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ABSTRACT

This study was an ethnography of high school students working as apprentices in university solid state physics labs, as part of a summer science program. It was designed to explore the learning potential for high school students in such an environment. It examined the social interactions between scientists and students and how these constrain/support learning. Video-taped key laboratory instructional events and student public presentations of what they were learning in their labs were submitted to an interactional sociolinguistic analysis. Findings focused on important discourse links between presentations and lab activities. Students selected a subset of topics from a range of topics covered in lab instruction. Contextualization cues employed by student and scientist to make sense of Lab talk were modeled in the Presentation. Conceptual understanding in Lab was sometimes represented in Presentation appropriately, sometimes vaguely or inconsistently. The speaker's vagueness was usually not apparent to the audience of a Presentation. A learning model for high school students in research labs is proposed based on the findings. The characterization of students learning in university research labs lays a foundation for a match between doing science in such research labs and doing science in school labs. (Author)

Learning Science in the Workplace: Ethnographic Accounts of High School Students as Apprentices in University Research Laboratories.

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Learning Science in the Workplace: Ethnographic Accounts of High School Students as Apprentices in University Research Laboratories.

Abstract

This study was an ethnography of high school students working as apprentices in university solid state physics labs, as part of a summer science program. It was designed to explore the learning potential for high school students in such an environment. It examined the social interactions between scientists and students and how these constrain/support learning. Video-taped key laboratory instructional events and student public presentations of what they were learning in their labs were submitted to an interactional sociolinguistic analysis. Findings focused on important discourse links between presentations and lab activities. Students selected a subset of topics from a range of topics covered in lab instruction. Contextualization cues employed by student and scientist to make sense of Lab talk were modeled in the Presentation. Conceptual understanding in Lab was sometimes represented in Presentation appropriately, sometimes vaguely or inconsistently. The speaker's vagueness was usually not apparent to the audience of a Presentation. A learning model for high school students in research labs is proposed based on the findings. The characterization of students learning in university research labs lays a foundation for a match between doing science in such research labs and doing science in school labs.

A large body of science education literature has established the importance of linking conceptual learning with hands-on experience (Wertsch, 1991; Brown, Collins & Duguid, 1988; Rubba, 1987; Staver, et al., 1987; Yager, 1984; Tamir & Shulman, 1973). Curriculum developers have taken heed of research advice, recommending a strong laboratory component in the K-12 science education framework (Shymansky & Kyle, 1992). Advocates of laboratory-oriented science programs see learning as a dynamic process, involving important elements of discovery and creativity (Tamir & Yager, 1992; Schwab, 1962). Involved in hands-on activity, the student brings prior practical knowledge to bear on new problems, making connections that lead to a clearer and better understanding of the phenomenon in question (Dewey, 1938).

The laboratory has always been the most distinctive feature of science instruction (Tamir, p.c. 1992). The rationale behind the emphasis upon laboratory experience is generally agreed upon by those researchers cited above, as well as most others, that the "collection of data and analysis of real phenomena, is an essential component of the enquiring curriculum" (Schwab , 1962), in that it "gives students an appreciation of the spirit and methods of science, promoting problem-solving, analystic and generalizing ability" (Ausabel, 1966).

A strong response to all this interest in science laboratory learning settings has come from outside the traditional school educational setting. The 1980's and 90's has seen a flurry of activity from the university and private industrial sectors aimed at involving K-12 students in summer science programs at university or industrial research sites (for example: Rose Tree-Widener University program, 1990; Rockwell Engineering mentorship program, 1992). One of the major strengths of such programs is that they embed the K-12 learning experience in a bonafide science laboratory setting: students are doing experiments not in school laboratories that are designed for practice-to-learn activities, but in labs in which scientists are conducting on-going scientific research designed to lead to publications and inventions of new technologies and equipment.

Little is known about how successful these programs have been, since there has been little empirical educational research on them. Such research would provide new insights into the characteristics of teaching-learning processes in science laboratory environments. Because K-12 students are involved, findings could have important implications for school science instruction. Such research could be viewed as laying a foundation for the match between students doing science in science settings and doing science in school settings. Calls for educational research in actual science settings are recurrent in the science education research community (Tamir & Shulman, 1973; Shymansky & Kyle, 1992).

