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Natural Pedagogical Conversations in a High School Students' Internship

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Abstract: Many science educators encourage student experiences of ''authentic'' science by means of student participation in science-related workplaces. Little research has been done, however, to investigate how ''teaching'' naturally occurs in such settings, where scientists or technicians normally do not have pedagogical training and generally do not have time (or value) receiving such training. This study examines how laboratory members without a pedagogical background or experience in teaching engage high school students *during* their internship activities. Drawing on conversation analysis, we analyze the minute-by-minute transactions that occurred while high school students participated in a leading environmental science laboratory. We find that the participation trajectory was based on demonstration-practice-connect (D-P-C) phases that continually recurred in the process of ''doing'' science. Concerning the transactional structures, we identify two basic conversation patterns—Initiate-Clarify-Reply (I-C-R) and Initiate-Reply-Clarify-Reply (I-R-C-R)—that do not only differ from the well-known Initiate-Reply-Evaluate (I-R-E) patterns previously observed in science classrooms, but also could be combined to constitute more complex patterns. With respect to the organization of natural pedagogical conversations, we find that there were not only of *preferred* and *dispreferred modes* of responding but also *ambiguous dispreferred modes*; and the formulating organization not only includes *self-formulating* but also *other-formulating*. These natural pedagogical conversations helped, on the one hand, students to clarify their understanding and, on the other hand, technicians (or teachers) to teach toward different needs for different students in different contexts. © 2008 Wiley Periodicals, Inc. J Res Sci Teach 00: 1–25, 2008
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Introduction

The American Association for the Advancement of Science (AAAS) and the National Research Council (NRC) have argued that K-12 science education needs to move beyond didactic instruction to a more constructivist, inquiry-based pedagogy in which students engage in ''authentic,'' long-term science investigations (AAAS, 1993; NRC, 1996; Soloway et al., 1997). The term *authentic* here is meant to denote forms of engagement that have a considerable degree of family resemblance with what scientists and technicians in science-related fields really do in their daily work. Some science educators interested in providing their students with ''authentic'' experiences therefore create opportunities for middle and high school students to work at the elbow of scientists and technicians in science laboratories (Barab & Hay, 2001) or at the elbow of environmentalists (Roth & Lee, 2004). Authentic science activities are important in promoting inquiry

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because they provide natural problem-solving contexts that exhibit a sufficiently high degree of complexity to make them interesting (Lee & Songer, 2003). Internships in science research settings and internship-like learning environments have received increasing attention as a means of helping students construct and appropriate understandings, practices, tools, and language used in scientific activity (Varelas, House, & Wenzel, 2005).

Existing studies conducted with middle and high school students focused on students' understanding of the nature of science and scientific inquiry (Bell, Blair, Crawford, & Lederman, 2003; Richmond & Kurth, 1999), attitude toward and interest in science (Abraham, 2002; Gibson & Chase, 2002), and evaluative criteria for characterizing the internship experiences (Barab & Hay, 2001). Most of these studies of student internships in authentic science settings used surveys or follow-up interviews to examine the impact participation in these settings had on students. However, little research has been carried out on the minute-by-minute transactional patterns involving students and laboratory staff. Instead of using the term ''interaction'' which is used to describe what happens when two, analytically independent persons do something together, we use the term ''transaction'' which does not take interlocutors as independent entities but takes the conversation itself a unit that is constituted by participants in particular contexts (Roth & Middleton, 2006). The purpose of this study is to investigate the participation trajectory, transaction structures, and natural organization of conversations of a science internship in a university science laboratory. In these settings, which normally are oriented toward the production of scientific knowledge, most scientists and technicians have no educational training and pedagogic background. How they ''teach'' what they know and what they do to high school students and how high school students learn science from non-teachers in the informal setting are the central issues of this study.

Background

Prior to the appearance of schools, natural (rather than formalized and formal) forms of teaching occurred through craft apprenticeship (Goody, 1989). With formal schooling, direct teaching has taken over as a way of ''transmitting'' cultural knowledge. However, in recent years apprenticeship has been used as a metaphor for guiding the design of science learning environments. In this case, because the focus is on knowing more generally, researchers use the term *cognitive apprenticeship*, though learning to do laboratory work also involves a lot of practical craft knowledge. In apprenticeship, novices advance their skills and understanding through participation with more-skilled partners in culturally organized, ongoing real (rather than simulated) activities (Rogoff, 1990). Apprenticeship thereby offers direct exposure to the realities of the actual workplace and, in this, facilitates the emergence of skills, problem solving techniques, knowledge, and language of practitioners in the context of everyday out-of-school practice (Roth, 1995). In terms of the developmental trajectory that apprentices undergo on the job, they mostly follow a path from the less complex aspect of work to those aspects that are more complex. A study of navigation, for example, reveals that most quartermasters learn what to do and how to do it while on the job (Hutchins, 1993). To advance to higher ranks, the newcomer works through a set of formal job assignments that cover the full spectrum of navigation practice. Their assignments must be reviewed and approved by a supervisor before the student can progress to the next rank in the rating.

In contrast to other learning theories that conceptualize knowing in terms of declarative and procedural knowledge stored in the brain, apprenticeship focuses the attention of learning theorists on *participation*, which we understand as constituting a centermargin dialectic where each moment of practice is understood as both central and marginal to the practice (Goulart & Roth, 2006). Learning on the job frequently is characterized by developmental trajectories as newcomers increasingly become knowledgeable and can take on more complex tasks. The concept of the *participation trajectory* is generally used in two ways (Strauss, 1993): (a) the course of any experienced phenomenon as it evolves over time and (b) the actions and transactions contributing to its evolution. That is, phenomena do not just automatically unfold; nor are they straightforwardly determined by social, economic, political, cultural, or other circumstances. Rather, they are shaped in part by the transactions that bind the concerned actors. The idea of a participation trajectory has been employed in investigating how these cultural means intersect in productive and less productive ways during the students' conceptual practice (Krange, 2007) and how students' agency is related to a highly structured, open-ended, and technology-rich learning environment (Rasmussen, Krange, & Ludvigsen, 2003).

