chapter 1
Two Minutes in One Science Classroom

Learning science means learning to *talk* science. It also means learning to use this specialized conceptual language in reading and writing, in reasoning and problem solving, and in guiding practical action in the laboratory and in daily life. It means learning to communicate in the language of science and act as a member of the community of people who do so. "Talking science" means observing, describing, comparing, classifying, analyzing, discussing, hypothesizing, theorizing, questioning, challenging, arguing, designing experiments, following procedures, judging, evaluating, deciding, concluding, generalizing, reporting, writing, lecturing, and teaching in and through the language of science.

How do we learn to talk science? We learn this language in much the same way we learn any other: by speaking it with those who have already mastered it and by employing it for the many purposes for which it is used. By the end of this book I hope to have shown that the language of science, like the language of each specialized field of human activity, has its own unique semantic patterns, its own specific ways of making meaning. For most people, if these ways are learned at all, they are learned in the dialogue of the science classroom. That is why I want to begin by looking at how we learn to talk science in classroom dialogue. The rules of that dialogue govern the activities through which we do, or do not, learn to talk science.

GETTING STARTED

Let's look first at the beginning of one science lesson:

Teacher: Before we get started . . . Before I erase the board. . .
Students: Sh!
Teacher: Uh . . . Look how fancy I got . . . [looks at board]
Students: Sh!
Teacher: This is a representation of the one S . . . orbital.
S'pozed to be, of course, three dimensional. . . .
What two elements could be represented by such a
diagram? . . . Jennifer?

This opening dialogue was transcribed from a tape recording of a high school chemistry lesson. In an Appendix at the end of this book, I describe the research project in which this class and many others were studied. In addition to the recordings, there are detailed notes about each lesson, made by myself and another observer. They will provide useful background information when we need to interpret dialogue in the context of the larger classroom events of which it is always a part. (You will find the full transcript of this and other episodes in the Appendix. See DRS-27-NOV.)

A lesson is a social activity. It has a pattern of organization, a *structure*. Events of specific kinds tend to follow one another in a more or less definite order. It has a start and a finish. But like all other kinds of social activities, it is *made*. It is a human social construction. People have to *do* something to get it started, to enact one kind of event after another, and to bring it to a close. In Chapter 3 we examine some of the many standard kinds of events that occur in science classroom lessons. This chapter discusses one episode, lasting about two minutes, at the beginning of a lesson. We look at how the teacher and students get this lesson started, what patterns of activity then follow, and how science gets talked as part of classroom activities.

When our dialogue begins, the students are still talking to one another and the classroom is noisy. The "period" may have begun in the technical sense that the bell has rung, but the "lesson" as a social activity has not yet started. The teacher and the students have to do some work to get it started. They have to get one another's attention, focus that attention on the same activity, and begin cooperating to produce the sequence of events that we recognize as a Lesson.

The first thing the teacher says to the class as a whole (line 1) contains the very words "get started," but he doesn't say something more usual like, "O.K. Let's get started now." Some students, nevertheless, do stop talking and start to listen to him. Others do not. The teacher does not finish his first sentence; instead he pauses briefly (represented by . . . in the transcripts) and starts a new sentence. He doesn't complete this sentence either. There are still students who are not paying attention to him. But some of those who are now turn and start to "shush" the others (line 2). The teacher starts again, hesitantly (line 3), making a remark and pointing to a fancy colored chalk diagram of an atom on the blackboard. Some students are still talking, and again others urge them to be quiet (line 4). The teacher now starts to describe the diagram, and as he does so the class become quiet and attentive. A lesson has begun.

What happened that got the lesson started? It was not just the teacher's words, or what the teacher did. It was a joint effort of all the participants. The teacher took the initiative by ending his private conversations with students at the front of the room. They went to their seats. He turned from facing the blackboard to facing the class as a whole and spoke for the first time in "teacher voice," that slightly louder, public tone of voice so different from the voice he used in private conversations a few seconds before. His whole action—turning around, looking at the class, using a particular tone of voice, as well as the words he spoke—constituted a *Bid to Start*. He was doing his part, but the students also had to do theirs. No teacher can start a lesson solely by his or her own efforts. Without the co-operation of the students, the lesson does not get started.

In this case more and more students act to ratify the teacher's Bid to Start. They stop their other conversations, look up from their notebooks, quiet other students and generally "pass the word" that the teacher wants to get started. In doing so, they do their part to start the lesson. It may not matter very much just what the teacher says, if the class is expecting him to start. In some lessons there are even "false starts," when the class quiets down but the teacher turns out not to have been ready to start and does not follow through. Students begin to talk again and there has to be a new Bid to Start by the teacher, which the students must again ratify with their cooperation.

The words the teacher actually does use here do fit the situation. The words "get started" at least mention what is supposed to happen, even if the unfinished sentence doesn't request or demand it. Even the words "erase the board" *allude* to the starting of lessons because erasing the board, like closing the classroom door, is an action that typically occurs at the start of a period, if not at the exact moment when a lesson is to begin. They are "cues" to the class. When the teacher changes strategy (line 3) and directs the class's attention to his fancy diagram, he is working to create a common focus of attention and interest, part of getting started. Calling attention to something on the board is another typical activity at the start of lessons.

By line 5 the teacher is ready to launch into the lesson. He completes a sentence that says something in the language of science for the first time. In fact, at this moment, not *everybody* in the class is paying full attention. The class settles down during the course of the next few lines and is fully attentive by the time Jennifer answers his question. The teacher's final and strongest bid to start the lesson is his simply going ahead with presenting the lesson content *as if* the lesson had begun.

There is no absolute criterion for when a lesson really does begin. In many classes the lesson has begun even though not everybody is fully attentive. In fact in most classes I have observed or taught it is *unusual* to get perfect 100% attention from a whole class, and you don't necessarily get it right at the start (see Chapter 5). In effect the lesson has begun when you can look back and realize that you are now in the midst of a sequence of events that makes sense only if the first event was, retrospectively, the start of a lesson. At the time the event is happening, there is no way to know that it will later turn out to have been the real start and not just a "false start."

All social activities are like this. They are "contingent" while they are happening, and definite only in retrospect. The contingencies of an event are the probabilities that different things will happen next. In real life, you never know for sure what is coming next, but if you can recognize that you are in the midst of a patterned, organized kind of social activity, like a lesson (or a ballgame, or a trial) you know the probabilities for what is likely to come next. All social cooperation is based on participants sharing a common sense of the structure of the activity: of what's happening, what the options are for what comes next, and who is supposed to do what. A lesson has this kind of *activity structure*.

