DOCUMENT RESUME

ED 357 953 SE 053 111

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TITLE	Saying What You Know in the Science Laboratory.
PUB DATE	90
NOTE	27p.; Paper presented at the Annual Meeting of the American Educational Research Association (Boston, MA, April 16-20, 1990).
PUB TYPE	Information Analyses (070) -- Speeches/Conference Papers (150)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	Biology; *Classroom Communication; Communication (Thought Transfer); Discourse Analysis; Discourse Modes; *Discussion (Teaching Technique); Elementary Secondary Education; *Knowledge Level; Models; Science Activities; Science Education; Science Experiments; *Science Instruction; *Science Teachers; Teacher Behavior; Teaching Methods
IDENTIFIERS	*Subject Content Knowledge

ABSTRACT

This paper analyzes discrepant findings from research on science teacher knowledge and classroom discourse. In new science teachers' classrooms, discourse during laboratory activities differed in important ways from discourse during other types of instruction. Furthermore, teacher subject-matter knowledge had effects that were not predicted by the study's conceptual f-amework, a model that relates teacher knowledge to active contr^l of discourse by the teacher. Although the discrepant findings and the conceptual framework are reconciled here, the reconciliatory process generated several questions about the underlying theoretical and methodological assumptions of research on teacher knowledge. In addition to outlining these questions and describing the effects of teacher knowledge on discourse in the laboratory, this paper suggest that methodological flexibility and attention to anomalous findings may help teacher-knowledge researchers avoid self-deception and appropriately limit the generalizability of their conclusions. (Author)

Saying What You Know in the Science Laboratory

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Abstract

This paper analyzes discrepant findings from research on science teacher knowledge and classroom discourse. In new science teachers' classrooms, discourse during laboratory activities differed in important ways from discourse during other types of instruction. Furthermore, teacher subject-matter knowledge had effects that were not predicted by the study's conceptual framework, a model that relates teacher knowledge to active control of discourse by the teacher. Although the discrepant findings and the conceptual framework are reconciled here, the reconciliatory process generated several questions about the underlying theoretical and methodological assumptions of research on teacher knowledge. In addition to outlining these questions and describing the effects of teacher knowledge on discourse in the laboratory, this paper suggests that methodological flexibility and attention to anomalous findings may help teacher-knowledge researchers avoid self-deception and appropriately limit the generalizability of their conclusions.

Teacher Knowledge and the Language of Science Teaching

Conceptual and methodological commitments shape our emerging understanding of the effects of teacher subject-matter knowledge on teaching. This paper reconsiders some of these commitments. Although the conclusions of this reconsideration are not revolutionary--I begin and end with a belief in the primacy of subject-matter knowledge in teaching--they point out that our theories, constructs, and ways of doing research both enlighten us and blind us.

Our paradigm's commitments merit attention for two reasons. First, the methods of current research on teacher subject-matter knowledge often neutralize the familiar empirical challenges to educational inquiry. Correlation coefficients are easily reevaluated; case studies are not. Methods new to educational research warrant critical attention as well as celebration. Second, the results of research on teacher subject-matter knowledge are being used as fuel in arguments about teacher education and certification. If history is any guide, there is some danger that the findings of research on teacher knowledge will be reformulated into policies that have unintended and undesirable consequences for teaching. Although clearly teachers must understand the subjects that they teach, translating "subject-matter knowledge" into, for example, specific certification requirements is a task with complex political, economic, and educational implications. Before rushing into reform, it may behoove us to acknowledge the limitations of our approach as a guide to policy making.

This paper is divided into two parts. The first part is an analysis of some puzzling results from research on the effects of science teacher subject-matter knowledge on classroom discourse. These data, collected during laboratory activities in biology classrooms, differed markedly from data collected during other instructional activities. At first glance, they appeared to refute the sociolinguistic model underlying the research--a model that predicted high levels of teacher discourse control in lessons on topics unfamiliar to the teacher. Continued analysis, however, suggested that the indicators of teacher discourse control initially used were methodologically inappropriate for the communicative context of the laboratory.

