start with Cornelius at the same spot as we were with Nicholas:

EXAMPLE 3

Chip: Are-- are the day and the night the same length/ the same number of hours? //

Cornelius: No/ because in the summer the days are longer and in the winter the days are shorter//

Ch: Okay// Why-why is that?//

Co: Because you have to set your clock one hour back//

Ch: But what/ what makes it happen?// I mean why/ why does it--

Co: 'Cause it's more colder and the sun goes down// earlier than / it stays / than it goes down in the summer//

Ch: Uh huh// So w-- so why-- why does it go down earlier?//

Co: 'Cause they/ --um/ they put the/ they um made the clock go back/ one hour//

Ch: So then -- / does setting the clock make it go down earlier?//
Or is -- or is

Co: No! No / you'd think it's / like one time but it's later than it is//

Ch: Uh huh//

Sarah: Are you talking about daylight savings time sort of?//

Co: Yeah and you have to make the clock go back one hour / [uh huh]

Ch: Is there something about the way / I mean / do-does the sun shine longer in the summer (nod) what's making it shine longer?

Co: Because it's more hotter//

S: Do you think it has to do with the heat / how does that work do you know?//

Ch: Do you know what makes it hotter?// It just happens?//

Co: No / cause the sun / the um the earth turns over to the sun/

In this example, Cornelius uses "because" six times, three times with evidential rather than causal force. In the first case, in lines 3 and 4, he justifies his answer "no" (to the question, "Are the day and night the same length?") with evidence to the contrary (in summer, days are longer, in winter -- shorter). He responds to why questions in lines 6, 8 and 9 as if he had been asked for his evidence that the phenomenon occurs, not for an underlying causal model of the phenomenon. It is as if he interprets the question "why are days longer in the summer?" as if it meant "how does it come about that we know that the days are longer in the summer? Because you have to set your clock one hour back."

It is clear that he is not suggesting that the length of the day is a result of having set the clocks back when Chip asks (line 13) if that makes it happen. He says, "NO," as if to say "of course not," but rather that just makes you think it is later than it is. When probed with questions such as "what makes it happen?" or "What makes it hotter?" as opposed to why questions, he uses "because" with causal, not evidential, meaning. First he states an observable fact, saying "Because it's more hotter." Only when pressed again, "what makes it hotter?" does he articulate the mechanism -- "the earth turns over to the sun." He still leaves the theoretical chain of causality between the earth turning to the sun, increased heat, and length of day implicit.

This is characteristic of Cornelius' explanatory discourse throughout the interview. He uses "because" in an evidential sense 6/16 times, and in 9/16 cases where he uses "because," the facts he embeds in his because clauses are derived from personal experiential knowledge, about setting back the clocks, when the sun goes down, etc. He rarely creates a model to explain his theories and then only when prompted by us to show us what he means by "the earth turns over to the sun." He uses discourse level "like" only twice in the entire transcript, and only once in a what might be called a modeling context. Every occurrence except one of "when" or "then" is a real time marker: "when it's winter"; "when it's summer"; "when you get around South Carolina"; "when it's hot"; indexing elements in an explanatory framework, but not running a mental model.

In addition to Cornelius' recurring strategy of interpreting why questions as requests for evidence for a belief, he also justifies his reasoning using personal, experientially based evidence. For example:

EXAMPLE 4

1 Chip: If you went south from here, south from Massachusetts/ would it get
2 hotter or colder?//

3 Cornelius: Hotter//

4 Ch: And what if you went way far south?//

5 Co: Hotter, no um, colder//

6 Ch: [When--
7 Sarah: [After a while it would start--

8 Ch: When would it start getting colder? //

9 Co: When you get around, like (pause) South Carolina/ I been/ I
10 never been there but I think its cold there// [uh huh] 'Cause I always go to
11 North Carolina// I never been to South// So I don't know//

12 Sarah: So you think it would get warmer if you went South?//

13 Co: No north// North is hot//

14 S: North is hot?//

15 Co: Yeah// N-- [interruption] North Carolina is hot//

16 Ch: So if you uh--

Co: Well / in the summer / I have never been in the winter//

Ch: Uh huh//

S: Uh huh// What about Florida / if you went all the way past North Carolina and past South Carolina down to Florida?//