The structure of a lesson as a whole is rather loose and complicated. It has a Start section, which has a structure of its own, consisting of Bids to Start by the teacher and Ratifications by students. It then typically has a series of episodes, some of which—like Taking Attendance, Going Over Homework, Class Announcements, and so on—tend to come first and be followed by events like Start Main Lesson (i.e., the teaching of the main content for the day's work, after all preliminaries), Reviews (of today's work, *after* the Main Lesson; or of yesterday's, *before*), and a Closing. Each of these is an activity in its own right, on a smaller scale than the lesson as a whole, and each has its own activity structure. In Chapter 3 we will survey the activity types of the science classroom.

Human behavior in structured activities is relatively predictable. For comparison with the Start of this lesson, here are some Bid Starts by other teachers in other lessons. One type is rather direct:

Come on people, let's go. We're already late.

All right, c'mon . . . focus!

All right, youth . . . let's get started.

Each of these is by a different teacher. Our teacher began less directly by alluding to typical start-of-lesson actions, like erasing the board. Here are some similar examples from other teachers:

O.K. Now open up [your notebooks] . . .

All right. Would you please find your seats.

O.K. As we can all see, we have three Do Now questions on the board.

Even the apparently strange "*Before* we get started . . ." finds its parallels:

> Two brief reminders and then we're ready to start.
>
> I'd like to ask you a couple questions before we start.

In these cases, as in our episode, the teacher is not only working to get things started, but to let the class know that the first episode is a only a preliminary one and that the main business of the lesson will come afterwards. This is another very general feature of human action: The same words, the same acts often have more than one function. They do several jobs at once. In this case, the teacher's words were part of a Bid to start the lesson, *and* an announcement that this was only a preliminary activity before the main business.

THE UNWRITTEN RULES OF CLASSROOM DIALOGUE

Consider the lesson started. What is the activity structure of the first episode? It is a very common pattern in modern education, well known to teachers and students, a special form of question-and-answer dialogue. Various versions of it have been described by many other research projects (see, for example, the books by Sinclair and Coulthard, 1975, and Mehan, 1979 in References). We can get at the structure of a lot of classroom talk by examining it carefully.

Teacher: This is a representation of the one S . . . orbital.
S'pozed to be, of course, three dimensional. . . .
What two elements could be represented by such a
diagram? . . . Jennifer?
Jennifer: Hydrogen and helium?
Teacher: Hydrogen and helium. Hydrogen would have one electron
. . . somewhere in there, and helium would have . . .?
Student: *Two* electrons.
Teacher: Two. . . . This is . . . one S, and . . . the white would be
. . .? Mark?
Mark: Two S.
Teacher: *Two* S. And the green would be . . .? uhh . . .
Janice: Two P. Two P.
Teacher: Janice.
Janice: Two P.
Teacher: Two P. Yeah, the green would be 2P *x* and 2P *y*.

The teacher's first question comes in lines 7–8, and we can take what Jennifer says next to be an answer to that question, even though she

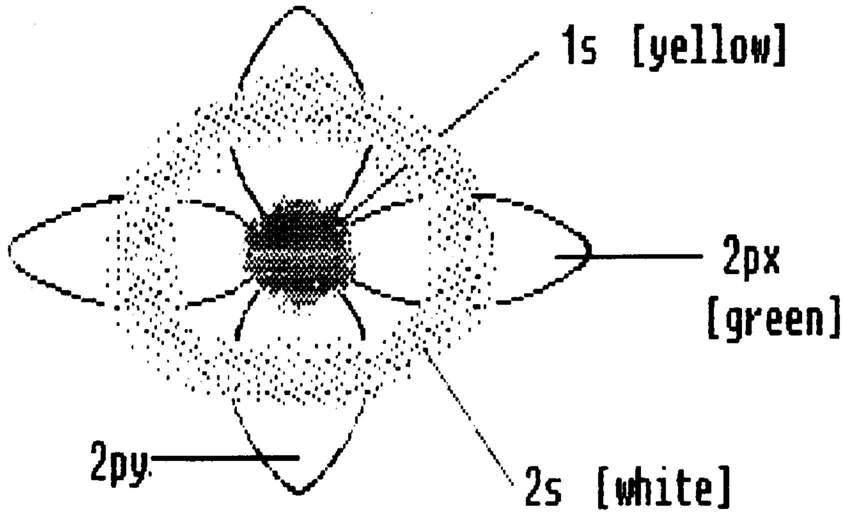

Figure 1.1. Atomic Orbital Diagram

says it with a questioning (rising) intonation. Line 11 seems to pose the next question, and line 12 is its answer. But there is a lot more being said besides the bare questions and answers. They are embedded in a larger, more complex, and more interesting pattern of activity structure.

Before his first question, the teacher describes the diagram he has on the board (see Figure 1.1). He points to the central area of the diagram and identifies it as "the 1s orbital." He points out that the diagram does not show that it really looks like a sphere, that is, three- rather than two-dimensional as it appears on the board. Only then does he ask a question which refers directly to the diagram, and not to the whole of it, but specifically to the part of it he has just described. He has prepared a context for his question first. Without the preparatory statements, the question would have been ambiguous or confusing for the class.

Not every Teacher Question is preceeded by a Teacher Preparation for that question, but many are, and every one *could* be. As with lesson Starts, you can't know for sure that what the teacher is saying at any given moment will turn out later to have been a Preparation for a question. But when the question comes, the odds are good that what immediately preceeded it (if they are linked semantically; see below) was, in retrospect, a Preparation and therefore relevant information for answering the question. Students who fail to connect Preparations and Questions are not in a good position to answer appropriately.

After the question, and before the answer, the teacher pauses and says (line 8), "Jennifer?" The pause marked the teacher's silent Call for

Bids to answer his question. This move in the dialogue structure is not usually verbalized. In many British classrooms, a teacher will say at this point, "Hands up." While it would only get a laugh in most American classrooms, its meaning is obvious enough in this context: Raise your hand if you want to be called on to answer. American teachers who silently wait for hands to go up, and don't see any, may say, "C'mon. Somebody give it a try." In that case it is a Second Call for Bids. But in this case Jennifer did raise her hand, and the teacher calls on her by name. This move is sometimes called the Nomination of the student. The whole Bid and Nomination exchange is optional in the structure, but teachers tend to prefer to have it occur.