The second part of this paper reflects upon the process of reconciling discrepant findings with the study's conceptual framework. This process raised several questions about the assumptions underlying the study. These assumptions necessarily qualify the generalizability of research findings concerning teacher subject-matter knowledge.

Part I. Language in the Science Laboratory

Conceptual Framework

The conceptual framework framing this research is a sociolinguistic model relating teacher subject-matter knowledge to control of classroom discourse (Carlsen, 1988). The framework predicts that new science teachers will most actively control discourse when they are teaching about unfamiliar subject matter, perhaps in order to avoid revealing the shallowness of their understanding.[1] A number of mechanisms for controlling discourse were explored, at the levels of curriculum, conversation, and individual utterance. These mechanisms depend upon the imbalances in rights that characterize classrooms: teachers choose topics for study, develop instructional activities, and decide who will talk and for how long. Furthermore, talk not only reflects the teacher's authority in the classroom, it may also serve to consolidate that authority.

Language in the Science Classroom

A year-long study of the teaching of four new biology teachers generally supported the conceptual framework outlined above. At the curricular level, teachers' choices of instructional activities varied with their subject-matter expertise. For example, analysis of lesson plans on familiar and unfamiliar topics revealed that lectures, recitations, and other types of large-group direct instruction were most common for biological topics familiar to the teacher. When they taught unfamiliar topics, these teachers preferred to schedule activities like student oral reports and small group deliberations.[2] If one considers large-group direct instruction to be conversationally risky, from the perspective that the teacher may be publicly asked a question that he or she cannot answer, there was a tendency for these teachers to avoid risky settings when teaching unfamiliar topics.

The conceptual framework was also supported by data gleaned from interviews with the teachers, classroom observations, and verbatim transcripts of thirty lessons.[3] From the perspective of prior research on classroom discourse, there were few surprises in the overall patterns of teacher-student talk in these four teachers' classrooms. For example, in teacher-student conversations, the teachers asked many more questions than the students and spoke more than all students combined, and discourse usually followed the ritualized patterns of teacher questions and student responses described elsewhere (Bellack, Kliebard, Hyman & Smith, 1966; Mehan, 1979). However, within-teacher contrasts revealed differences related to teacher knowledge, when classroom activity was held constant. For example, when conducting large-group instruction on unfamiliar biological topics, the teachers asked their students frequent low cognitive-level questions that required short student responses, dominated the speaking floor, and resisted student attempts to change the topic of discourse.[4] When teaching familiar topics, the teachers asked fewer low-level questions, talked less, more readily yielded the floor, and permitted students to change the topic of discourse. These findings were consistent with the prediction that teachers more actively control classroom discourse when they are teaching unfamiliar subject matter.

The Discrepant Case of the Laboratory

The general picture outlined above failed to describe classroom communication during science laboratory activities. Teacher knowledge did not appear to affect the frequency with which laboratories were scheduled. Students asked questions more often than teachers. The teachers talked more in laboratories on familiar topics than unfamiliar topics.

Discourse in laboratories differed from discourse in other classroom activities, including activities that were structurally very similar. The teachers frequently had students work in small groups on projects that did not require specialized scientific equipment or experimental procedures: building cell models, solving paper-and-pencil puzzles, working together on problems in the textbook, or preparing oral reports. Superficially, communication during such activities resembled that of the laboratory: students worked together in small groups, and the teacher moved around the room, encouraging students, providing hints, and asking and answering questions. Examined more closely, however, discourse was consistent with the conceptual framework. First, group work was commonly scheduled for subject matter unfamiliar to the teacher. Second, students asked questions rarely; and, third, when they did, the questions dealt almost exclusively with procedures, not content. Finally, the teachers talked more when the subject-matter topic was unfamiliar, effectively dominating conversations with small groups.