Didactic conversations often follow patterns that are characteristic of the activity system as a whole. For example, a common dialogue structure in modern education, well known to teachers and students, is the three-part exchange structure referred to as *triadic dialogue* (Lemke, 1990), constituted by a teacher *initiation* turn, followed by a student *response* turn, and completed by a teacher *evaluation* turn (Mehan, 1979). Some researchers refer to the same structure and turn-taking routine as *Initiation-Response-Follow-up* (Sinclair & Coulthard, 1975). The same basic triadic dialogue (i.e., I-R-E or I-R-F) can take a variety of forms and may be recruited by teachers for a wide variety of functions, depending on the goal of the tasks that the discourse serves to mediate and, in particular, on the use that is made of the follow-up move (Nassaji & Wells, 2000).

In this study, we draw on conversation analysis (CA) to assist us in identifying natural pedagogical conversations during the apprenticeship-like internship in a scientific laboratory. Conversation analysis is a method that was designed to allow investigators to find out what is being done in a particular natural setting by carefully attending to the meaning-making resources that transaction participants make available for one another and use to accomplish what they are in the process of doing (Sacks, Schegloff, & Jefferson, 1974). The aims of CA are to uncover and describe the underlying "machinery" that enables participants to achieve conversational organization and interaction orders and to discover how participants understand and respond to one another in their turns at talk. We understand transactions as being shaped by and producing/renewing the context. In this context, conversations cannot be understood as being put together by independent contributions but that the conversation is the unit that constrains what participants can say and how they can say it.

Preference and *formulating* are two of the central analytical concepts in CA. For the conversation organization-*preference*, there is a bias intrinsic to many aspects of the organization of talk that is generally favorable to the maintenance of bonds of solidarity between actors and that promotes the avoidance of conflict (Heritage, 1984). When alternative responses are possible, *preferred* actions are normally delivered without hesitation and are frequently used to support social solidarity; *dispreferred* actions are generally accompanied by hesitation, are often prefaced by markers such as "well" and "uh," and are usually expected to be accounted for by the respondent. For instance, the preferred response to an offer or invitation is acceptance and the dispreferred response is refusal; for self-deprecation, the preferred response is disagreement and the dispreferred action is agreement. *Formulating* is a pervasive conversation feature of talk in transaction and is about what is being done and what has been done (Roth, 2005). For example, responding to a question by saying "I have to think about it" and then staring up in the air as if thinking is a typical instance of formulating *what* the person is doing while doing it.

Study Design

This study is part of a research program concerned with the development of scientific literacy, which, in our project has been promoted both through participation in everyday environmentalism and through internships in scientific laboratories. There are 13 high school students who participated, in groups of three or four individuals, in the 2-month internship. In this article we particularly focus on how their transactional conversations made teaching and learning happened in the internship. In the following sections, we report our ethnographic observations both in the high school classroom and the science laboratory conducted before high school students' internship participation, and further describe the nature of the internship, our data sources and analysis.

Ethnography of School Science and Career Preparation

To better understand what and how students learn during authentic experiences, we conducted an ethnographic study in the school prior to the students' realization of the internship opportunity. We observed their biology lessons and their career preparation course for a period of 22 lessons (1 month). The high school students attended a public school in a mid-sized Canadian city where they were enrolled in an 11th-grade honors biology class (28 students). Twenty out of these 28 students also participated in a biology career preparation course integrated into the same course. The career preparation students normally used extra school time to participate in various science activities to complete the career preparation course, which requires the completion of 100 course-related hours over 2 years (11th and 12th grade). Students normally relied on the biology teacher to get information about science activities and count on her arrangements to participate in them. The internship activity in this study was one of their career preparation course activities.

The teacher involved in this study had 26 years of teaching experiences and was the head of the science department. In this course, she guided students to learn biology through lectures, experiments, demonstrations, etc. She also used multiple resources to buttress her teaching, including videos, microscopes, dissection equipment, textbooks, overheads, chalkboard, and newspapers, etc. In addition to teaching 11th-grade biology, the teacher arranged and conducted a variety of scientific activities in which students can participate. To ease her task, the school released her from one course of teaching. There were many career preparation courses in this school, including in the arts, carpentry, human services, and music. The biology career preparation course in this study was the only academic career preparation course that relates to fundamental science (e.g., biology, physics, chemistry, and math) in the entire district (eight high schools in this school district; some of the high schools in the suburbs had science and environment programs). The career preparation course was funded by the school district, allowing the school to finance some student learning resources, such as science magazines, microscopes and bus tickets for visiting science laboratories.

Ethnography of the Scientific Laboratory

Meanwhile, to understand the events when the students would join the lab, we conducted a 6-month ethnographic study of the biology laboratory. To deepen our understanding of the scientific work and everyday life in the university laboratory, the chief scientist and head of the laboratory became part of our research team for validating or cross-referencing our observations. We observed scientists' and technicians' weekly and monthly meetings and their work in the laboratory for 6 months to better understand their work and establish a relationship of trust. We followed respectively the four scientific projects that high school students would participate in later to better understand the respective science work. The biology laboratory cooperated with many partners (e.g., the city), funding agencies, and researchers at other universities to investigate the environmental parameters of drinking water supplies.