We now get (line 9) Jennifer's answer. Or is it a question? That depends mainly on what follows it. In itself it is a little bit of both; it serves more than a single function, as so many actions do. But within the structure is it taken to be a Student Answer or not? Here it is, as we will see. The teacher might have said, "Are you asking me or telling me?" That would have been a question *and* an instruction to Jennifer to commit herself to her answer, not hedging as she did before. It would also retroactively deny her words the status of Answer. Jennifer's questioning answer subtly undermines the structure in an important way, as we will see later, but in this case the teacher simply ignores her intonation and treats what she said as a *bona fide* Answer.

He does so by repeating her answer with a firm declarative (falling) intonation. Other teachers at this point might have said, "O.K." or "Yes." or "Good." The teacher is confirming what she said as the Answer, giving it a positive Evaluation. This is the most characteristic feature of classroom dialogue of this sort.

Ordinarily, in conversation, or in any situation where one asks a question to obtain information, it is ridiculous or impolite to accept or reject the answer. An exchange like: "How old are you?" "35" "That's right" is condescending at best. The difference in the classroom is that the teacher is already supposed to know the Answer. He is not asking for information; he is testing to see if the student knows the information. We will need to ask later *why* it is, if the teacher knows and the students may not know, that teachers rather than students ask most of the questions, and students rather than teachers do the answering. When students do ask teachers questions, the students do not usually evaluate the teachers' answers (at least not out loud). There is, of course, another activity type in which students do ask the questions, but it has a very different organizational pattern, a different activity structure, from the one we are now analyzing (see Chapter 3).

The Teacher Evaluation move is not optional in the structure we are now analyzing. If the teacher does not give a positive Evaluation—for example, if he remains silent—the students will assume that this silence is tantamoumt to a negative Evaluation and will try a different answer. Teachers have to accustom students to a different activity pattern if they want to avoid this. Whatever the teacher does after an Answer is assumed to be an Evaluation, and a negative one if it is not obviously positive. Of course, there are other options teachers have at this point. They can give a neutral Evaluation, or a partially positive one (e.g., "O.K. That's interesting. I'd like to hear some other answers." or "O.K., Lynn. John, do you agree or disagree?")

Following a negative Evaluation, the teacher has a number of options which I will not discuss here. The dialogue tends to continue until a positive Evaluation is reached. After the positive Evaluation, the teacher has another optional move. In lines 10–11, what the teacher says about hydrogen partly serves the function of a Preparation for the next question, but it also functions partly as an Elaboration on the previous answer. In line 20 we have a positive Evaluation followed by an Elaboration on the answer, that has much less connection to the question that follows it. There are many cases where it may have no connection to what follows (e.g., at the end of an episode; see below). The Elaboration move adds more information to the answer.

What we find then, both here and pervasively in classroom dialogue, is not a simple two-part Question-Answer structure. Instead there is at least a three-part Question-Answer-Evaluation pattern, which I will call Triadic Dialogue. A typical round of this dialogue would be:

[Teacher Preparation]
Teacher Question
[Teacher Call for Bids (Silent)]
[Student Bid to Answer (Hand)]
[Teacher Nomination]
Student Answer
Teacher Evaluation
[Teacher Elaboration]

The moves in brackets are optional and often omitted. The essential triad of moves are shown in boldface. The moves come in the order listed, and the list shows the usual expectations about what precedes or follows a particular move. I have left out the other "branch" of this structure: the options following a negative Evaluation. A more formal presentation would look like a flowchart, giving the probabilities for each option following a given event (cf. Martin, 1985a).

If you look back at the episode so far, you will see that everything from line 5 to line 20 fits this pattern. But there is evidently something odd happening in lines 16–20 when Janice answers. Let's look at this in more detail.

SOME STRATEGIES THAT PLAY BY THE RULES

People are not slaves to the activity structures of their community. We do not just "follow the rules"—we use those rules as resources for playing the game according to our own strategies. There are many possible games of chess that conform to the rules, many possible English sentences that are "grammatical," and many possible sequences of classroom moves that fit the overall structures of lesson activity, including the triadic dialogue pattern. The differences between actual sequences of dialogue moves are like the differences between actual games: They are records of different strategies being played out move by move within the rules. Consider what happens in lines 16–20.

The teacher is asking students to identify the parts of his diagram by naming the atomic orbitals they represent. Mark has just identified the part in white chalk as the 2s orbital (lines 13–16). There is no Elaboration, and no additional Preparation for the question which follows, in which the teacher asks about the part done in green chalk (line 16). The new question is an exact parallel to the previous question, and in the pause, Janice answers it (correctly as it turns out) by saying, "Two P." We expect the usual positive Evaluation to come next in the form preferred by this teacher: a firm repeat of her correct answer. But this is not what happens.

The teacher's "uhh . . ." is a sort of verbal hesitation, a voiced pause in which he fills his turn to speak without advancing the action at all. Janice responds to this by repeating her answer quite loudly and clearly. Looking back, we could say that the teacher's "uhh" was taken by Janice as an indication that he hadn't quite heard her answer. But even now we do not get a positive Evaluation. Instead the teacher says, "Janice." In the tone of voice used this can only be taken as a Nomination (not, say, as an admonition, cf. Chapter 3). But according to the pattern of triadic dialogue, a Nomination should *precede*, not follow an Answer. If the teacher's move stands as a Nomination, then Janice's answers are demoted to the status of Bids to answer, and she must now Answer yet again.

There is no doubt that the teacher and all the students must have heard at least Janice's second clear answer. If she repeats it a third time, it would be strictly pro forma to acknowledge the structure the teacher wants to make, not the one she was previously following. In fact she does repeat her answer one more time, but much more quietly than before. And the teacher does not even bother to let her finish saying it before he overlaps her voice with his own, giving the positive Evaluation. (Note that when a line in the transcript does not begin at the left margin, it is to be read as simultaneous with the line above it. Otherwise each line follows in time the end of the line above.) This overlap is quite unusual, and would be impolite in other circumstances. But here it serves to acknowledge that Janice's last answer not only counts at last as the Answer, but that it was only a pro forma repeat.