The anomalies outlined above might be interpreted as refuting the sociolinguistic model relating teacher knowledge with discourse control. Wholesale refutation is unsatisfying, however, because the model was generally explanatory in settings other than the laboratory. An alternative approach to these discrepant findings, consistent with current approaches to qualitative data analysis, is to treat the laboratory activity as an outlier, and hence an opportunity to test the generality of findings and guard against biases (Miles & Huberman, 1984, p. 237).

Scheduling Laboratory Activities

The conceptual framework for this study predicted that teachers would be more likely to schedule laboratory activities to teach unfamiliar subject matter than to teach familiar subject matter. This prediction was based solely upon an assessment of the gross communicative characteristics of laboratory activities. In the laboratory, teachers tend to talk with individual students or small groups of students. Since there is no single speaking floor, there is little chance that the teacher's knowledge will be tested in front of the whole class. From this simple perspective, the laboratory is, like student seatwork, a communicative setting with relatively little risk.

Analysis of the entire year's lesson plans for these four teachers failed to support this prediction. Although two of the teachers scheduled labs more often for unfamiliar topics than familiar topics, one teacher showed no knowledge-related difference, and the fourth scheduled a large number of labs for familiar topics.

One explanation for the anomalous distribution of labs across familiar and unfamiliar topics is that laboratories tend to be scheduled by groups of teachers. Many of the labs, for example, used live or perishable materials ordered by science departments and used by several teachers. Hence, the scheduling of biology laboratories was dependent on other teachers' plans; this dependence may have mediated teacher knowledge effects, which might otherwise have favored scheduling laboratories on unfamiliar topics.

A second explanation for the distribution of laboratories is that it may be difficult for new teachers with little formal study of a particular biological topic to develop and conduct laboratory activities. Laboratories differ from other types of group work in that they often demand specialized knowledge about materials and methods that is not gleaned easily from a teacher's manual. Inadequate teacher subject-matter knowledge may prevent teachers from <u>constructing</u> some types of classroom activities, a possibility that is not suggested by the conceptual framework, which views curricular planning as a process of choosing from an array of instructional strategies.

Third, compared to other types of student group work, the outcomes of a laboratory exercise may be relatively unpredictable. If students preparing an oral report run into problems, the teacher can send them to the library; if students running a titration fail to get a color change, they will turn to the teacher and expect more specific assistance. Although the small size of the speaking floor may reduce communicative risk for the teacher, the indeterminacies of laboratory work may increase this risk. Students may encounter problems with laboratory procedures that the teacher cannot resolve, or the teacher's directions or predictions may be rebutted by students' experiences later in the lesson.

There was evidence in this study to support each of these three explanations. Each points out a different simplistic assumption of the research. First, teacher curricular planning is assumed to be an activity of a single teacher. This assumption ignores the institutional constraints and opportunities that affect teachers' planning (and, consequently, what happens in classrooms). Second, teacher curricular planning is portrayed here as a process of choosing between options. The teacher picks an instructional strategy from an array of equally attractive instructional alternatives: "Will it be laboratory today or lecture?" As Clark and Peterson (1986) point out, models of teacher decision-making need to be much more sophisticated than this. Teachers do not just choose instructional activities, they build them. If their subject-matter knowledge is weak, it may be difficult for them to construct certain types of activities. Third, the mechanism explaining <u>why</u> teacher knowledge matters is extremely narrow. Although teacher knowledge and its outcomes are conceptualized broadly, the explanatory chain linking them passes through a narrow definition of communicative risk.

These three <u>a posteriori</u> mechanisms concerning the anomalous scheduling of laboratory activities are neither mutually exclusive nor even exhaustive of all possible explanations, which include errors in sampling, bias in teachers' written plans, or gross errors in analysis. Nevertheless, they suggest that in studies of teacher knowledge, the roots of empirical variation may brachiate widely. Furthermore, digging up each of these roots may require a different analytical shovel, aimed at uncovering either institutional constraints in scheduling, the subject-matter demands of lesson planning, or teachers' perceptions of indeterminacy and risk. In an emergent qualitative analysis, each <u>a posteriori</u> mechanism would suggest a new direction for the research.