Purpose

This study begins to develop a learning model for high school students in research science labs. It examined the learning opportunities of high school students working one-on-one with scientists involved in on-going research projects in university laboratories. This paper focuses on one student, examining discourse links between communication in the Lab and in the student's public science Presentation. More specifically, I was interested in questions such as:

1. What was the match between topics discussed in Lab and those displayed in a public Presentation by the student?

2. In the Presentation, is there evidence of the student modeling discourse strategies or structuring of topic development that were used in lab instructional talk?

3. Do contextualization cues employed by the student in the Presentation reveal anything about his confidence in understanding a specific topic?

Theoretical Perspective

This research is conducted from a social constructivist perspective that is concerned with how social, cultural, and institutional factors support and/or constrain what is learned and recognized by participants as science. From this perspective, the subject matter knowledge of a particular scientific discipline is not taken as a given object, but rather one that is socially constructed moment-by-moment by participants, and subject to change over time

(Lynch, 1985; Woolgar, 1988; Latour & Woolgar, 1986; Knorr-Cetina, 1981). Ways of discussing, presenting, and doing science can be viewed as constructed through the social interactions of participants (Green, 1992; Santa Barbara Classroom Discourse Group, 1992; Bloome, in press). The way instruction engages students in science influences access to scientific knowledge (Lemke, 1990); the opportunities that students have to learn science (Cochran, 1990); and in the actions of teachers in familiar and unfamiliar content areas of science (Carlsen, 1992); conceptual knowledge development (Roth & Roychundry, 1992).

Method

Design

The study design was a, three phase, topic-oriented ethnography. The phases involved data collection in the laboratory before, during, and after students entered as summer science program participants. The topic orientation was a characterization of student learning in the lab over time. Focus was upon the social interaction between scientist and high school student involved in specific laboratory activities. This study was ethnographic in two senses (Erickson, 1984): it explored issues of learning from the participant's point of view; it characterized how members of the lab established ways of talking and doing science together in order to achieve common goals.

Participants and Setting

This study was carried out at The Center for Quantized Electronic Structures (QUEST) at the University of California at Santa Barbara (UCSB). QUEST is a Science and Technology Center funded by the National Science Foundation. Research at QUEST is focused on the physical phenomena of microscopically small quantum electronic structures, made primarily from semiconductor materials. Eventually the techniques and knowledge developed from this research will be used to create a new generation of electronic and optoelectronic devices.

The participant in this study was a 16 year-old male high school student, one of 12 (five females, 7 males), attending the Apprentice Researchers at QUEST (ARQ) program, which brings high school students and teachers into the laboratories at QUEST to participate in the process of scientific research and inquiry. The high school students and teachers worked as apprentice researchers in collaboration with graduate student mentors, under the supervision of QUEST faculty. As apprentices, they developed specific laboratory skills on sophisticated experimental equipment, as well as first-hand experience of how science research is conducted.

The program is funded by the National Science Foundation through the Education and Human Resources Division. This summer program, ran for six weeks, from July 6th to August 14th.

Data Collection

Data were collected daily during the six week program. I assumed the role of a participant observer (Spradley, 1981; Erickson, 1984) and recorded all events firsthand. Multiple sources of data were gathered, including: audio-visual tape recordings, direct observation field notes, interviews of participants, student log books, student lab books, presentation overheads slides and notes, questionnaires, and various laboratory data printouts and documents. All lab activities were recorded on a Hi-8 camcorder; the high school student wore a Nady HP-180 wireless microphone, transmitting to the camcorder. The student presentation was recorded with two cameras, one focused on the student, one on the audience.

Interactional Sociolinguistics

The ethnography identified key instructional events. Socio-communicative acts in these events were submitted to discourse analysis from an interactional sociolinguistic perspective (Gumperz 1984; Green 1983). Interactional sociolinguistics views learning situations as cultures and teaching/learning processes as socio-communicative in nature (Collins & Green, 1992). From this perspective, as student and scientist work together in the lab over time, they develop: patterned ways of doing things in the lab; common ways of talking about lab activities; shared perceptions of lab results.

The discourse analytic methods employed in interactional sociolinguistcs are based on the assumption that, in instructional situations, the participants are actively cooperating in the discourse to try to understand one another's communicative signals (Grice, 1975). To maintain a sense of mutual understanding about what each is trying to communicate to the other, people are constantly attending to communicative signals from one another. Interpretations of the communicative messages of others involves inferring what the other person is trying to communicate through a range of contextualization cues. Such cues are defined by Gumperz (1986) as:

> any feature of linguistic form that contributes to the signaling of contextual presuppositions. Such cues may have a number of such linguistic repertoire of the participants ... code, dialect and style switching, prosody ...