But why? What is the teacher trying to maintain here, even at the risk of confusing Janice and the class as to what he is doing (and possibly even as to whether the answer really is correct)? He is maintaining the rule that students need to be called on (Nomination) before they can legitimately answer. Janice answered without being called on. This was not unprecedented, because in line 12 another student had answered under the same circumstances and his answer had been accepted. The teacher was not consistent about maintaining the rule that there should be Bids and Nomination before an Answer. In forcing Janice to observe this convention, he is maintaining "discipline." He is also maintaining his power in the class to decide who will answer. And in the context of this relatively easy review question, he is willing to sacrifice the continuity of development of the subject matter to maintain the structure he wants to see in use.

The teacher has used a "ruse," a *strategy* operating within the rules of the triadic dialogue structure, to achieve a certain result. He has made an unusual move, the late Nomination, which retroactively redefines the status of previous moves. Janice did not have to go along, of course. She might have said, after the "Nomination," something like an ingenuous "What?"—in effect declining to acknowledge it as a Nomination. Or she could have said, "I already said it," pushing to have her prior answer recognized as the Answer. In fact, she yields to the teacher, allowing his redefinitions to go unchallenged, and he as much as admits that this is what's happening by overlapping her answer and making it strictly an Answer pro forma. The low, quiet voice in which Janice gives her final Answer is her only protest, her bid to have it be known that the last repeat was just pro forma. So she has used a little strategy, too.

Students are quite good strategic players. In line 9, Jennifer's questioning intonation on her Answer hedges against it's being counted as wrong by the teacher. At the same time it expresses her uncertainty, and subtly turns the tables on the teacher by in effect asking *him* a question. The teacher does not respond in kind but simply sticks to the triadic dialogue pattern. Something different could have happened. Suppose Jennifer had said, "I don't know. Would they be hydrogen and helium?" and the teacher had said, "Yes." Then we would have come closer to shifting to an alternative dialogue pattern, one in which students ask the questions and the teacher answers. Another student might then have asked about the electrons or about what the colored parts of the diagram represented.

It's fairly common to get a series of student questions if the teacher accepts a first one and lets the dialogue pattern shift away from Triadic (see Chapter 3). But teachers don't usually deviate from the Triadic pattern because maintaining it gives the teacher many advantages. In this structure teachers get to initiate exchanges, set the topic, and control the direction in which the topic develops. They get to decide which students will answer which questions and to say which answers are correct. We have seen that they can even decide which answers will count as the legitimate Answer. In contrast, students have little or no opportunity for initiative, for controlling the direction of the discussion, or for contesting teacher prerogatives under Triadic Dialogue.

As we will see in the next chapter, students can get the upper hand by shifting to other dialogue patterns, where they have more latitude for strategic play within the rules. In Triadic Dialogue the deck is stacked against them. The rules heavily favor the power of the teacher, and this is no doubt one of the reasons why it has become such a popular style of teaching. We will return later to some of the troubling educational and value questions raised by the predominance of the triadic pattern in the classroom.

But first we need to look at this episode less from the viewpoint of the organization of its social interaction, its *activity structure*, and consider how the science content of the lesson is embodied in this dialogue.

FINDING THE SCIENCE IN THE DIALOGUE

A lesson is not just give-and-take between teacher and students. In the course of moves in the dialogue game, some science is getting talked about. The organizational pattern of the dialogue merely provides the structure within which teachers and students talk science in the classroom. The structure is important, but it does not tell us how to find the *science* in the dialogue. The lesson could be about atoms or about genes, about the weather or about earthquakes, and it could still have exactly the same activity structure of questions, bids and nominations, answers and evaluations.

Students also need to find the science in the dialogue. If they don't, they may learn how to play the classroom game, but they won't learn how to talk physics or biology. Most crucially, they need to learn how to separate and combine the science content and the dialogue forms in which it is expressed at any given moment. They need to know how to extract the science meaning from a Question-Answer-Evaluation triad and write it in their notes as a statement, or on a test as an answer. They need to be able to take a teacher's Elaboration on a previous answer and restate it as a question after class. To do this they need of course to undertand the relations of one move in an activity structure to another (e.g., how a Preparation helps determine the meaning of the Question, or how an Elaboration can modify the meaning of an Answer). But they need to use that understanding, even if only unconsciously, to piece together the pattern of meanings that we call the science content of the exchange, the episode, or the lesson.

The science in the dialogue is not just a matter of vocabulary. Classroom language is not just a list of technical terms, or even just a recital of definitions. It is the *use* of those terms in relation to one another, across a wide variety of contexts. Students have to learn how to *combine the meanings* of different terms according to the accepted ways of talking science. They have to talk and write and reason in phrases, clauses, sentences, and paragraphs of scientific language.

If you have ever studied a foreign language, you will know that reading definitions in a dictionary is not enough to tell you how to use those words properly in combination with other words. Even apart from correct grammar (endings, tenses, cases, articles, etc.), you need to learn the "semantics" of words: how their meanings fit together in different contexts. Definitions try to give a sense of the meanings of words, but to speak and understand, to write or read, you need to find the meanings of whole phrases and sentences, and not just of words.

When words combine, the meaning of the whole is more than the sum of its separate parts. To get the meaning of the whole, you need to know more than the meaning of each word: you need to know *the relations of meaning* between different words. A student may know the definitions of "electron," "element," and "orbital," but that does not mean he or she could use those words *together* in a sentence correctly, or say how their meanings relate to each other. To do so requires additional knowledge: knowledge of how these words are used in talking science.

The pattern of connections among the meanings of words in a particular field of science I will call their *thematic pattern*. It is a pattern of semantic relationships that describes the thematic content, the science content, of a particular topic area. It is like a network of relationships among the scientific concepts in a field, but described semantically, in terms of how language is used in that field. There is science in the dialogue exactly to the extent that the semantic relationships and the thematic pattern built up by the dialogue reproduce the thematic pattern of language use in some field of science.

The notion of a thematic pattern of semantic relationships is difficult and abstract at first. It will become more concrete and familiar as we use it to analyze classroom dialogues. In this chapter I just want to introduce the idea of the thematic pattern of a science dialogue. In the next chapter we will make more use of it, and in Chapter 4 we will see that it is a powerful tool for analyzing the language of science and science teaching.