Each mechanism would be tested more or less directly, with appropriate methods; both the conceptual framework and the design of the research would evolve.

Multimethodological analysis (e.g., Brewer & Hunter, 1989; Green & Harker, 1988) offers an alternative to emergent research designs. Rather than adopt new methods in the face of anomalous findings, complementary but different data sets are collected simultaneously and analyzed in different ways. When one analysis poses puzzles, another may shed light. This may be true even when--as in this study--complementary analyses pose complementary puzzles.

Discourse in the Laboratory

As noted earlier, characteristics of discourse in the laboratory were inconsistent with the conceptual framework. Attempting to explain these anomalies requires reference to actual discourse. The following analysis compares two laboratory activities supervised by the same teacher, one on an intermediate-knowledge topic and one on a high-knowledge topic. In doing this analysis, evidence is sought to strengthen or discredit the mechanisms proposed to account for anomalies in scheduling.

Intermediate-knowledge laboratory on the microscope. An instructional unit on cell biology in Ms. Ross's biology class included a laboratory activity on the microscope. Ms. Ross rated her knowledge of cell biology 8th strongest of 14 topics, a rating which was supported by the subject-matter knowledge interview and analysis of her university transcripts.

At the beginning of this lesson, each student was given a six-page handout entitled, "The Microscope." The handout was one of a set of commercially-prepared supplemental lab activities which accompanied the class textbook. The lab procedures were explained step by step, and required the student to study the parts of the microscope, prepare a wet mount slide, and answer a number of questions. To complete the lab, the students needed to answer ten essay questions, list the functions of seven parts of the microscope, do five calculations, label twelve parts on a picture of a microscope, and sketch two pictures. Answering two of the essay questions and drawing the two sketches required using the microscope; the answers to the other questions were in the handout. For example, on page 2 the functions of each part of the microscope were described, and on page 3, the student was asked to list the functions of some of these parts.

Teacher's actions. During the laboratory activity, Ms. Ross walked around the room, monitoring student work, answering questions, asking questions, and helping students who needed assistance. Her movement from group to group did not appear to follow any particular pattern: she spoke with some boys at the front of the room, helped a student near the back, checked the microscope supplies at the side of the room, and so on. Most of her comments dealt with lab procedures and took the form of very short utterances, as in the following exchange:

TEACHER TALK	STUDENT TALK
So you guys know what these knobs are used for, huh?	
	BOY: Yeah.
Great.	
How you doing?	
	BOY: I'm fine. I'm done.
You're done? Have you looked at the other stuff?	
	BOY: Yeah, just.
	BOY: Um, I have a question.

Uh-huh.

BOY: I couldn't get, I couldn't focus on it, I mean I couldn't actually find it.

Well. Is this exactly what you saw? Under that magnification? Just exactly like that?

BOY: No. No.

You oughta try again.

BOY: What, draw it bigger?

No, I think you oughta look at it again, OK.

BOY: ... ten X ...

You saw the whole D on ten X?

BOY: Yeah, it's a small D.

BOY: Yeah.

Wow. OK.

[Ross05, 22:24-23:04]

For purposes of later comparison, there were 153 utterances in this 40 minute laboratory activity.[5] Only 6 of these (4.2%) were longer than 20 seconds in duration. The longest was 30 seconds. The mean duration of teacher utterances in this lab was 6.70 seconds (s.d.=6.33). Many of the utterances were short questions. Of the 85 teacher questions, 62 were procedural (noninstructional) questions. For example:

18:30 How you doing?

25:43 Janice, are you working with someone?

31:02 Anybody else have a question?

However, there were a number of instructional questions (N=23):

32:31 What's the magnification here, on this one, right now?

36:57 Can you tell me, what's different about what you saw and what's, what's under there?

With the exception of a 45-second conversation with one student about school athletics, almost all of Ms. Ross's comments dealt with the material described in the lab handout.

The teacher's role in this lab might be described as "detached." Her remarks revealed little enthusiasm about the lab. She remained with student groups only briefly, said very little, and asked questions to monitor student progress or focus students on a written question in their handout.