The laboratory members included the chief scientist and head of the research program, a laboratory manager, three scientists, five postdoctoral fellows, one administrative assistant, 28 technicians (e.g., field managers, research assistants, graduate students et al.), and a large and more frequently changing number of undergraduate co-op students. Technicians were the main contacts for the high school students throughout the internship. Most technicians were in their 20s or 30s and have biology-related majors. Technicians usually worked in the laboratory for 8 hours a day and had lunchtime and coffee break time and sometimes collected samples in the field. There were many different projects going on at the same time and technicians often went back and forth in the laboratory to use different equipment and instrument for their work, or even went to other laboratories for different instrument if necessary. The atmosphere in the scientific laboratory was energetic and collaborative. For instance, music is playing in the background during laboratory work, members chated over lunch or coffee, and lab members had celebrations on special days such as dressing in Halloween and holding Christmas party in the laboratory.

Participants and Participation

The high school students who were interested in participating in the project voluntarily came to the laboratory in groups of three to four students. We organized the first meeting for these high school students, scientists, and technicians to discuss the scientific projects, negotiate time schedules and discuss the scientific work in preparation for the internship in the university scientific laboratory. After meeting with the scientists and technicians, students made their own arrangements and, after school, took the bus to the university biology laboratory. This group of 13 students participating in the internship was composed of two male and 11 female students. Each group followed one or two technicians to learn science knowledge and to practice science techniques of the ongoing scientific projects and spent about 6–12 hours in the science laboratory (10–16 hours total for the entire internship) during the 2-month period. Normally students started the internship by reading relevant scientific papers selected by the technicians. They also participated in discussions and scientific seminars; and they practiced particular techniques in respective science projects in different laboratories or collected samples from the fields. After the internship activity, the students presented their experiences and what they learned during the internship to the an audience of about 50 individuals including laboratory members (scientists, technicians, and university students), their biology teacher, other high school students, and staff from our research center.

The chief scientist and the laboratory manager (scientist) supervised all the internship activities during the 2 months. The scientists selected four scientific projects closely related to everyday life for the internship. These projects focused on (a) tracking bacterial sources in surface waters (the demonstrative group in the paper); (b) tracking chemicals in aboriginal seafoods (the supplement group in the paper); (c) determining pharmaceuticals products in municipal wastewater; and (d) designing household biosand water filters. Before the arrival of the students, scientists communicated the internship structure and time schedule with the high school biology teacher and discussed the ways of guiding the students with the technicians. Technicians designed an internship plan beforehand and discussed the feasibility of the plan with the scientists. The technicians had no pedagogical training background. When these technicians needed instruction or help during the internship, they approached the scientists for advice. The purpose of the internship from the scientists' and technicians' point of view was to demonstrate regular work in laboratories, to show the connection with and application of scientific knowledge to daily life, and to provide some scientific practice for high school students. The intentions of the laboratory members are evident in their comments: "I would like them to see the overall picture," "I would like them to learn, like how science is done, how we develop scientific questions, and once we have the question how do we go about researching them . . . what this science means for science itself but also for human health and well-being and their life."

Our post-interviews with scientists and technicians confirmed that from their perspective these objectives had been achieved. Some of the typical comments included: "I think that they had a pretty good understanding of the concepts, and what was happening for sure," "I was surprised at how well they were able to put it into context, I was surprised when they started talking about debt relief and all this other kind of stuff I was like okay that's awesome, she has a good idea of the bigger picture," "I think they got very excited about how we develop questions, and then go about addressing the question, I think they understood most of the science we are doing, and how we actually do science, and I think most exciting part was that how those small things you are doing could have a big impact in a long run."

Data Sources and Analysis

As part of a larger study on learning about science in school and in real laboratories, we videotaped more than 126 hours in different settings (e.g., school, science laboratories). Data were collected by means of observation and field notes; and science activities were videotaped in laboratories and in the field. In this study, we draw on conversation analysis as the method of choice, because it allows the researcher to uncover the structures that are salient in the naturalistic setting of the science laboratory. Conversation analysis does not *interpret* the meaning of what a single person says, but follows how next speakers or agents take up what has been done and said. Conversation analysis therefore reveals the participants' rather than the analyst's interpretations. Detailed conversation analysis procedures are provided in Psathas (1995), Hutchby and Wooffit (1988), and ten Have (1999). The main principles we draw on are "unmotivated looking, or being open to discover patterns or phenomena," "an inductive search through a data base to establish a collection of instances of the phenomena," "establish regularities and patterns in relation to occurrences of the phenomena," "detailed analysis of single instances of the phenomenon," and "a more generalized account of how the phenomenon related to the broader matrix of interaction."

We transcribed all the episodes using transcription notation, adopting basic Jeffersonian system notation (Atkinson & Heritage, 1984, see Appendix) and repeatedly read the transcripts while conducting an open coding procedure. By coding and recoding the transcripts, we found more manageable chunks or patterns for analysis. We formulated tentative patterns and subsequently subjected these patterns to peer review and public discussion with members of our research laboratory who are working on other research projects and do not have a stake in this project. [This aspect of our method sometimes is referred to as review by disinterested peers (Guba & Lincoln, 1989).] We formulated hypotheses of functions and effects in the internship discourse. During the repeated process of generating hypotheses, reading relevant literature about conversation structures, and testing them by rereading the transcripts, we ultimately derived the transaction structures, conversation organizations, and other features reported here.

Reliability and Validity

Conversation analysis has its own way of establishing reliability and validity (Seedhouse, 2005): by making data (transcripts) and analysis publicly available for readers, CA allows a transparent analysis process that is repeatable to achieve reliability. By transcribing elaborate detail, not attempting to use existing theories to explain the transactions, and refusing to take external aspects (e.g., cultural or social identity) into account (''since there are an indefinite number of external aspects that could be potentially relevant to any given instance of talk-in-interaction. . .and analysis can only show these innumerable, potentially relevant characteristics through analyzing details of the interaction'' [p. 255]), CA uses these data-driven analysis strategies to build internal validity. By explicating the organization of the micro-transaction in a particular social setting, CA studies provide aspects of generalizable descriptions of the interactional organization of the setting to achieve external validity. By recording naturally occurring talk in its natural social setting and portraying how the participants perform their social actions through talk by reference to the same transactional organization that the participants are using, the ecological validity of CA studies tends to be exceptionally strong by comparison to other methods.