Science dialogue, then, has *two* patterns: an organizational pattern, represented by its activity structure, and a thematic pattern. In all dialogue there are at least two different things going on. First, people are interacting with one another, move by move, strategically playing within some particular set of expectations about what can happen next (the activity structure). But they are also constructing complex meanings about a particular topic by combining words and other symbols (the thematic pattern).

Let's find the thematic pattern of the science in the dialogue of this episode.

So far as language goes, the science content begins in line 5. (Nonverbally, the teacher's pointing to the atom diagram, line 3, might also count as introducing science content.) Certainly the terms "1s" and "orbital" are technical terms, and the word "representation" has a semitechnical sense here, but could probably have been left out without changing the meaning much (e.g., "This is the 1s orbital," cf. line 13). The word "this," of course, refers to the center part of the diagram in Figure 1.1, to which he is pointing. Does the sentence tell us anything about the *relation in meaning* between "1s" and "orbital"? Actually, in a very subtle way it does. In the expression "1s orbital," as in so many expressions in science, the "1s" functions as a *classifier*. It tells us *which kind* of orbital is meant in some classification of orbitals. If a student is alert to this kind of semantic relationship, he or she will know that this is one kind of orbital and that there are other kinds. This is like understanding that "a grey squirrel" doesn't have to mean simply that the squirrel is grey, it can be used to refer to a *kind* of squirrel, and not specifically to its color alone.

Line 6 supplies a characteristic of the orbital; it is three-dimensional. All orbitals are three-dimensional; this is not a classifier, but a simple descriptive quality.

Lines 7–8 are in the form of a question, but even a question can provide thematic information. It can tell us something about the relations of the meanings of its key terms. This question implies that the parts of the diagram can be used to represent elements. The term "elements" is new, and we learn something about its use from this question. Of course, it takes many examples of usage before one can begin to extract the thematic pattern of a scientific field with any degree of certainty. But each example contributes something.

In dialogue a Question is often thematically incomplete without its Answer, and in triadic dialogue it needs the Evaluation of the Answer as well. In this dialogue, the teacher and Jennifer together, through the whole exchange of lines 7–10, tell us that the two elements, hydrogen and helium, can both be represented by the same part of the the diagram. If we add the information from the Preparation (line 5), we learn that these two elements can be represented by the 1s orbital. A specific relationship between the meanings of "orbital" and "element" is being constructed over six lines of dialogue. We also learn, from lines 7–10, that there is a particular relationship between the term "elements" and the terms "hydrogen" and "helium." The answer would not make sense in relation to the way the question was asked unless hydrogen and helium *were* two of the chemical elements. Each is a member of the class of elements. This too is a semantic relationship, and part of the thematics of the topic.

So far, then, we have the following special terms from the language of science used in the dialogue: *1s, orbital, three-dimensional, element, hydrogen, helium*. But in addition there are certain relationships among these terms that can be read from the dialogue:

1s	[is a type of]	orbital
orbital	[has quality]	3-dimensional
orbital	[can represent]	element
hydrogen	[is example of]	element
helium	[is example of]	element

These are semantic relationships. The thematic pattern of the dialogue is the pattern in which these relationships are joined together. If the relationships themselves and the pattern in which they are joined is the same as what we would find in science textbooks or the language of professional scientists, we can say that the thematic pattern of the dialogue is truly "talking science." We know that there is a larger pattern in this dialogue beyond just the relationships listed in the table because the dialogue has linked several of them together in order to tell us that the "1s [type of] orbital [can represent] the elements [known as] hydrogen and helium." As the dialogue continues and the pattern becomes more complex, we can draw a thematic diagram to show how the terms combine semantically in this field (see Figure 1.2).

Lines 10–13 introduce one new term, *electron*, and two new relation-

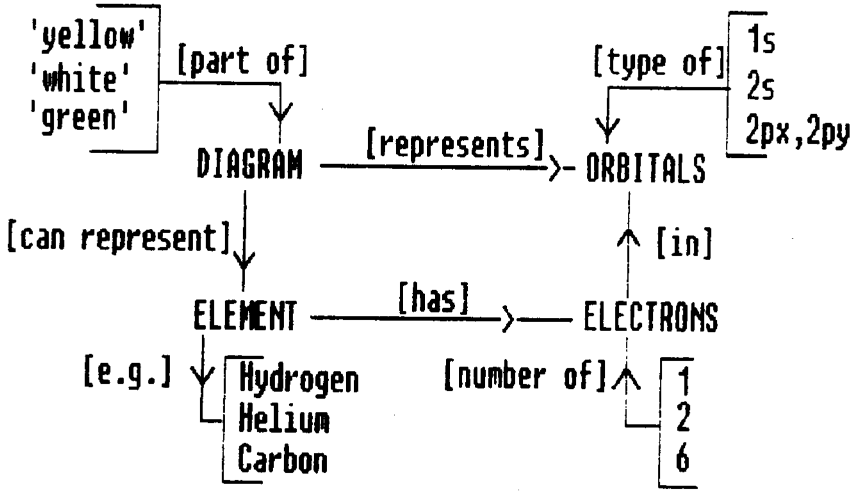

Figure 1.2. Informal Thematic Diagram

ships to previous terms. One is the relationship expressed by saying that hydrogen or helium (that is, these two *elements*) "has" electrons. In fact, in both cases *electron* is preceded by a number. The general semantic pattern is:

element [has] number [of] electrons

Different elements have different numbers of electrons. This is certainly part of the thematic pattern of physics and chemistry. But there is another semantic relationship implied here in line 11. Perhaps it is only in retrospect, or only if we are already familiar with the pattern, that it stands out. The phrase "somewhere in there" seems to connect electron to orbital in a *spatial* sense. That is also a semantic relationship. Since it is an important one, we ought to look for more evidence for it. It is an important characteristic of science dialogue that key semantic relationships, that is, those that do belong to the general thematic pattern of the subject matter, will be repeated again and again as they are used and reused in the dialogue. Look at the next few lines (21–24):

21 *Teacher:* If I have one electron in the 2Px, one electron in the
22 2Py, . . . two electrons in the 2S, two electrons in the
23 1S, what element is being represented by this
24 configuration?