Co: Florida is hot//

S: Hot?// And what if you went past Florida to South America?//

Co: Thats hot!! //

S: Hot?// Even hotter?//

Co: The equator's around there//

S: Why is it hot at the equator?//

Co: Because the equator is right even with the sun//

Ch: Uh huh and what (..)-- and so what happens there?//

Co: The sun moves right up to the equator//

S: Okay// Now if you go past the equator down towards the / South Pole?//

Co: It'd be / sort of hot / sort of cold / just like here//

S: Uh huh// And then if you went further and further and back to the South Pole?//

Co: It'd be colder//

Ch: So-- say again / in this picture / how long does it take the earth to go around?//

Co: 24 hours//

Ch: Uh huh//

S: And what takes 365 days?//

41 Co: A year//

42 S: A year?//

43 Co: To spring and fall / and all that / takes all the seasons// (...) and
44 we move closer to the sun//

Cornelius articulates many facts, and exactly the same distance theory that Nicholas uses. When he interprets our questions as asking for causal theories he has no trouble producing them, but he tends not to spontaneously articulate mechanisms, or the theoretical relationships among facts, as when he explained the short days in winter by saying, "'Cause it's more colder and the sun goes down earlier than in the summer." The implicit theory is that the earth turns away from the sun in the winter. That makes it cold and that makes the days shorter. His explanatory discourse, then, tends to be theory- and mechanism-implicit, so that if we had not probed repeatedly for mechanisms and relationships between facts, his active theorizing might not have been apparent. But what was easily apparent to us as listeners was the narrative, evidential quality of his discourse, most noticeable when his personal experience actually led him astray as in the South Carolina example. Cornelius, in short, does not sound scientific.

<u>Multiple discourse worlds</u>

Last, let us look at some examples from Tanika. Unlike Cornelius, Tanika is an excellent reader and excellent student. But all her exposure to technical science comes from the textbook and school activities. In the interview, she moves between discourse worlds.

At times, Tanika sounds as if she is reading from the textbook. When asked about the way the earth turns she says, "Well, we know that it has an imaginary line in the middle called the equator and a line through the middle that spins around called an axis. And it spins about every 24 hours, but we can't feel it, I guess it's because of gravity." When discussing the earth's tilt and talking about the angle of the sun's rays, she talks about indirect and direct rays and creates a model using discourse level "like," running her model with "when" and "then." At other times she sounds quite folksy, using teleological reasoning. For example, she says that if you went south, it would keep getting hotter, and hotter, and hotter. When asked if that process continues without limit, she says, "Well it would stop at about 99 or 100. Because if it gets too hot you could die because the pressure of the heat is too hot. And you'll get drained out. You have to have water or you will get drained out and you will be sitting there like a bowl of jello."

Occasionally, her knowledge from the books and her knowledge of the world conflict. She talks about the earth's axis -- which she defines as a pole that helps the earth turn around on it saying "it's imaginary just like the equator line. You can't see them but they're there". Then in answer to a followup question about the tilt, she says, "The axis is tilting, it's tilting this way, and I think it's this way, and the earth turns. No it's this way, I think I saw it in a book this way.

Then it turns around on its axis, but it's tilted. But the earth isn't tilted, because if it was tilted, we would all be sitting like this [tilts her torso over] or something, so it's not really tilted. The earth isn't tilted, but the pole is and you can't see it." Here science and the real world are reconciled -- scientific facts assume the status of real but "imaginary." This is consistent with the textbooks' stress on the imaginary status of the axis, poles and the equator.

Tanika uses "because" frequently, 31 times (compared to Nicholas' 6) in a comparably long interview. She uses it evidentially 42% of the time and is evenly divided between facts from personal experience and facts from her science text.

One last example with Tanika -- at the same place in the interview as we were with Nicholas and Cornelius -- shows well how Tanika's discourse of explanation clashes with our expectations. We miss her theorizing altogether and because we do, our follow-up question is way off the mark and actually prompts a shift from theoretical to teleological reasoning:

EXAMPLE 5

Chip: Are the days and nights always the same length, the same number of hours?

Tanika: The days and nights? Not quite.

C: Why not quite?

T: Because during the summer time, some of the days are longer then nights.

C: What about other times?