To establish the validity of our research, besides drawing on CA, we also adopted several techniques from *fourth-generation evaluation* (Guba & Lincoln, 1989). To satisfy the criterion of *prolonged engagement*, we interacted with teachers and students for 6 months by going to the high school and the scientific laboratory to observe their daily life. Meanwhile, we took field notes and had conversations with the teacher and students before and after classes, talked with the scientists and technicians about their work, and videotaped each classroom session and events in the laboratory. These techniques constitute a form of *persistent observation*. By discussing research questions and findings with peers who had no contractual interest in the situation, we were able to *test working hypotheses* outside the context. After analyzing all the videotapes, and through continuous discussions with peers and conducting a literature review, the findings were constantly adjusted until they emerged in their current form. The gradually developing process of generating research questions and findings allowed us to reduce privilege and satisfied the criterion of *progressive subjectivity* (i.e., through researchers' records of developing constructions and discussions with other researchers to avoid bias that researchers brought in before the study and prevent researchers only ''find'' what they expect to find).

Participation Trajectories, Transactional Structures, and Organization of Natural Pedagogical Conversations

Although educators have called for ''authentic'' science experiences, that is, not just observation of scientists at work but personal engagement in scientific work, little research has been done on how students learn during such experiences and even less on the forms their participation in these unfamiliar places take. This study was designed to investigate the processes of transactional patterns that allowed teaching and learning to happen in a laboratory where high school students completed an internship experience integral to their biology and career preparation course. As our research agenda is concerned with better understanding how students can be more directly involved in the enactment of science, we were particularly interested in the (a) participation trajectories, (b) transactional structures, and the (c) organization of natural pedagogical discourse, that is, the pedagogical discourse on the part of individuals not trained as teachers. As described, there were four groups of students participating in four different scientific projects and we found that there was a high degree of similarity in the transactions that occurred among the groups. To provide readers with a better sense of the internship experiences, we selected the data mainly from one group (the technician Nora with the students Cindy, Kelly, and Joe). We chose Nora's group because every student practiced every technique thereby exhibiting the similar structures as in other groups but in more ''concentrated'' form. To provide evidence for the similarities of these transactions between groups, we also draw on data from a second group. Pseudonyms are used throughout in the paper.

Participation Trajectories

The group featured in this study was led by the laboratory technician Nora, who worked on the identification of fecal contamination of surface water. In this work, many techniques and different technologies were used in this laboratory. From water sampling, to incubating bacteria, antibiotic resistant plating, extracting DNA from bacteria, and, finally, identifying the source of DNA, students were shown how to operate the different apparatuses and enact different techniques that are constitutive of Nora's everyday work. Before the students arrived in the laboratory, Nora prepared lab coats, gloves, instruments, and the equipment for each student. Following the technical sequence of the scientific project that Nora had introduced to the students during their first meeting, she guided the students to practice these techniques step by step. In the 5 days (about ten hours in total), Nora prepared different tasks for students to engage in.

We found that similar participation patterns occurred regularly despite the difference between tasks. The three main phases include *demonstration*, *practice*, and *connection*. In the *demonstration phase*, Nora usually introduced the purpose of the task and demonstrated the techniques at the same time. She either stood or sat in front of the equipment and the students gathered around her to watch the demonstration and clarify Nora's actions prior to engaging in the tasks themselves (Figure 1). In the *practice phase*, Nora invited students to do the rest of the work while she stood beside the practicing individual to monitor his or her practice. The students continually checked their actions with Nora. The other students would watch their peer's actions, clarify their understanding of these actions, observe other aspects of the environment, and ask relevant questions. With easier tasks, if space was available, the three students would sometimes practice together. In the *connection phase*, Nora usually explained the connection between the previous task and the next step by showing concrete results from the previous task. Because of the invisible nature of microbiological objects, students could not easily observe what they had done. Nora always prepared some concrete samples or pictures to show them the results of similar actions before starting the next task. For example, after filtering water with a pump, the paper filters need to be incubated overnight to allow bacteria to grow on the plates so that they can be observed with the unaided eye. In this case, after practicing the filter techniques, Nora would show samples that already had been incubated overnight. She explained the purpose of the previous task and made a connection to the next task (e.g., "Nora: so tomorrow these guys will look like these [agar plates with growing bacteria patterns on them]. Cindy: Oh, and then just like so much Ecoli in there!").

We noticed that these three phases always occurred in the demonstration-practice-connection (D-P-C) sequence, but sometimes connection phases would overlap with practice. For example, after the first two students' practice, Nora generally started building the connection to the next step while the third student was practicing. In D-P-C, *practice* is the central component. If Nora had only demonstrated to the students and no students had practiced this step, we would not consider it to be a task but simply a demonstration phase.

During the 5 days of internship, there were a total of eighteen tasks with practice phases. By counting all the D-P-C sequences in 5 days, on average, 36.2%, 53.0%, and 10.8% of the time was spent in the demonstration, practice, and connection phases, respectively. Figure 2 exemplifies the temporal structure on one of the 5 days and shows that the practice phases are the longest among the three phases. Day 1 contained 5 tasks that took different time periods to be accomplished. For instance, in Task 2, the technician took 3:25 minutes to demonstrate how to collect bacteria from water sample by using pump and paper filters and

Figure 1. In the internship, both groups of students observe their technician's demonstrations in the laboratory (Permission of these pictures for publication obtained from all of these participants).