Students' actions. Students asked the teacher 39 questions, of which all but two were procedural questions. A typical example was a boy's question at 31:47, "So we just draw this now?" The function of almost all of these questions was to initiate discourse with the teacher about procedure. As Ms. Ross walked by, a student would hail her by asking a question. She would respond, then continue her movement around the room.

Summary of the intermediate-knowledge laboratory. This laboratory activity was a highly-structured assignment defined by a handout. The teacher's role in the activity was to monitor student progress and answer questions. The teacher spent little time with each group of two or three students, spoke for brief periods, and asked many questions, many of them high or low-cognitive level (instructional) questions. The students usually initiated conversations with the teacher by asking procedural questions. Almost all of the teacher-student talk dealt with a small amount of material described in the handout.

High-knowledge laboratory on the circulatory system. The second lab was a dissection of the circulatory system of fetal pigs. The assignment was less structured than the microscope laboratory: the students were given fetal pigs, dissecting tools and dissection manuals (about 30 pages long), then told to dissect the circulatory system. The students were not expected to answer any questions or turn in any written materials. Ms. Ross spent four minutes at the beginning of the period highlighting some of the features of the circulatory system, then the students divided into groups and began working.

Teacher's actions. Ms. Ross's actions in this lab contrasted very strongly with her actions in the microscope lab. During this lesson, she moved very systematically between student groups. She began at the front of the room, spent several minutes with one group, moved to the next group, spent several minutes with them, and so on. She reached the last group in the back of the room only several minutes before the end of the period.

Each time Ms. Ross moved to a new group of students, one or more students immediately asked her a question or pointed out a problem they were having with the dissection. The teacher typically sat down, picked up a probe, and began responding to the student questions, pointing out parts of the digestive system, and commenting on the dissection that had been done so far. Only one of Ms. Ross's forty-four questions was coded as instructional; all of the others were procedural, such as, "How are you guys doing?"

When Ms. Ross spoke, she spoke for much longer periods of time than she did during the microscope lab. For example, the following exchange is one utterance:

> Coming up, right here. And that,
> if you can follow it, if you have
> to take out the liver to do so.
> If you follow it out, you'll see.
> Yeah, that's it. It has just lost
> its dye. OK. Then if you move away

some of the small intestine, you'll see, one lobe of the kidney right here. Now that's two of em. And, in the kidney, they have um. This is the bladder here. And, the ureters are tubes that lead, out of the kidney, and down into the bladder, so

BOY: Is it those things?

Yeah. You haven't-, some pigs are real easy to see on, and some they have a little bit harder time. But, this is the peritoneum right here. And if you remove it you can see, these little tubes. And if you follow those tubes. You'll see they come right out at this point here. And you'll also see the vessels. That also lead into and out of the kidney. And these are stained for you, so you know that the blue is the, the renal vein. And the pink is the renal artery. OK. So you'll need to do that. OK. So you need to kind of cut away so that you can see, um. You can see the

BOY: Yes.

[Ross15, 30:12-31:08]

In this lesson, 17.3% of the teacher's 127 utterances were more than 20 seconds long (compared to 4.2% in the intermediate-knowledge lab). The mean duration of teacher utterances (13.2 sec.) was more than twice as long as in the microscope lab. Furthermore, although the dissection manual was much longer and more detailed than the microscope handout used in the intermediate-knowledge lab, many of the teacher's comments dealt with topics not discussed in the printed materials. Ms. Ross talked about the latex dyes used to distinguish between arteries and veins, differences between some of the pigs in the classroom, the pig's digestive system, the human respiratory system, and her difficulty in finding the adrenal gland. She frequently made evaluative comments about people's dissection technique (usually favorable), and on three occasions referred students to another group's pig, which had been skillfully dissected to show a particular feature.