Even though the term orbital does not occur here, if we already know that, like 1s, the terms *2px, 2py,* and *2s* are types of orbitals, then we see that in each case *electrons* are said to be "in" *orbitals*. This is the semantic relationship:

electrons [are located in] orbitals

We also find out that certain numbers of electrons are said to be in each orbital. But how do we tell from the dialogue that, say, 2s is a type of orbital? Looking back at lines 13–16, the exchange with Mark, we see that the relationship between the Preparation, the Question, the Answer, and the Evaluation presumes that 1s (yellow circle in the board diagram) and 2s (a white circle) are two orbitals, each represented by a different part of the diagram (cf. line 5). The same applies to 2p (consisting of a vertical and a horizontal loop, representing the 2px and 2py, in green) in lines 16–20. You can begin to see here how the various semantic relationships *have to* form a pattern in order to make sense of what is being said here. We need to use links between several semantic relationships to piece together the meaning.

Not all of these relationships are part of the general thematic pattern of atomic theory. The fact that the 2p orbital is represented by a part of the diagram that is colored green is not part of the general conventions of atomic theory. It is an ad hoc convention of this diagram and this dialogue. It is not something that a student probably has to master. It is not part of the language of atomic theory and is not needed in order to talk science. The relationships between the orbitals and their colors in the diagram are part of the thematic pattern of this particular dialogue, but not part of the thematic pattern of the science field. On the other hand, the *shapes* and relative *sizes* of the parts of the diagram *are* part of the conventions of the field, even if their colors are not. This will become relevant at the end of the episode.

A very simple thematic pattern diagram, showing the links between the semantic relationships used so far in the dialogue, is drawn in Figure 1.2. So far, I have not been using formal semantic theory to describe these relationships. I will only do so when we really need it, but I am implicitly using semantic theory as a guide in identifying the relationships as we go through the dialogue. Figure 1.2 also uses only informal labels for the semantic relationships between the terms. If you follow the directions of the arrows, reading the diagram is like reading the possible sentences that use these terms together correctly according to the thematic pattern of the dialogue. With the understanding that the colors of the parts of the blackboard diagram represent the visual appearance of the parts, not colors as such, Figure 1.2 shows the thematic pattern of the science in the dialogue so far.

And so far the teacher has also obtained only right answers to all his questions. This has made it very easy to develop the thematic pattern of the dialogue bit by bit. The class, of course, is actually *reviewing* a thematic pattern that is already familiar. If this were the first time that the pattern was being taught, its parts would probably have been systematically developed one by one, then joined together. Here many of the linkages between semantic relationships have been indirect or assumed. In fact, it can be difficult or impossible to teach a thematic pattern one piece at a time because it often takes a mastery of the whole pattern before any of its parts seem to make sense. It is not just in science that we find concepts that can only be fully understood in terms of one another: Each piece of the puzzle makes sense only if you already have all the other pieces. This is one of the fundamental problems of science teaching, and indeed of teaching and communication generally, that analyzing thematic patterns can help us understand better.

This teacher has had such a smooth time so far that he could actually afford to sacrifice thematic development to the maintenance of discipline at one point (lines 16–20). When every move in the dialogue has meaning both as part of a thematic pattern and as part of an activity structure, it is not always possible to successfully carry out both a thematic development strategy and a social interaction strategy at the same time. Sometimes we must choose between them. In lines 16–20 the teacher chose to reinforce an interaction pattern that requires students to be recognized before they can legitimately answer. We have seen how that choice slowed up thematic development and could have potentially confused students. This sort of conflict arises again in this short episode, so I want to continue the analysis of the thematic pattern and the activity structure of the dialogue together.

TEACHING CONTENT VS. KEEPING CONTROL

Lines 21–24, as part of the activity structure of the episode, pose a Question. It is a long and relatively difficult one. After a brief interruption, the teacher returns to the triadic dialogue pattern with a Nomination:

27 *Teacher:* Ron?
28 *Ron:* Boron?
29 *Teacher:* That would be—That'd have uh . . . *seven* electrons. So
30 you'd have to have one here, one here, one here, one here, one here . . . one
31 here—Who said it? you?

32 *Student:* Carbon.
33 *Teacher:* What's—
34 *Students:* Carbon! Carbon!
35 *Teacher:* Carbon. Carbon. Here. Six electrons. And they can be anywhere within those—confining—orbitals.

After the Nomination, we get an Answer (line 28), but then we do not get the usual positive Evaluation. Instead the teacher makes one of the possible moves that follow a wrong answer. He tries to show Ron why his answer could not be right, contrasting the features of Ron's answer with, by implication, those of the right answer. We'll come back to some of the details later. The teacher's response, however, is now interrupted by first one student (line 32) and then others (line 34) calling out the correct answer.

"Discipline," in the sense of the activity structure rules the teacher wants to see maintained, is now breaking down far more seriously than it did when Janice answered without being called on (line 17). There the teacher forced her to a third, pro forma repeat of her correct answer, just to maintain the rules. Now, not one but several students are calling out the answer. They are also interrupting the teacher. In Janice's case, answering without a Nomination was a possible option in triadic dialogue, and the teacher had already accepted this pattern once in the lesson already. Now, however, there is no option to cover what's happening. It is simply outside the rules.

The teacher's initial response (line 31) is to try to find out who said it first. If he had succeeded, he might have then Nominated that student for a pro forma repeat and gotten the action back into the triadic pattern. He tries to frame a question (line 33), perhaps one to which "Carbon" would be the answer, which might also have restored the interactional pattern. But other students are calling out the answer, and the teacher finally just gives a positive Evaluation (line 35), confirming Carbon as the correct Answer. He then gives a three-part Elaboration on the Answer, restoring the triadic pattern by completing it.

The teacher *could* have worked to restore the pattern when it broke down (lines 32–34). He could have insisted that the students answer one at a time, raise their hands, and not call out answers. He could have gone through a Bid-Nomination-Answer sequence before giving his positive Evaluation. He did this with Janice; he did not do it here. But circumstances were different here. Janice had given a correct answer to an easy question. It came at the end of a series of smooth dialogue triads with right answers. The teacher could afford the luxury of a brief delay in the thematic development, in getting on with the science in the dialogue, in order to restore a certain pattern to the activity structure.

This time, however, the question had been a difficult one. It was long and complex and represented a synthesis and application of much of what preceded it. The teacher had called on one of the brightest students in the class to answer it, hoping for another right answer and another smooth step at this more difficult point in the thematic development. The fact that Ron got the wrong answer likely meant that others in the class were having trouble piecing together the links in the semantic chain needed to get the right one. The teacher did not simply give a negative Evaluation of Ron's answer and call on another of the students who had raised their hands initially. He decided to provide more thematic links, to remind students of other parts of the thematic pattern that they could use to get the answer (lines 29–31).