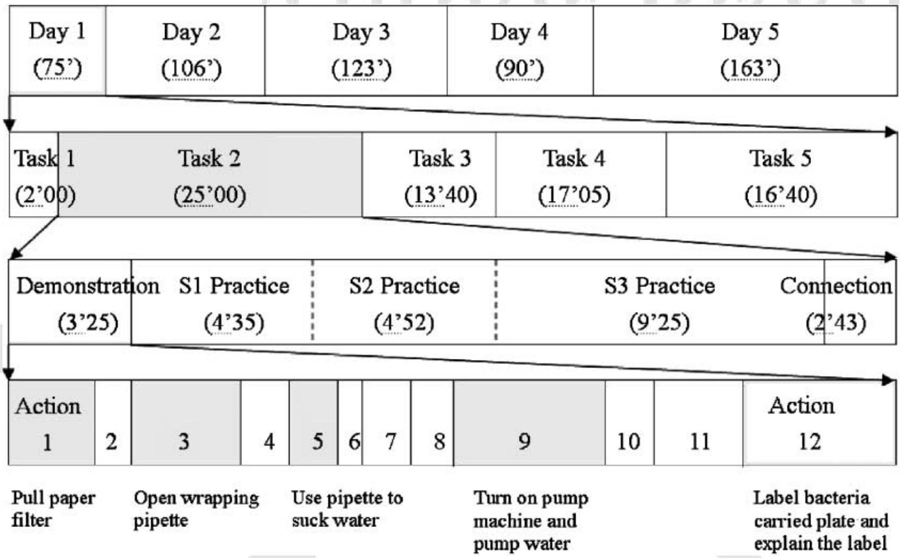

Figure 2. The trajectory of internship in doing science.

three students took 4:35, 4:52 and 9:25 minutes, respectively, to practice the technique. Then the technician took 2:43 minutes explain how this techniques connect to this next task—picking bacteria from paper filter and nurturing them on agar. Further, in the trajectory of doing science, many actions were implemented in each phase. For instance, in the demonstration phase of Task 2, many actions occurred. Twelve actions were identified as main actions in terms of what the technicians explicitly orientated and said. From (a) pulling out the paper filter from a package, (b) putting the paper filter on the pump bottle, (c) opening wrapped pipette, (d) putting pipette on pipette handle, (e) using pipette to suck water, (f) squirting sample water into pump bottle through filter paper, (g) using pipette to suck water again, (h) squirting sample water into pump bottle through filter paper again, (i) turning on the pump machine for pumping air out of pump bottle, (j) picking paper filter from pump bottle, (k) putting paper filter on medium plate, and (l) labeling the bacteria-carried medium plate. The technician orchestrated the participation trajectory during the internship by connecting the sequence of techniques step by step from collecting bacteria to identifying their DNA host with support of showing gradual results.

Transactional Structures

Classroom transactions are characterized by the I-R-E turn-taking routine that involves teachers who *I*nitiate an exchange, students who *R*espond to the query, and teachers who *E*valuate student responses (Lemke, 1990)—though science teachers with high levels of subject matter competence may deviate considerably from this pattern (Roth, 1996). This I-R-E structure, as well as the ones described here, can be understood as the building block of transaction ritual chains that form the basis of society as it is realized in schools (Collins, 2004). In our study, based on our analysis of turn-taking and sequence patterns, we identified two main transactional structures. The first transactional structure was characterized by the Initiate-Clarify-Reply (I-C-R) sequence. In I-C-R, ''I'' could be a description, gesture, body movement, or formulation; ''C'' could be clarifying, confirming, a concern, gesture, or body movement; and ''R'' could be reply, response, gesture, or body movement. The second transactional structure was characterized by the sequence Initiate-Reply-Clarify-Reply (I-R-C-R).

These two transactional structures (I-C-R and I-R-C-R) are very different from the I-R-E classroom conversation structure: The transactions with initiation by technicians are different from those observed in school science classrooms and that are initiated by science teachers. Responding to the initiation from technicians, students clarified their understanding with technicians to access more knowledge. When responding to the initiation from teachers, however, students usually gave their answers to the teacher to be evaluated. In contrast to the I-R-E pattern, I-C-R and I-R-C-R are not limited to the technicians' questions but may begin with technician statements or student questions. More so, the two patterns are building blocks for more complex transactional structures. In the following, we exemplify and elaborate simple and more complex transactional structures. (We use episode numbers and line numbers to refer to specific places relevant to the interpretative text; thus, 1:03 denotes line number 3 in Episode 1.)

In Episode 1, I-C-R transactional structure unfolded during the demonstration phase. Nora demonstrated the use of a pump to "suck" water from a filter and the students stood beside her watching the demonstration to prepare for their practice (although the term "suck" is incorrect scientifically, its deployment here reflects participants' own [i.e., *emic* (Geertz, 1973)] use).

Episode 1 (022110345)

01	Nora:	and then this is gonna get a little loud ((turns on the pump)).	I
02		(5.08)	
03	Cindy:	oh that is just like suck the water down [faster ↑] ((points	C
04		to the filter which sucking water down))	
05	Nora:	[ya (.)] what is this doing, is like it's suctioning down	R

Before turning on the pump, Nora formulates her actions and the subsequent phenomenon: "this is gonna get a little loud" (1:01) to *initiate* this conversation. After a long, 5-second pause that allows anyone to follow up on this conversation and without being informed by Nora, Cindy watches Nora's actions and the subsequent phenomenon (i.e., a loud sound and water sucking down through the paper filter). [The standard maximum silence in conversations has been determined to be of the order of 1 second (Jefferson, 1989).] She *clarifies/confirms* the purpose of the action "oh that is just like suck the water down faster?" (1:03). Confirming Cindy's reference "ya" (1:05), Nora supplements the explanation for her actions in *reply* to Cindy's clarifying questions.