In other words, such cues are signals that speakers and listeners send or attend to in order to come to a common understanding of what is being talked about. Through tacit awareness of such cues, participants make sense of their interaction with others. This creates the potential for learning.

Interactional sociolinguistics employs a repertoire of discourse analytic methods that is consistent with its theoretical perspective on social interaction. The basic unit of analysis, based on face-to-face interactions, is the message unit, situationally characterized by contextualization cues. From this perspective, pertinent educational questions can be examined such as: who can say/do what, with whom, on what occasions, for what purposes, and with what consequences.

Analytic Procedures

First stage of analysis: transcription.

All lab activities and the student presentation were video-taped. Transcriptions were prepared from these tapes.

Based on the interactional sociolinguistic perspective, a particular transcription system was employed (Gumperz & Berenz, 1990). It attempted to account for most of the perceptual cues that participants use in order to maintain a conversation. It was therefore important to represent such items as pause times, rhythm, prosody, and other paralinguistic features. Besides verbal, non-verbal cues needed to be represented in the transcript, as these were important to the inferential processes that people employed to engage in on-going conversation. Each line on the transcript represented a message unit. An example follows:

t: that's a good one
that's this one?
y: yeah
that's the one
exactly right

Second stage of analysis.

At this stage, more attention was paid to timing in two ways: first, the timing of pauses, and second, the timing placement of non-verbals within the context of the verbal text. The technique of inserting a superscript number 1 at the point in the text where the non-verbal occurred and then inserting the parenthesized non-verbal at the end of the message unit line was employed.

Once the above process was completed, the transcript was reformatted into a table. An example of a Table is depicted in Figure 1.

Insert Figure 1 about here

Line numbers have been added in column one for reference purposes. Speaker is designated in the next column. Columns three and four contain the transcript broken up into message units and the associated non-verbals respectively. Each square in the next column corresponds to one message unit. This technique facilitates subsequent analytic steps. The final blank column provides space for analytical, methodological, and theoretical notes.

Table in hand, relevant segments of audio-video tapes were reviewed several times, the researcher noting "interaction units". They are determined by contextualization cues in this sense: the manner in which a speaker delivers a message unit can suggest (by intonation, pitch, etc.) that the next message unit is tied to it. Such tied message units are referred to as interaction units and represent the the next larger analytic unit based on the message unit. These interaction units can be composed of one or a series of message units.

The next larger analytic unit is called a sequence unit. Sequence units are not determined by the contextualization cues as are message units and interaction units. They are determined by the content or topic of conversation. A shift in the general topic being discussed would indicate the boundary between sequence units. Sequence units are an important analytic link between the contextualized talk and the content (topic) being developed in that conversation.

Sequence units are linked together to form phases. Phases are complete parts of an instructional event in terms of their purpose and content; they are thematically tied. Particular kinds of instructional work are accomplished in a phase. The various phases in an instructional event will form the whole "lesson" or in the case of a presentation, a complete "explanation" of something the speaker wanted to get across to the audience.

Once these analytic units had been established, the Table was updated, indicating where the interaction, sequence, and phase units began and ended in table columns designated for this.

Third stage of analysis.

Through examination of transcription Tables, I began to see important links between key instructional Lab events and subsequent student Presentations. Links were made visible first by comparison of the overall topic structure of each event, and more distinctly by comparison of the message by message interaction in the transcribed talk of each. As links were established, they were collected into a third research document, a Link Map. An example of one is shown in Figure 2.

Insert Figure 2 about here

The linked message units were chosen by careful consideration of the ethnographic context in which they occured. This required triangulation of fieldnotes with transcript tables for each linked event. The linguistic content and contextualization cues suggested strong connections between the two. From this analytic representation, it is possible to tease out supportable interpretations about how the communicative acts in the event that took place later in sequential time were connected to the communicative acts in a prior event. This is as far as I needed to carry the analysis in order to inform the questions in this study. It is conceivable that the analysis could be carried on further at either more micro or macro levels.