In a sense his strategy may have worked, because several students do suddenly seem to grasp the answer. But if his thematic strategy worked, the result was to upset his interactional strategy. The appropriate next move in that strategy would have been for him to ask a Follow-up Question to Ron, hoping for a corrected Answer, a positive Evaluation, and so on. But confronted with the correct answer being called out, and seeing that a simple effort would not be enough to get the interaction pattern back on the standard triadic track, he chooses to complete the thematic pattern at the cost of the interactional one. He gets "Carbon" established as the correct answer at a moment when students seem to see why it is correct, that is, when they have fit it into the thematic pattern of the subject. And he ignores the breach of discipline, not even referring to it afterwards.

I would not disagree with this teacher's choice. It probably was much more important here to complete the thematic pattern than to enforce rules for the activity structure. But the situation illustrates the kinds of conflict that frequently arise in the classroom between teaching the science content and enforcing a particular set of rules for classroom interaction. The analysis of classroom dialogue must always take into account both of these two dimensions and how they relate to one another, moment by moment.

An activity structure like triadic dialogue is an important part of the "form" in which the science "content" is taught and learned. As we have seen, the relationships between Preparation, Question, Answer, Evaluation, and Elaboration often must be used to correctly piece together the semantic relations and overall thematic pattern of the science in the dialogue. In that sense they are not just "form," they are part of the content, part of the message. One needs to understand what they contribute to the message in order to extract the purely thematic pattern of the science content. How the science content is presented depends as much on interactional strategies and activity structures as it does on the thematic development strategy and the thematic pattern itself. These two aspects of the dialogue are intimately interdependent in the processes of teaching and learning through language.

What happens next? The teacher has just restored the triadic pattern by following his Evaluation with a series of Elaborations on the Answer, "Carbon." Notice that he can simply say "six electrons" with no other link to *Carbon*, because within the thematic pattern that has been established, we can deduce the semantic relationship, from the fact that carbon is an *element* and therefore "has" an appropriate number of electrons, in this case six. But this is the end of the triadic dialogue pattern in this episode. In the remaining lines, something quite different is happening:

Teacher: Carbon. Carbon. Here. Six electrons. And they can be anywhere within those—confining—orbitals. This is also from the notes from before. The term orbital refers to the average *region* transversed [sic] by an electron. Electrons occupy orbitals that may differ in size, shape, or space orientation. That's—that's from the other class, we might as well use it for review. [6 second pause]

In lines 36–37 the teacher makes a statement about the status of the discussion. This kind of talk about talk is called *meta-discourse* (after the term "metamathematics," which applies to mathematical theorems about how mathematics itself works), and so we can call this move a Metastatement. It is characteristic of the beginnings and endings of episodes and is part of the activity structure. It is one of the principal ways in which we control of the flow of activity by signaling boundaries. It also carries the message that what has been discussed is "from before," that is, something discussed more fully in a previous lesson and not new material.

From line 37 to line 40 we find another brief activity type, a Summary. Here this is perhaps best thought of as simply a section of the Review activity. How do we know that it is a summary? Because it highlights the most important term of the episode, *orbital*, by defining it (informally) and then it outlines the progression of the thematic development concerning orbitals. This last point might not be obvious unless you know, from the thematics of the subject of atomic theory, that the progression from *1s* to *2s*, from *2s* to *2p*, and then to *2px* and *2py* (in lines 5–20, in reverse from 21–24, and at the board in the aborted effort of lines 29–31) exactly illustrates pairs of orbitals that differ first in size, then in shape, and finally in spatial orientation.

Lines 40–42 are another Metastatement, marking the end of this Review episode, and naming it as such. Metadiscourse moves in an activity structure are powerful strategies of control. This teacher, having only just "rescued" the triadic structure (lines 35–36), immediately used such a move to signal the end of the discussion, and the end of triadic dialogue. He then shifts into a monologue structure, the Teacher Summary, which returns control and the focus of attention to himself. And finally he ends the Review episode altogether by this second metadiscourse move.

LANGUAGE, SEMANTICS, AND LEARNING

We have just analyzed a short episode of classroom dialogue. In it we found a regular pattern of interaction between teacher and students, within which they could play strategically off one another's moves. We also found that, through moves within this activity structure, the teacher and his students were developing a thematic pattern of relationships among the meanings of key science terms. In this episode we have seen one way of talking science. The thesis of this book is that the mastery of a specialized subject like science is in large part mastery of its specialized ways of using language.

What makes the language of science distinctive is primarily, but not exclusively, its *semantics*: the specific relationships of scientific meanings to one another, and how those relationships are assembled into thematic patterns. The work of assembling semantic relationships into larger patterns is done partly through grammar, partly through rhetorical structures and figures of speech, and partly through the moves of an activity structure.

The language of science has evolved certain grammatical preferences, especially in writing, but also in formal speech (including that of teachers). There is a lot of use of the passive voice, of abstract nouns in place of verbs, of verbs of abstract relation (e.g., *be, have, represent*) in place of verbs of material action. It also has its preferred figures of speech, like analogy, and rhetorical patterns (e.g., Thesis-Evidence-Conclusion). It also works through a variety of activity structures, whether triadic dialogue, ordinary question-and-answer, lecture, or summary monologues, or many others. It even has its own special forms of written texts: laboratory notes, reports of experiments, theoretical treatises, and so on. It has, in short, its own ways of organizing and presenting information and meaning, and its own patterns of meaning to present.

There is a lot of science in classroom talk, but most of it requires students to do the work of piecing together the meanings and thematic patterns. Once you have mastered those patterns, reading or listening to science is relatively easy, but before you have done so, when you are still trying to work out the patterns, much of what is said may seem to make very little sense at all. It is surprising how little classroom dialogue is devoted to the exposition of the patterns, to explicitly telling students just what the relationships of key terms are and how those relationships fit together into a larger pattern. Most of the time the patterns are simply there *implicitly*. They are assumed, presupposed, made use of. But rarely are they shown and explained directly.