Students' actions. Despite Ms. Ross's lengthy comments, the students in this lab asked many questions. Furthermore, 28 of the 112 student questions were high or low cognitive level questions (in the other lab, only 2 were so classified). Here are some examples:

21:58	GIRL:	Where is the primary bronchi?
28:00	GIRL:	The things that go in are the renal arteries and the renal veins?
28:17	BOY:	Is there five lobes or seven?

During this lab, students asked more than twice as many questions as the teacher. Many of these questions served to initiate discourse or change the topic of discourse. This pattern, common in laboratories (especially high teacher-knowledge laboratories like this one) was relatively uncommon during other classroom activities.

Summary of the high-knowledge laboratory. Compared to the intermediate-knowledge microscope lab, this lab was not a highly-structured activity in which student actions were scripted by a handout. The teacher moved systematically and slowly from the front of the classroom to the back. She spent several minutes with each group of students. Her role appeared to be one of "visiting expert;" more often than not, upon arriving at a student group, she was asked a question, whereupon she sat down, picked up a tool, and proceeded to do some of the dissection herself, talking out loud as she worked. She asked only one question of an instructional nature, but the students asked many such questions.

Reconciling the Laboratory with the Conceptual Framework

In this study, teachers usually talked more when they taught unfamiliar subject matter than when they taught familiar topics. Across most common classroom activities, this generalization held irregardless of whether the amount of teacher talk was measured by the mean duration of teacher utterances or the percentage of class time that teachers talked.[6] Laboratory activities were the one exception to this generalization. This phenomenon appears to be related to student questions, which were more common in the laboratory than during any other classroom activity.

In laboratories like the microscope lesson, student questions tended to be procedural, and typically demanded only brief teacher responses. This was especially true when the laboratory assignment was clearly defined and the student's task focused on answering questions on paper. In contrast, in lessons on topics familiar to the teacher, student questions more commonly dealt with the subject matter than with procedures. In studying these and other laboratory activities with teacher-knowledge contrasts, several possible reasons for this emerged. First, high-knowledge labs tended to be less clearly defined. They were not, in science slang, "cookbooky." Second, the teacher took a more active role as a participant in high-knowledge labs. This role was less oriented toward making sure that everyone was working than with making sure that students who were working understood what they were doing. Third, the teacher was more likely to talk about peripheral material related to the subject-matter of the laboratory, but not written down in the instructional materials.

Unlike teacher talk in other activities, teacher utterances in laboratories often functioned as conversational response moves, rather than initiation moves. Student questions in laboratories--especially high-knowledge laboratories--helped to define a communicative setting very different from other activities. As questioners and discourse initiators, students commonly directed conversation in ways that were uncommon in other class activities. Turn allocation control, for example, was frequently relinquished by the teacher in laboratories: it was common to hear students answer each other's questions without teacher redirection, something rarely heard in other class activities.

A unique feature of the laboratory was that long periods of teacher talk in laboratories typically followed student questions. Consequently, these extended periods of teacher talk are probably inappropriately viewed as efforts by the teacher to control discourse. On the contrary, they attest to the seriousness with which student questions are addressed. These extended teacher responses to student questions may encourage further student questions. In contrast, long periods of teacher talk without student prompting (common in other classroom activities) focus on the teacher's, not the students', agenda.

Analysis of the anomalous effects of teacher knowledge on laboratory instruction sheds some light on the absence of teacher knowledge effects in the scheduling of laboratories. The first possible mechanism proposed to account for laboratory scheduling anomalies was interaction between teachers' plans and the plans of their colleagues. In this study, which focused on four teacher interns, laboratories were commonly borrowed or adapted from other teachers. Both of the laboratories discussed in detail here, for example, utilized materials provided by another teacher: microscopes, fetal pigs, dissecting tools, and resource books.