I-C-R patterns were also identified in other groups, for example, in the group that followed the aboriginal scientific project investigating the contamination of traditional seafood. The technician shared her reading about fishery with her students (031511412): "People do weird things though. I was reading this paper yesterday and it was talking about toxaphene and it's used to kill fish, and it said 'it's used to kill rough fish in the sixties,' and I was like what are rough fish? So I looked it up, and rough fish are fish that sports fishers don't want to catch so they put this toxaphene in there to kill the fish because they think the rough fish are competing with the fish that they want to catch" (Initiation). One student then expressed a concern about her understanding of the information that the technician had provided: "But why would they only want to kill one of them?" (Concerns/Clarification). To respond the student's concern, the technician replied, "Well I think it kills all the fish and then they restock it with the fish they want, toxaphene is really bad for you so it seems ironic that they are going to put something in that is going to kill everything and restock, like who is going to want to eat all the fish that were in there, right?" (Reply). Here, again, the conversation demonstrates an I-C-R pattern. We especially can notice the importance of students' turn of expressing her concerns to clarify her understanding, as she now understand that the toxaphene not just kills one kind of fishes. The I-C-R transactions also became basic building blocks for more complex transaction chains. Sometimes these transaction structures occurred on a larger scale when participants had a long conversation. They might follow up with more clarifying and replying, leading to "I-C-R-C_1-R_1-C_2-R_2-. . ." structures.

In our database, the I-C-R transactional structure has a very clear function: students clarified what they observe and understand from what technicians said or demonstrated. These clarifying actions not only supplied students with opportunities for confirming their understanding, but also helped technicians explicitly understand students' understanding and creating opportunities for further explanation. Sometimes, students also initiated the I-C-R structure and the technician clarified what she heard from students. Through their clarifying actions and the response, technicians and students both endeavored to make each other understand what they said, observed, and thought.

In addition to the I-C-R structure, there was a second basic pattern characterizing technician-student transactions: I-C-R-C (Initiate-Reply-Clarify-Reply). In Episode 2, I-R-C-R transactional structure emerged from the practice phase. While Joe was practicing, a big transparent water can in the lab attracted Kelly's attention, and Nora tried to explain its nature.

Episode 2 (022111230)

01	Kelly:	what is this? (0.34) ((pointing to a water can))	I
02	Nora:	mm (0.34) double-distilled water (0.87)	R
03	Kelly:	like really clean water ↑	C
04	Nora:	ya (.) super pure water	R

Kelly *initiates* this conversation by her question "what is this?" (2:01) with her gesture (pointing at the water can). Nora *replies* to Kelly's question by naming the water inside the can "double-distilled water" (2:02). By asking a question again, Kelly *clarifies/confirms* her understanding of Nora's reply "like really clean water?" (2:03). Then, Nora *replies* to Kelly's question by using synonyms (i.e., "super" replaces "really" and "pure" replaces "clean").

I-C-R-C patterns were also identified in other groups' conversions. For instance, while students were practicing relevant techniques in the aboriginal seafood project group (031520413), one of them observed their technician's demonstration and asked a question "What is the machine doing right now? Like what is this doing to your sample?" (Initiation). The technician then responded to the question "We add some solvent into the extracted cell and rinse it, and use pressure to rinse it, so the fish muscles is soaked in the DCM solvent" (Reply). The students again asked another question to clarify her understanding "It breaks it down or?" (Clarification). And the technician responded to the second clarifying question, "Um it doesn't break it down, it just soak in it, because organic things can often dissolve organic things. ya water dissolves salt those kind of things" (Reply). Here, again the conversation followed the I-R-C-R pattern. The example shows the importance of the student's clarifying action, as she might risk misunderstanding the technician's introduction if she did not clarify.

Likewise, the I-R-C-R transactions may also serve basic building blocks for more complex transaction chains. They could follow up with more clarifying and replying, having a bigger scale of "I-R-C-R-C_1-R_1-C_2-R_2-. . ." structures when participants enacted a long conversation. In Episode 3, we demonstrate the long I-R-C-R chains when Cindy continually clarified her understanding about a centrifuge. After Nora demonstrated how to use the centrifuge, Cindy become curious about the running frequency of the centrifuge and asked relevant questions. Nora responded to Cindy's questions by communicating both orally and through body movements in front of the centrifuge. In Episode 3, Cindy responded to these answers and supplied opportunities for the technician to evolve further explanations.

Episode 3 (040311100)

1	Cindy:	cool (1.53) this is how many times it's spinning ↑ ((the	I
2		right hand points to the screen of micro centrifuge))	
3	Nora:	that's how fast it's spinning. ((the left hand points to	R
4		the screen of centrifuge)) (1.21) um:: (0.38) what is that	
5		measurement then (.hhh) (1.52) RPM (1.03) rounds per	

6		minute(1.33) or revolutions per minute I guess::	
8	Cindy:	so every minute only goes around ten times↑	C
9	Nora:	UM:: ten thousands times.	R
11	Cindy:	OH:::↑OH [times a thousand.	C_1
12	Nora:	[times a - YA:::↑	R_1
13	Cindy:	I was like that is <QUITE slow:::> like I thought it was	C_2
14		like sh::((right index finger whirl in the air))	
15	Nora:	oh ya it's going fast.	R_2