Results

Upon working through the entire corpus of collected data, I found four sets of events that could be distinctly linked through the analytic procedures outlined above. These sets of events are closely related to what Mehan (1982) called episodes, chunks of instructional discourse that group together to form a cohesive topic development unit. I will present evidence from one such episode to illustrate interpretations. Representative findings consistent across all four episodes will then be outlined indicating implications to theory and practice.

The EELS Episode

Background

EELS is an acronym for Electron Energy Loss Spectrometer, an instrument used extensively in surface science research. Its job is to take pictures of how molecules are bonding to metallic surfaces: these pictures are called spectra, and look similar to EKG graphs with peaks stretching out across the page. Interpretation of what these peaks mean is the main task of the scientists in this lab.

The high school student, whom we will call Tony (t) worked in a laboratory with two of graduate student scientists, Brian (b) and Jon (j). The EELS Episode links Tony's public Presentation (15 minutes in duration) of what he had learned about a laboratory instrument called by acronym, EELS, to three prior key laboratory instructional events, two with Brian of 55 and 41 minutes duration each (Event 1, Event 2), and one with Jon of 60 minutes duration (Event 3). The three Lab events took place on the two days to the preceding the Presentation.

Presentation

In his Presentation, Tony read verbatim from overhead projector (OHP) transparencies for 170 message unit lines out of a total of the 387 message units that composed the main body of his talk (excluding his acknowledgments and questions & answers sections). This represents 44% of the total delivered presentation in terms of message units of talk. Talk based on the OHP transparencies, but not read verbatim, made up about 10% of the talk. The remaining 46% of the talk was directly related to "point to and describe" tours of two transparencies of schematics.

Event 1

The first linked Lab Event (Event 1) took place two days before the presentation: participants were Brian, Tony, and myself. One of the most notable features of Brian's instructional talk with Tony is the extensive use of schematic diagrams, drawn freehand on notebook paper, to help illustrate his explanations of theoretical concepts behind the EELS; ninety-five percent of the talk was directly supported by Brian's illustrative drawings. The predominant proxemic during the entire event was Brian and Tony seated at Brian's desk, side by side, bent over paper and pencil supported explanation.

Event 2

The second Lab Event (Event 2) took place the next day involving the same participants. The talk took place primarily (95%) at Brian's desk, with Tony seated beside him, while he read over Tony's computer printed notes for his presentation, made written comments on them, and sometimes elaborated theoretical points using hand-drawn schematics on notebook paper or in the margins of the note sheets to help support them.

Event 3

The third Lab Event (Event 3) involved Jon, Brian, and myself. Talk was mostly built around Tony's proposed Presentation slides and notes. This event was intended by both Jon and Tony to be a rehearsal of Tony's Presentation. Tony ended up rehearsing about 25% of the time, while Jon further elaborated/clarified/ extended various conceptual points to be covered in it. Ninety percent of the talk was directly supported by OHP slides or paper & pencil diagrams and/or notes of explanations. The 10% of the talk not so supported were pointers from Jon on how to relax and deliver the Presentation from a psychological point of view.

Perceived Purpose of Events 1, 2, 3

Brian's mentoring was initiated by the expressed purpose of helping Tony learn more about how to interpret an EELS spectrum, how electrons actually gave up energy to surface vibrations on both a practical and theoretical level, and particular advice on how to explain things in the presentation. Brian perceived his task as providing Tony with a technical understanding of both the theory behind and the hands-on interpretation of an EELS spectrum. Jon's mentoring built upon Brian's, as it followed on the same day and had the same overall goal of helping Tony prepare for the presentation. Jon helped in clearing up specific questions Tony still had about spectrum interpretation; he perceived his main role as that of helping Tony construct the format of that knowledge. This is evident in the types of talk and activity apparent across events.

Links

The Link Map for this Episode, illustrates the message unit-by message unit linking of Tony's presentation to Lab events. This is a useful representation for tracking topic coverage, documenting important supportive and constraining features, and foregrounding inconsistencies in content information across events. The entire Link Map ran for 557 message unit lines and covered 44 pages. Two representative examples that demonstrate different interpretations made possible by examination of Link Maps will be illustrated here.

Link Map: Example 1. Figure 3 contains a segment from a section of the Presentation that had been introduced as "How does EELS function". Lines 155 - 167 were read verbatim from an OHP slide titled just that.