Students are not taught *how to talk* science: how to put together workable science sentences and paragraphs, how to combine terms and meanings, how to speak, argue, analyze, or write science. It seems to be taken for granted that they will just "catch on" to how to do so, and to the thematic patterns of the topic. When they do, we are proud of them and praise their "understanding" and "comprehension." When they don't catch on, we conclude that they weren't bright enough or didn't try hard enough. But we don't directly teach them how to. We demonstrate to them a set of complex and subtle skills and expect them to figure out how we do it. Is it any wonder that very few succeed? Or that those from social backgrounds where the activity structures, preferred grammar, rhetorical patterns, and figures of speech that they are used to are least like those of science and the classroom do least well? We will look at these questions from a number of perspectives in later chapters.

The difficulty many students have in catching on to the semantic patterns of science is less surprising if you look at a few examples of the subtle language cues they have to go on. Of course, teachers do make meaning relationships explicit when they are first introduced, and occasionally afterwards during a review or summary. But that represents a small fraction of all classroom dialogue. For a far greater proportion of the time, teachers simply *use* the meaning relationships, and the outward signs as to what those relationships are can be quite subtle. It is these pervasive but extremely subtle cues that provide most of a student's opportunities for catching on to the semantics of the subject. The effect is to magnify the advantages of students who are used to language patterns, whether grammatical, rhetorical, or interactional that are close to those of classroom science dialogue. Let's take a few examples from this episode.

Compare, for instance, the wording of two superficially similar, but semantically very different Questions, those in lines 7–8 and lines 21–24:

What two elements could be represented by such a diagram?	What element is being represented by this configuration?

Grammatically, the differences are subtle. In one case *element* is singular, in the other case it is plural. In one there is a modal verb ("could"); in the other case, none. These differences are important cues to the differences in meaning between the thematic patterns that lie behind the two questions. Other differences, such as having the progressive verb in one and the simple verb in the other, or using the demonstrative "such a" vs. "this" don't really matter. In the first case the question is about an *orbital*, which *can* represent more than one element. In the second case, it is about a configuration of *electrons [in] orbitals*, which *do* represent one and only one element. The teacher uses the semitechnical term "configuration," but he could just as well have said "this diagram" again, since at the board he had just put in the electrons for Carbon. Then the *only* cues would have been the subtle grammatical ones.

When Ron misses the second question, the teacher tries to show him his mistake by describing some features of his Answer, "Boron," that don't fit the specifications of the question (lines 29–31). He begins by trying to get his own semantics right, switching from "be" to "have" to fit the pattern: *element [has] electrons*. But in both forms, he has used the subjunctive mood ("would"), which is a subtle cue that the answer "Boron" is wrong. Even subtler is the contrastive emphasis on "*seven.*" We know that the underlying thematic pattern is that different *elements [have]* different *numbers [of] electrons*. The correct answer, Carbon, is an element with only six electrons, and if you read the full question carefully (lines 21–23), you can count up the number of electrons and see that they total six.

This subtle emphasis on the total number of electrons as being crucial, rather than the more complex sorting out of which electrons are in which orbitals (which is actually unnecessary to get the answer), is probably enough to cue the students in to the correct answer, Carbon. When the teacher does confirm this answer as correct, his Elaboration first points ("Here.") to Carbon on the Periodic Table of the Chemical Elements, a wallchart in front of the classroom, where the number 6 is prominently displayed next to the symbol C for Carbon. Then he emphasizes "Six electrons." As we have noted before, he does not fill in the rest of the sentence. The students are expected to use the thematic pattern to interpret this as "The element Carbon has six electrons."

Most teachers know, I think, that just giving a definition or explanation at the beginning when a new term or principle is first introduced, is not enough. Very few students will be able to use the term or relate it to other terms without having had more experience with it. Very few can guess how a principle is to be applied, just from knowing the formal statement of the principle. That is why there is a great deal of repetition, use of examples, and implicit use of terms and principles across a variety of contexts in good teaching. We know that it is only through and towards the end of this process that students seem to catch on to the semantic patterns of usage of terms and to the larger thematic patterns within which terms and principles are used. Successful students are learning through the *use* of terms and principles in context, by hearing and making sense of the subtle cues that accompany those uses. Those who catch on to the correct thematic patterns first have a much easier time making sense of the rest of what they hear.

In the next chapter we will consider what happens when students try to make sense of what the teacher is saying by fitting it to a thematic pattern that is *not* the one the teacher is using. In that episode, from a different lesson, we can tell what the students' own thematic pattern is because we hear them talking science a lot. In the episode we have just analyzed, and in most classroom dialogue, the students don't get much practice at talking science. This is partly the result of the pattern of triadic dialogue itself. It favors teacher dominance of the dialogue just as surely as the lecture method produces a teacher-dominated monologue. At least in triadic dialogue, the students have some small degree of active participation, even if only as followers of the teacher's lead. But lecturing often provides for more explicit teaching of semantic relationships and larger thematic patterns. Triadic dialogue tends to keep the thematics of the science content implicit and effectively hidden from many students despite the best efforts and intentions of a good teacher.

In triadic dialogue and the other principal patterns of classroom learning, students mainly listen to and read the language of science. But they talk very little science and they write less. Just as with learning a foreign language, fluency in science requires practice at speaking, not just listening. It is when we have to put words together and make sense, when we have to formulate questions, argue, reason, and generalize, that we learn the thematics of talking science. If students cannot demonstrate their mastery of science by talking or writing, we can wonder if their test answers and problem solutions truly represent the ability to reason with science. For reasoning, too, is a way of talking oneself through a problem, a way of mobilizing the semantic resources of scientific language (including its diagrams and formulas) to make sense of a situation. In Chapter 4 we will see in more detail how scientific "thinking" can be better understood as another example of talking science. This chapter has done quite enough, I think, with one short episode. It's time to look at another classroom, where conflict rather than cooperation is at the root of the dialogue.

EXPLORING FURTHER

The linguistic analysis of classroom talk was pioneered by Sinclair and Coulthard in *Towards an Analysis of Discourse* (1975). Mehan's *Learning Lessons* (1979) describes many basic patterns of classroom talk in detail. Two more recent views of the subject are Cazden's review article ("Classroom Discourse", 1986) and Edwards and Westgate's book *Investigating Classroom Talk* (1986). My own work is also described in *Classroom Communication of Science* (1983b), which gives more detail on some topics, and *Using Language in the Classroom* (1985b), which presents a brief overview. I will suggest some references on the techniques of discourse analysis itself at the end of Chapter 2.