The second mechanism proposed to account for anomalies in the scheduling of laboratories was the inability of teachers to construct laboratory activities on unfamiliar subject matter. Ms. Ross's two lessons are illustrative of one way that teachers may deal with this problem. In her instructional unit on cell biology, she selected and assigned highly-structured laboratory handouts that carefully scripted the activities of her students. The microscope handout was illustrative. To complete its many questions, actual student use of the microscopes was almost unnecessary. While moving around the room, Ms. Ross's remarks indicated that her primary expectation for students was to complete the written questions. Student questions to the teacher focused almost exclusively on answering the questions. In contrast, to teach about the circulatory system, Ms. Ross selected a complex dissection and distributed written instructions that asked only rhetorical questions. She also brought in supplemental materials, including a cow heart that she picked up at the butcher's. Her movement about the room was slow, systematic, deliberate, and unaccompanied by control talk. She encouraged students not to rely too heavily on the laboratory manual, cautioning that one organ was difficult to see, that another group's dissection-in-progress was worth checking, that she hadn't yet seen one of the described glands. In the dissection laboratory, the actions and the talk of teacher and the students diverged widely from what was written down.

The third mechanism proposed to account for the anomalous scheduling of laboratories argued that, although the small size of the speaking floor in the laboratory may reduce communicative risk for the teacher, another source of risk may be added: the unpredictabilities of laboratory work. In these and other laboratories, instructional glitches were fairly common. Tightly-scripted laboratories may reduce the risk that such glitches will prove disruptive or embarrassing to the teacher, but they will not eliminate the risk.

In summary, three possible mechanisms were outlined to account for the anomalous scheduling of laboratory activities. Support for each mechanism emerged from analysis of transcripts of laboratory lessons. These mechanisms suggest that although the conceptual framework is sound, two problems exist. First, the framework is insensitive to the effects of institutions on how laboratories are scheduled. These effects are likely to be most important for teachers like those participating in this research: interns who are new to teaching, in the school only part time, and teaching in another teacher's classroom, under another teacher's supervision. Second, measures useful in studying other classroom activities proved problematic in studying laboratories. The amount of teacher talk, for example, proved to be an unreliable indicator of teacher domination of the speaking floor, because teacher talk was prompted, more often than not, by student questions.

Part II. Assumptions Underlying the Research

The analytic process described above raised a number of questions about the assumptions underlying this research on teacher subject-matter knowledge. In this section, I make some of these assumptions explicit and suggest ways in which they necessarily qualify conclusions about the importance of teacher knowledge.

The first assumption of this research was that <u>the effects of teacher subject-matter knowledge are apparent in verbal interactions between teachers</u>

and students. This assumption is problematic for two reasons. First, teachers may devote little teaching time to unfamiliar subject matter. Second, they may utilize highly directed written materials to teach unfamiliar topics, effectively reducing their role in the classroom to traffic cop. The net effect of these two factors may be that recordings of classroom discourse show very little teacher talk of a substantive nature.

A second assumption of this research was that classroom activities like the laboratory have characteristic participation structures, or arrangements of speakers and the rules governing their participation (Schultz, Erickson & Florio, 1982). In looking for teacher knowledge effects on the scheduling of laboratories, I assumed that communication across laboratories would be structurally very similar, differing only in minor ways such as the amount the teacher talked. These two laboratories, however, point out that participation structures in the laboratory can differ greatly, depending on the students' understanding of the task and the teacher's supervisory style.

A third assumption of this research was that control of discourse is obvious in written transcripts of discourse. A number of theory-laden decisions about methodology influence both the construction of transcripts and the analyst's reading of them. For example, transcripts in this paper reflect a common teacher-centric bias (Edwards & Westgate, 1987, chapter 2), because the primary microphone was carried by the teacher (hence all teacher talk but only some of the student talk was transcribed) and because the teacher's remarks are transcribed in the left hand column, subtly biasing the reader to view exchanges as teacher-initiated (Mishler, 1984; Ochs, 1979; Stubbs, 1983, chapter 11). The net effect of these methodological biases is to exaggerate the role of the teacher in initiating and controlling discourse.