Insert Figure 3 about here

Firstly, where did the words represented on this read off slide in the Presentation come from? Lines 156 - 159 come from a textbook about EELS, by Ibach, a famous surface scientist. Jon had given this book to Tony early in the program, and he had extracted these words from the introduction to that text. It is notable that "thermionic emitter" and "electrostatic energy selector" were never subsequently explained in the presentation. Also, both Brian and Jon had advised Tony not to use "a lot of scientific jargon" and "bore the pants off them", rather to "explain things basically" in "your own Tony speak": these lines demonstrate that this advise was not always heeded. Lines 160 - 167 were derived from mentoring in Lab Events.

Looking at the Lab column, lines 155 - 158, Brian's explanation of the flow of electrons through the EELS device, though similar in form, uses different technical terms: "cathode" instead of "thermionic emitter", "lens system" instead of "electrostatic energy selector". "Electrostatic" was employed by Brian to try to explain the forces acting upon electrons passing through the EELS: he subsequently gave up this attempt and explained things in what he perceived to be easier to understand terms such as "bounce", "electron", "lose energy", "scattering". Lines 160 - 163 demonstrate close modelling of Brian's "mentoring talk" in Tony's "presentation talk".

What Tony understands conceptually about EELS cannot be determined solely from looking at the Presentation transcript. This segment of the Presentation, entitled "How does EELS function", introduced several terms and some explanation: it avoided the fundamental explanation of how EELS functions, by not mentioning the quantum mechanical theory behind it. Lab members considered this knowledge important; Brian and Jon spent an extraordinary amount of time and effort explaining it to Tony. Fundamental to how EELS operates is the concept of energy loss: energy lost by electrons travelling from the EELS device, hitting the surface of interest, and coming back into the EELS device to be analyzed. How the electrons lose energy is explained by quantum mechanics. Tony mentioned the word "quantum" or "quantum mechanics" exactly zero times in the Presentation. The scenario of electrons bouncing off the crystal and losing energy was discussed explicitly, 33 times, by Brian and Jon.

Tony does return to the subject of energy loss later in the Presentation in a section that aims at explaining what can be learned from studying an EELS spectrum. He says "*the electron can bounce off (the crystal) elastically* that is uhm losing uh no no energy or *it can excite the uh molecule from a ground state to an excited state in which it does give off energy*". The italicized words were read verbatim from a slide. This would have been a good start in the earlier section on "how does EELS function" to the quantum mechanics explanation. Furthermore, the mention of technical terms such as "excited state" and "ground state" without explanation of what these mean is noticeably inappropriate to the aim of explaining things to the audience. Evidence for the hypothesis that Tony's struggled repeatedly with his understanding of Brian's explanation of quantum mechanics is supported by his question patterns during Lab Events. For example: at the end of a 107 message unit long explanation of quantum mechanics by Brian, in response to Brian's prompt "do you understand", Tony responded: "I uh kind of understand" (spoken with little conviction in his tone of voice). This led to another extended turn of talk by Brian to explain it one more time (1 of 11 such repetitions), followed by another such response from Tony.

This example of something missing from the Display is not meant to build a case of "badly learned" science, or "badly presented" science. The point is that what can be displayed in a presentation, as learned conceptual understanding, is usually judged by what can be seen and heard. The important things that may be missing may not be evident at all to those listening to such a presentation. The missing items may not be marked by contextualization cues or by interruption of the logical development of topic in the talk. This may not be a problem for an instructor or classroom teacher that has participated with the learner in co-constructing prior instructional activities: it can certainly be misleading to interested others attending a presentation.

Link Map: Example 2.

This example involved a different mentor, Jon. It implicitly illustrates some of the instructional problems involved when more than one person is giving instruction on the same topic at different points in time. This segment of the presentation took place about half way through the talk. The Link Map for Example 2 is illustrated in Figure 4.