As Nora operates the centrifuge, Cindy is curious about the equipment and *initiates* the question about the meaning of numbers showing on the screen of the centrifuge ''this is how many times it's spinning?'' (3:01) with her fingers pointing to the screen. Nora *replies* to Cindy by saying ''That's how fast it's spinning'' and further explains the meaning of sign ''RPM'' as ''revolution per minute'' (3:05-06). This answer from Nora makes Cindy *clarify* her understanding and apply it by using exact numbers showing on screen ''so, every minute only goes around ten times?'' (3:08). Nora *replies with* ''um, ten thousands times'' (3:09). Here, without Cindy's clarification, students may actually misunderstand the explanation that the technician gives (i.e., ten times). After the response from Nora ''um, ten thousands times,'' Cindy *confirms* the number showing on the screen (e.g., ''ten'' [10]) need to times a thousand to be the exact running frequency of the spinning and then receives a *reply* form the technician ''Ya'' (4:12). Further, Cindy expresses her previous *concern* ''I was like, that is quite slow'' (3:13) and the technician then *replies* Cindy's concern ''oh ya, it's going fast''(3:15). This episode provides evidence that Cindy continually supplies opportunities for the technicians to have further explanation and at the same time provides herself opportunities to make more and better sense of the centrifuge. Without Cindy's clarifying actions, the technician would not have the opportunity to explain more scientific knowledge for Cindy's particular need.

Our analyses show that the I-R-C-R based conversation transactions serve a special function: participants, especially students, actively initiate a conversation by asking questions without having explicit facilitation from others. In this way, some tacit knowledge that normally goes without saying comes to be made salient, noticed, and explicitly discussed. Thus, active participants evolved better and more fruitful understandings. As we can see, I-R-C-R transactional structures have similar and overlapping portions with I-C-R transactional structures. They both have I-C-R structures but I-R-C-R structures have one more ''R'' after ''I.'' In this study, the technician usually initiated I-C-R structures while students preferentially began I-R-C-R structures (see more detail in Table 3). That is, in this study students began a lot of clarifying events during their internship in the science laboratory.

Organization of Natural Pedagogical Conversations

To better understand scientist/technician-high school student transactions during internship experiences, we analyzed the ways in which conversations were organized. We were interested in this organization because none of our participants in the science laboratory had formal pedagogical training, which therefore provided us with opportunities to study ''natural pedagogy'' in the process. In our study, we identified both common and unique transactional forms and functions between students and technicians. In this section, we describe and characterize how these natural conversational organization and features occurred in the internship in the authentic science laboratory.

Preference. In the following sections, we are interested in how the technician and students respond each other according to the *preference organization* introduced in conversation analysis. Preference is an organizational form that realizes the mechanism of sequence- or turn-organizational features of conversation rather than expressing the motivation of participants (Sacks et al., 1974). Actions that are performed in a straightforward way and without delay generally coincide with "preferred" responses, whereas those that are delayed, qualified, and accounted are associated with "dispreferred" actions (Heritage, 1984). In terms of preference, besides preferred and dispreferred organizations, we found an interesting dispreferred preference organization—*ambiguous dispreferred preference*—which is different from the preferred or dispreferred terms and indicates a simultaneously preferred and dispreferred organization. To avoid confusion, we named the extremely opposite response to the preferred one *obvious dispreferred response*. In the study, these ambiguous dispreferred preferences were identified in three different contexts: (a) offer/invitation, (b) assessment, and (c) self-inadequacy/deprecation. The responses of three different contexts of preference organization are listed in Table 1. In the following paragraphs, we also exemplify these ambiguous preferences from both groups' conversations.

Offer/Invitation. Usually, in an offer/invitation "Would you like to have dinner with me tonight?," the regular preferred response is quick and short acceptance "Yes!" and the obvious dispreferred response is a delay and longer account for refusal "Well, let me think, tonight is my son's birthday, so I probably will go home earlier and could not go to dinner with you." This internship study also revealed these offer/invitation turns but in a modified form: there were not only preferred and obvious dispreferred responses but also ambiguous dispreferred responses. Sometimes in doing science with the technicians, students had their own opinions about doing particular tasks and tried to improve their skills by offering their own solutions. In Episode 4, we demonstrate the ambiguous preferences used by Nora to respond to Cindy's offer to solve the difficulties of pulling the paper filter out.

Episode 4 (022110718)

```
01  Cindy:  Is it easier like to take off the whole plastic part, and then
02          (0.29) it doesn't rip? Or (0.57) ((left hand holding the filter
03          and right hand holding the tweezers))
04  Nora:   I don't (0.52) personally I don't find it that way, but=
05  Cindy   =oh okay=
06  Nora    =if (0.85) I don't know
```

After ripping the paper filter and struggling to pull the filter from the slot for 53 seconds, Cindy offers a suggestion for pulling out the filter: "Is it easier, like, to take off the whole plastic part, and then it doesn't rip?"(4:01-02). Responding to this offer, Nora does not say "yes" or "no" but "I don't personally; I don't find it that way" (4:04). Here Nora responds in an ambiguous way to respond Cindy's offer. By saying, "but if... I don't know," (4:04-06) Nora opens the possibility of implementing Cindy's ideas. By entering ambiguity, Nora does not accept or refuse Cindy's offer directly, but both accepts and refuses the offer simultaneously. That is, the ambiguous preference allows this offer/invitation as a *possible* rather than *necessary* solution and indicates that more options exist for those who have other preferences.

Table 1
Preferred, dispreferred and ambiguous preference organization in apprenticeship[Q2]

Action	Preferred	Dispreferred	
		Obvious	Ambiguous
Offer/invitation	Acceptance	Refusal	Open option
Assessment	Agreement	Disagreement	Suggestion
Self inadequacy/deprecation	Disagreement	Agreement	Reasonableness

This pattern was also identified in other groups, such as when one student questioned the sequence of using chemicals when operating techniques "Why do you start with the DCM solvent and not hexane, why do you switch over?" (031536213). The technician answered ambiguously, "I think, my own theory, you can ask my supervisor and he may give me a better answer, but my own thing I think DCM must be a better extracting solvent, because I know hexane dissolves PCB very well maybe not pesticides very well." Here again, we see how the student proposed an alternative action that was not directly rejected by the technician. Rather, the technician responded in an ambiguous manner (i.e., "my own theory") and thereby opened a possible space for further discussions with a supervisor (scientist) and allowed the technician to reflect her own practices.