T: Other times like now, in the winter time, no because it gets dark earlier than it does in the summer time, because now it gets dark around four and the rest of it is night time so there is more night than day time now.

C: Why does that happen?

T: I guess because it's cold and it's much hotter in the summer time than it is in the winter time and the summer lasts longer.

C: So how does being hot make the days longer?

T: Make the days longer, how does the heat make the days longer? Well, because it freezes sometimes when its real cold so maybe it gets dark because if it's cold and hot because it's much hotter and hotter and it stretches the day because the sun is out a lot more in the summer time than in the winter.

C: Okay. Can you think of reason why the sun would be out more?

T: Because it's summer?

C: Yes.

T: It's summer and some people, we need to have sun for flower and things to grow and plants

We establish with her that the days are longer in the summer than in the winter. When we ask why, Tanika responds (lines 13-14), "I guess because it's cold and it's much hotter in the summer time than it is in the winter time and the summer lasts longer." The underlying theory here is that heat and cold influence the length of the day (contracting and expanding it), and therefore summer lasts longer (meaning, summer days last longer). "Because" is used causally, but the discourse is theory- and mechanism-implicit. We probe further (line 15) to get Tanika to be more explicit. She reponds (lines 16-20), "Make the days longer, how does the heat make the days longer? Well, because it freezes sometimes when it's real cold so maybe it gets dark because if it's cold and hot because it's much hotter and hotter and it stretches the day because the sun is out a lot more in the summer time than in the winter".

If we look closely at the structure of this explanation, it is a perfect expansion of the earlier explanation, with more of the theory and the mechanism made explicit. Figure 3 sketches one structural and functional analysis of this explanation.

BECAUSE (EVIDENTIAL) it freezes sometimes when it's real cold

so maybe it gets dark
BECAUSE (CAUSAL) if it's cold

and hot
BECAUSE (CAUSAL) it's much hotter and hotter

AND (MECHANISM) it stretches the day

BECAUSE (EVIDENTIAL) the sun is out a lot more in the summer time than in the winter.

Figure 3. Analysis of Tanika's explanation.

Embedded between two evidential "because" clauses is Tanika's theory: cold causes short (dark) days; heat stretches the day. Notice that the one place where Tanika does NOT use "because" is when she states the causal mechanism -- precisely where we would expect it to occur. She does not highlight it as salient in the explanation. She ends with an evidential "because" clause, as if to say, it's hot and the heat stretches the day and so the sun is out more in the summer time than in the winter; that's good evidence for my claim.

Here is a thoughtful, internally consistent, albeit wrong, explanation of a very hard to understand phenomenon. And how do we respond -- to this incorrect, but nonetheless plausible theory of why the sun would be out more in the summer? Chip says, "OK, can you think of a reason why the sun would be out more?" (line 21). Somewhat puzzled, Tanika expands the question, "because it's summer?" (line 22) as if to say, "you mean is your question 'can you think of a reason why the sun would be out more in the summer?'" With our assent, she answers, "It's summer and some people, we need to have sun for flowers and things to grow and plants" (lines 24-25).

No doubt confused that she has just been asked for A reason after giving THE reason, she perhaps assumes we must be looking for something radically different here--perhaps the purpose that the sun serves in the world. She ends up sounding magical and totally unscientific. In this case, her theorizing and her explicit statement of a causal mechanism went unheard, simply uninterpreted. Our first impression of Tanika -- both as participants in the interview, and as analysts on an initial reading of the transcripts -- was that she had gained facts and terms from the book but was reasoning in predominantly teleological ways. What is clear now is that Tanika controls multiple voices in talking about scientific phenomena -- the discourse of the textbook, naive observer, and of formal theory building. But because her explanatory discourse is not organized and signalled in the ways we were expecting, we actually elicit from her magical sounding discourse. This confirms our evolving impression of her as spouting facts but not reasoning through them scientifically, (much as the textbook does) as if she lacked any sense of what counts as a scientific theory.