Insert Figure 4 about here

This talk is tied to a point-and-describe context in which Tony explains an EELS spectrum specifically for the case of CO (carbon monoxide) on ruthenium. This is a classical surface chemistry experiment. Its purpose is to examine how CO bonds to the surface: it is not intended as a study in reaction mechanisms. This is the key point that alludes Tony. He has confused the aim of Brian and Jon in using EELS to examine new reaction mechanisms between various chemicals on various surfaces with this specific spectrum which is not aimed at such experiments at all. In the Presentation, Tony explains that he chose this example because of its simplicity, and therefore ease of understanding. By using the word "reaction" in line 317, he has caused confusion for himself. Jon has used the same term in describing it as a "basic reaction", as can be seen at the top of the Lab column: this talk comes early in Event 3. Brian, however, had earlier made it clear, in Event 1, that studying CO on ruthenium was not a reaction system/mechanism study, but rather a characterization study aimed at examining adsorption sites only. Tony's comments given here are representative of comments he made throughout the entire instructional sequence on this topic. He gives clues, especially in his "this is one step" that are not picked up by Brian as confusion in understanding. Because they are not followed up, Brian finished his explanation and Tony let it rest, without a final attempt to ask a pertinent question about it. Thus, the confusion on this topic was never resolved in Events 1 or 2. Jon's unintended reinforcement of the idea of CO on ruthenium being a reaction study is the most recent instructional event before the Presentation. This pattern of topic development across Events involving different mentors provides some support for the hypothesis that most recent instruction has the greatest probability of finding its way into the Presentation in the form given in that instrúction. At any rate, Line 321 ties back to the hands-on point and explain of the schematic at hand, and gets Tony smoothly back under way of explaining CO on ruthenium EELS spectrum peak details. The remainder of this topic proceeds successfully along these lines, closely tied to the schematic. As no questions were later asked at the end of the presentation about why CO on ruthenium is studied, this vague connection on Tony's part did not upset the presentation in a noticeable manner.

Findings

• **Finding 1: The student selected a subset of topics covered in Lab to talk about in the Presentation.**

While it would be expected that the time constraints in a Presentation event would necessitate a speaker's selecting a subset of possible topics to cover, there is more to the finding than this (Gage, 1991). Examination of Presentation-Lab discourse links revealed that such selection was related to speaker self-perception of conceptual understanding of particular topics. Student and mentor interview data and analysis of Presentations for all 12 high school students support that this principle behind selection was consistently evident.

Given insider firsthand knowledge of the instructional activities preceding a Presentation, examination of topics represented in a particular talk could signal areas of weak or strong conceptual knowledge. This has direct implications for the classroom teacher. It is not uncommon to require high school students to deliver class presentations as part of course requirements. Teachers generally assess such presentations on overall impressions received in listening, or sometimes with a pre-designed scoring sheet. Such assessment focuses on the manner of delivery (i.e., smoothness of style), and accuracy of information presented. This finding suggests that teachers may be able to obtain valuable diagnostic information from examining presentations by

Presentation-Lab considerations of topic development.

- Finding 2

A. Contextualiztion cues employed by student and scientist to make sense of instructional talk in lab were modeled in the student's new role of "presenter of knowledge" in the Presentation.

B. The overall structure of topic development in the Presentation modeled that of instructional talk in the Lab.

C. In the Presentation, the student tended to model the scientist's choice of visual aides, and mode of employing these in explanations.

This finding covers three aspects of modeling: 1)modeling of the contextualization cues (signaling system) used in the Lab setting; 2) modeling of the structure of topic development constructed in the Lab; 3) modeling the scientist's choice and use of visual aides to support Lab explanations.

Modeling as an active principle in learning has been studied extensively (Perrett-Clermont, 1980). A Vygotskiian approach to learning environments urges teachers to provide substantial modeling, especially designed to scaffold the learner in the zone of proximal development (Cole, 1985). In my own teaching practice, I have found modeling activities for students to be an effective method to promote learning. Also, it was a fairly common observation in my classes to see many examples of students modeling my activities and strategies in the classroom, laboratory, and field.

It was confirmatory to the above experience to note that, in this study, students modeled both their own laboratory communication signals and those of their mentors in their Presentations. At first glance, this finding appears fairly trivial: don't we usually signal our communicative intent in much the same manner in all situations? Well, surprisingly, research[1] indicates that people employ a different repertoire of contextualization cues for different social situations: a student will talk in a much different register and style in talking with a mentor informally one-on-one than when talking to an audience formally one-to-many. It is always surprising and interesting to hear a student for the first time giving a formal public talk: how differently they talk!