A fourth assumption of this research was that teacher knowledge about a topic and student interest about the same topic are independent. This study compared lessons on familiar topics with lessons on unfamiliar topics, holding the student group constant. Hence, each teacher was considered a subject-matter expert on some topics and a novice on others. One threat to the validity of this design was the possibility that students might be naturally more interested in topics that were familiar to their teachers, and consequently more willing to talk about them, regardless of the teacher's actions. This possibility proved troublesome but not impossible to rule out, because the backgrounds of the four teachers were similar in many ways. For example, "human systems" was a high-knowledge topic for all four teachers. Fortunately, variation in teacher knowledge on other topics and the availability of data from a pilot study done the previous year helped to rule out confounding by student interest.

Conclusions

Although the assumptions outlined above are not universal to research on teacher subject-matter knowledge, their roots are embedded in a common paradigm. Their limitations, therefore, may be important considerations for other researchers studying teacher subject-matter knowledge.

First, although teacher talk may provide a window into teachers' cognitions, this study suggests that when they teach unfamiliar subject matter, teachers sometimes draw the blinds. Strategies like curricular avoidance and reliance upon highly structured activities may change the character and amount of teacher talk drastically, shifting its focus from subject-matter issues to procedural ones. While this may be illustrative of teacher thinking in some respects, it makes it difficult to compare, for example, teacher explanations or certain types of questions, because they disappear from conversation.

Second, the rules of sociolinguistic engagement can vary considerably between activities that are called the same thing by the teacher. Although "laboratories" are in many respects very similar, analysis of discourse in these two lessons suggests that it would be dangerous to conclude much about communication in other, unobserved, laboratories without access to other data.

Third, transcription of discourse is a theory-laden activity that merits being made problematic, both before and during research.

Finally, teachers study in greatest detail those topics that they find most interesting. It is likely that those topics will also be interesting to their students. In biology, for example, there are probably more teachers and students interested in studying ecology than in studying monerans. This interaction between teacher and student interest may be misleading. Lively student engagement in discourse need not be a function of the teacher's behavior; it may simply reflect student interest.

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1. Although the cognitions underlying a teacher's decision to exert tight control over discourse were not a focus of this research, some speculation about these cognitions is necessary in order to qualify the findings. New teachers commonly report anxieties about their command of their subject matter and about classroom discipline (Veenman, 1984). The two may be closely related: for new teachers, subject-matter expertise provides a warrant for the teacher's authority to determine what will be studied and how students will behave. As the teacher matures as a teacher, the rationale behind the warrant for authority-wielding may be broadened, effectively lessening the impact of subject-matter knowledge. This does not mean that control necessarily becomes less important to the teacher, just that it may be driven by a broader spectrum of concerns. In addition, the experienced teacher may develop sensitivity about the controllability of different types of verbal interactions with students. For example, Cooper, Burger and Seymour (1979) suggest that teacher-initiated interactions are more controllable than student-initiated interactions.

2. Findings at the curricular level are presented in detail elsewhere (Carlsen, 1989a). It should be noted that the primary contrasts within this research are within-teacher, comparing the teaching of familiar and unfamiliar subject matter to the same students in the same school. Because the biology curriculum is very broad, none of these new teachers were familiar with all of the topics that they were expected to teach. Teacher subject-matter knowledge was assessed in three ways: a card-sort task administered during a curriculum workshop prior to the school year, interviews on teachers's sources of knowledge (conducted at the end of the school year), and analyses of undergraduate and graduate course transcripts.

3. For each teacher, transcripts were made from audiotape recordings of four lessons on familiar subject matter and four lessons on unfamiliar subject matter. Hence, discourse data can be viewed as coming from a factorial design: 2 lessons x 2 topics x 2 knowledge levels x 4 teachers. For one teacher, two audiotapes (on different unfamiliar topics) were unusable, leaving a total of 30 usable tapes.

4. See Carlsen (1989a, in press).

5. An utterance is operationally defined here as a stretch of speech terminated by a pause of three seconds. This rather mechanical definition is insensitive to the social functions of talk (in contrast to, for example, the treatment of utterances in speech act theory), but provided several advantages in analysis. For example, software routines were easily written to permit looking at discourse from new levels of abstraction (see Carlsen, 1989b).

6. See Carlsen (1990).