Discussion

It is important and relevant to note that without exception, we found it easier to interview the "scientific" sounding kids. We could follow their reasoning and ask coherent follow-up questions. The exchanges were smooth, with little or no evidence of puzzlement, hesitation, interruption. With other kids, there is evidence of confusion on our part, repeated questions prompting internally inconsistent responses from the kids, marked surprise in our voice at their answers, even mishearing them in telling ways (as when Cornelius tells us he learned what he knows about planets like Pluto and Saturn in a book called, <u>All About Signs</u>, and Chip says animatedly, "Oh <u>All About Science</u>," Cornelius says "yeah, like you know September, that's Libra," and we both say "Oh, Signs, like astrology.") There were also more long pauses, or abrupt shifts to a new line of questioning, when we simply couldn't generate a follow-up question. This is particularly notable in light of the fact that none of the kids understood correctly what causes seasonal change. Moreover, nearly all of the students were working with the incorrect distance theory.

What should we conclude, then, about these different ways of talking science? And how do they relate to ways of doing and learning science?What could a teacher take from this -- assuming the analysis of seasons talk holds up in other domains of science talk as well? And let's assume too that these discourse phenomena do influence how these students tend to be perceived as science learners, by teachers and tests.

First, it is clear that organizing science instruction around this or comparable texts is highly unlikely to serve all or perhaps arguably, any of the students. The texts are full of incorrect, irrelevant, misleading information -- with an emphasis on terms over explanation-- terms such as "direct" and "indirect" rays, which actually end up reinforcing the intuitive distance theory. And the texts do not in any way take into account or build on divergent discourses of explanation. They remove most causal connectors, like "because," and do not encourage mental or physical modeling -- making an impoverished input for the acquisition of new discourse markers and devices for doing scientific explanations.

But while it is easy to criticize the texts, it is also probably true that simply proposing a better text and more talk, more open-ended discussion of evidence and theory, science as colloquium -- is similarly not the solution. As our interviews show, these differences in discourse go unnoticed on the spot, and get interpreted instead as evidence of unscientific thinking, rather than divergent ways of speaking. These dialogues likewise do not serve as good environments for acquisition of discourse markers -- as the dialogue itself is often problematic, confused, or prematurely ended.

But there are some tentative, constructive suggestions which follow from these admittedly very preliminary and limited findings. First, the teacher needs to have an articulated theoretical analysis of the domain -- an analysis characterizing the prerequisite, relevant facts, underlying theory, and commonly held misconceptions -- so as to have a target to check students' understandings. On the basis of informal checking, many teachers who teach the seasons in elementary school do not understand it themselves, though they are able to with only a few minutes of cogent explanation.

Secondly, there needs to be among all the students a shared store of facts, common terms and common evidence, to be explained by the theory. This argues for a hands-on, investigation-based approach to science, in which students collaboratively collect observational data, record it, analyze it, interpret it, recount it, etc., (in this case data on daytime astronomy). Here, the evidential, narrative strengths of kids like Cornelius may serve them to advantage.

Thirdly, there needs to be explicit talk about talk -- metalevel discourse about evidential vs. causal uses of "because," about theory- and mechanism-explicit vs. implicit explanations, about how to use physical and mental modeling in explanations vs. analogizing discourse. There need to be opportunities for students to commit to a particular theory and to reflect as a community of learners on the variety of discourses of explanation, a chance to record, analyze, and critique competing modes of explanation, and to practice them, orally, and in writing. All of this, of course, argues for more time, and hence a reorganization of the science curriculum into far fewer topics and more in-depth observation, theorizing, and talk about theorizing.

Conclusion

Finally, it is important to stand back and think critically, as Lemke (198-) and others have urged, about the status of the discourse of science itself. At the same time that we think about how to promote the acquisition of so-called scientific discourse, so that kids like Cornelius and Tanika are not ultimately shut out of the dialogue with members of the scientific community, it is important for researchers and teachers to take a more reflective and critical stance toward our assumptions about the naturalness and objectivity of scientific discourse. Ruth Hubbard, a professor of Biology at Harvard, recently criticized Alexander Cockburn for having written in one of his Nation columns, "At least in the sciences nature sets the terms." Hubbard, the biologist, responds,

> No doubt, it "sets terms," but not "the terms." The nature that the sciences -- which means, scientists --- tell us about is a nature that scientists invent so as to provide the kinds of explanations of it, and uses of it, that society requires. Societal intentions toward nature are what shape scientific descriptions of it, the descriptions, if you will, are intention-laden. ... Science and the conceptualizations of nature that scientists explain by means of it are no less cultural products and social productions than are economics, political science and philosophy.

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