This in mind, instances of speaker's employing the same contextualization cues in formal talk, observed in lab informal instructional laboratory talk with the mentor are foregrounded: they stand out against the background of the more dominant "formal talk" cues. Such instances were most often linked to two situations: explicating details of a schematic diagram or data summary

[1] A large corpus of studies from Conversational Analysis (see for example, Atkinson & Heritage, 1984), and sociolinguistics (see for example, Gumperz, 1984) support this contention: people use different repertoires of contextualization cues in different discourse situations.

graph/table; presenting an analogy to explain a difficult theoretical issue. Examination of the links between Presentations and Lab revealed that schematics and analogies presented in student Presentations were those emphasized by mentors in Lab. Perhaps, because of this emphasis, the contextualization cues employed by mentors and/or students when engaged in the extended instructional talk around these discourse topics were strongly tied to the topics for the student. This tying would have the natural consequence of the student employing Lab contextualization cues when explaining the same items to an audience in the Presentation. Certainly, student presentations of analogies and schematics were marked by noticeable changes in contextualization cues.

Sequencing of topics in Presentations generally modeled that of Lab: students usually presented the sections of their talk in more or less the same order as they were presented by mentors in Lab. This is not so surprising, if one considers that the Presentations involved the student in trying to explain some rather technical and difficult to understand science topics. Scientific conceptual instruction traditionally involves a pyramidal approach (Tamir, 1992): learning a fundamental concept leads to more complex concepts based on the previous ones. Since the mentors in this study received their science instruction in this manner, it is not surprising that this was their strategy of choice when instructing the high school students. Interviews with the students revealed that they were quite used to this same strategy in their school science courses. It is not difficult to explain why this sequential, pyramidal topic development was modeled by students in their Presentations.

Experimental approaches to topic development have been tried in short-term research.[2] It would be interesting to extend these into longitudinal studies: cost and tradition are tough barriers to overcome.[3]

Teacher explanations are commonly rich in analogy (Clement, 1986): inclusion of visual schematics to support talk varies across content areas, but is noticeably present in science classrooms. Usually a visitor to a classroom can ascertain that it is a science classroom by the charts, graphs, models, equipment, and other visuals present. These visuals are pointed to and talked about by the teacher when explaining science to the class. Teachers are generally aware of the importance of visuals in understanding science concepts. It is a common classroom activity for students to meticulously replicate and/or label the parts of a diagram (for example, most of us have had the classroom experience of filling in the lines with names on a diagram such as bones of the human skeleton).

This finding suggests that it may be important to develop, in both students and teachers, the skill of increasing their awareness of how they are talking about a particular topic: especially, when

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[2]Pinchas Tamir, 1992, personal communication.
[3]George and Louise Spindler, 1991, personal conversation.

that topic is being developed around a visual aide. At present, most classroom attention is placed on aspects of conceptual knowledge: description, analysis, synthesis, interpretation, judgment, etc. Increasing awareness of the contextualization cues that are being employed in instructional talk would lead, hopefully, to clearer communication of the conceptual knowledge that is intended as an objective of the activity. It is now well documented that poor communication is the result of a mismatch between speaker intention and listener inference (Gumperz, 1984; Tannen, 1986)

- **Finding 3**
  A. Conceptual understandings in Lab were sometimes represented in the Presentation appropriately, sometimes vaguely or inconsistently.
  B. The speaker's conceptual vagueness or inconsistency was usually not apparent to the audience of a Presentation, except as revealed through the speaker's choice of contextualization cues.

This finding presupposes that the observer has the necessary level of content knowledge in order to make the judgment about conceptual understanding demonstrated by a speaker. Besides this, it is necessary have knowledge of what and how a student was instructed lab to the Presentation. Given these two prerequisites, Presentations are ideal opportunities to diagnose learning difficulties arising at a particular point in time for a student.

In classroom instructional activities, teachers can diagnose problem areas partly by student talk during class meetings, especially from the types of questions asked and responses offered by students to teacher questions. The problem is that generally science teachers perceive their role as presenters and organizer of information: the lesson is designed to get information across, not an occasion to diagnose student conceptual understanding (Gallagher, 1989).

In agreement with work by Lemke (1990), this finding suggests that teachers could learn a good deal of information about their students' conceptual understanding on a moment-by-moment basis if they paid close attention to student talk during lessons. Implementation of such a suggestion would require a major shift in purpose for classroom talk in the case of the majority of science classes.

Occasions of obvious loss of continuity in a talk often signaled to the audience that the speaker was approaching unfamiliar or weakly understood conceptual territory in the talk. More interestingly, the audience was unaware (as far as can be inferred from careful observation of audience affiliation signs) of conceptual vagueness that was not accompanied by such signaling contextualization cues.

Such a finding is somewhat disconcerting, as it implies that as long as a speaker can deliver a talk smoothly and in an interesting manner, there is a strong chance that the audience (assuming they are not knowledgeable in the subject) could be mislead by incorrect information. However, this would normally not be a real issue in the science classroom setting, in which the teacher usually knows enough about the topic not to be misled. In this case, it would be valuable for the teacher to note areas of vagueness or inconsistency and provide feedback to the student that could repair the problem area. It would also be necessary (though politically tricky) to assure that such presented inconsistencies were corrected for the class audience so as not to set them off in the wrong conceptual direction.

Conclusions and Future Research

The high school student and lab scientist co-constructed an instructional state of affairs with the common goal of gains in conceptual knowledge/lab skills. The process was fundamentally communicative: scientist and student actively attending to one another's contextualiztion cues in a effort to arrive at a common understanding. Post interviews with all twelve student program participants, their mentors, program coordinators, parents and teachers (involved in the program) indicated a consistent perception that students had gained substantial conceptual knowledge, lab skills, interpersonal skills, communication repertoire, more positive attitudes towards science, scientists, and doing science, and an appreciation of the connection between science research and technology.

It is not enough to simply give the student the opportunity to work with equipment in the lab setting. Findings indicate that the social interaction between student and scientist is critical to successful student learning in the research lab setting. Immediate future research plans are to examine student-scientist interactions across more participant dyads during the next summer science program in order to develop a viable teaching-learning model for such settings.

Because the participants were high school students, this study demonstrates a broad range of scientific conceptual knowledge, laboratory skills, and discourse repertoire which they are capable of expressing and demonstrating quite conclusively, given the opportunity.

More direct links between high school students learning in science work settings and school need to be developed and studied. This study seeks to lay a foundation for the match between doing science in research labs and doing science in school labs.

Figure 1. Table

007	T:	that's[1] a good one	1 Tony now looking at the schematic.	☐
008		that's this one?		☐
009	Y:	yeah		☐
010		that's the one		☐
011		exactly right		☐
012	T:	except there's nothing[1] on the bottom though	1 Tony notices the schematic differs from the actual pump	☐
013	Y:	uh yeah		☐
014		we're missing the heater		☐

Figure 2. Link Map

	Presentation	Lab Event
100	t: and the heater heats up the oil	(p3) when you heat it up okay
101	and then the oil vapor like	the oil vapor come up
102	rises to the top of	becomes like a steam okay
103	this thing right there	y: but it started as vapor not not oil okay?
104	and shoots out	then it just shoot

Figure 3. EELS Episode: Presentation-Lab Link Map

(t=Tony; j=Jon; b=Brian; aud=audience)

line#	Tony's presentation	Lab Instructional talk
155	**t:** a low energy beam of electrons	
156	uh flows from a	**b:** the electrons pass through here
157	thermionic emitter	and this is basically just (.) uh
158	and passes through an electrostatic energy selector	you know electrostatic
159	which focuses on the crystal in the chamber	
160	the electron beam bounces off the surface	**b:** but however some electrons= =as I was explaining to you
161	with some electrons losing energy	actually do interact and give up energy
162	to surface vibrations	to surface vibrations
163	and the scattered beam is then collected in the	**b:** ... the scattered
164	detector	
165	its given and uh	
166	an elec	
167	electron energy loss spectrum	

Figure 4. EELS Episode: Presentation-Lab Link Map

(t=Tony; b=Brian; j=Jon)

line#	Tony's presentation	Lab instructional talk
312	**t:** this is uh carbon monoxide	**j:** why are we interested in carbon monoxide on ruthenium
313	on ruthenium=	and its because its a very basic reaction
314	=and why	and by studying this reaction we can know the
315	I chose this	inter-how is the molecule interact with the surface
316	is its a	
317	fairly uhm simple reaction	**b:** this is very simple this is
318	that takes place	**t:** yeah small
319	its kind of	**b:** yeah
320	its easy to understand	this is just looking at characterizing
321	and uhm	carbon monoxide adsorption site
322	you can tell by looking at this	how it adsorbs and how it
		t: this is one step
		b: yeah that's yeah but see

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