Assessment. Responding to an assessment question "this flower is called daffodil, right?," a preferred response might take the form of a short agreement "Yes" to agree what the previous person's intention whereas a obvious dispreferred could be an explanatory disagreement, "Well, I don't think so, it looks like lily." To get a preferred response-agreement, the first person needs to know or sense that the flower is likely a daffodil. Thus, a short "Yes" from the second person indicates that the first person already has a sense of what is meant. In the study, we observed frequent assessment contexts that included not only agreements or disagreement but also ambiguous dispreferred responses that functioned neither as agreements nor as disagreements but as both concurrently.

In Episode 5, we demonstrate an ambiguous dispreferred response when students assessed their own actions with the technician. After watching the demonstration, the students generally were more familiar with each technique and understood what to do in their practice. To make sure they understood and remembered, the students usually checked with the technician prior to acting. Sometimes they mixed the sequence or forgot some steps, but by checking with Nora, they avoided mistakes. Episode 5 shows the structure of such events in the featured group: the students asked Nora a question, to which she replied ambiguously once again.

Episode 5 (022110630)

```
01  Cindy:  Okay (.) so (.) just take one twenty five↑ ((right hand points to
02          the pipette))
03  Nora:   Um,Ya (.) but you want to put the filter on first ((points to the
04          filter))
```

Demonstrating how to filter the water included putting the paper filter on the pump filter, covering it, using the pipette to "suck" 25 ml of water, and squirting it into the pump filter. Cindy is the first student to practice this task, and before her action, she checks with Nora "Okay, so, just take one twenty-five?" (5:01) while her right hand moves towards the pipette. Here, Cindy apparently forgets that the first step is to put the paper filter on the pump filter and she tries to start using the pipette to suck up the water. Despite the wrong sequence, Nora does not directly say "No" but "Ya" (5:03) and suggests doing another action first: "Put the filter on first" (5:03). Here, Nora responds ambiguously to Cindy's assessment. She agrees with Cindy's assessment but also slightly disagrees and suggests the alternative sequence. The ambiguous preference in the assessment context supplies a bigger timescale for responding to students' understanding rather than just judging the present action. Therefore, students not only may come to understand what they should have done but also may come to anticipate what their next steps ought to be.

These ambiguous preferences in assessment contexts are also found in other groups' conversations. For example, one student assessed the technician's demonstration about operating a technician "Is that like a gel thing?" (031533928). The technician responded to the question in an ambiguous way "it is not a gel, very similar to a gel." Following the ambiguous response, the student further asked, "is that a gas?" Here, we can see the flexible space provided by the ambiguous response that reflected students' observations (i.e., "very similar to a gel") and also encouraged the students to further ask and access more information (i.e., "is that a gas"). That is, the ambiguous response encouraged the student to engage a discussion with the technician.

Self-Inadequacy/Deprecation. In a self-inadequacy/deprecation context ''Oh, I think I made a big mistake,'' a preferred response might be a disagreement ''no, not at all'' while a obvious dispreferred response might be an agreement ''well. . . ya, I think you should do it again.'' In this study, ambiguous dispreferred responses sometimes appeared when students were aware of their own inadequacies where the technician neither agree nor disagree their inadequacies. As the students were newcomers in the science laboratory, their ''errors'' almost were inevitable, particularly during the practice phase. After watching the demonstration and knowing the ''right'' actions from observing the technician, students were frequently aware of their inadequate actions while practicing the techniques. When a mistake happened, students usually stopped and informed Nora to allow her to respond. Episode 6 exhibits the ambiguous preference Nora used in the context of a student's self-deprecation.

Episode 6 (022110800)

```
01   Cindy:  what a mess here ((laughter))

02   Nora:   that’s okay (.) so am I. ((continute next actions without

03           correcting the mess))
```

Reflecting on self-actions in the filtering process, Cindy messes up the order of the equipment and comments ''What a mess here,'' which expresses her awareness of inadequacy (a form of self-deprecation). In saying ''That's okay, so am I'' (6:02), Nora comments that Cindy had experienced the same situation as Nora. Rather than saying ''No'' (preferred) or ''Yes'' (obviously dispreferred) to agree or disagree with Cindy's comment, Nora shares a similar experience to alleviate the disaffiliation. That is, Nora disagrees that Cindy has made a mess: ''That's okay,'' but at the same time she agrees that it was the same mess ''So am I'' as hers previously. Here the ambiguous preference allowed reasonable and acceptable ''error'' without trying to fix it or redo the process.

We also find this type of situation in other groups. For instance, one student practiced a technique in the aboriginal seafood project, she had difficulty of using a pipette to suck up liquid from a flask and she commented the situation ''I am not getting this thing, so hard'' (031533400). The technician responded by saying ''after you do it for some time, you get the little tricks.'' Here, the technician neither agreed nor disagreed with the student's statement. But she responded in an ambiguous way that encouraged students. That is, once the student practiced more, it would not be as difficult as it is now. In this way, the space of preference became flexible rather than being determinate. Sometimes, ambiguous response was implemented by silence in which nobody responded to the self-deprecation.

These ambiguous organizations in different contexts allow a flexible space for students' different thoughts and actions. Knowing the feasibility of different possibilities that students themselves suggested might serve as a springboard for creating more ideas concerning improvement and for allowing students to become aware of the unfinished nature of authentic science. Furthermore, this ambiguous organization actually may empower students to experience science-in-the-making, since their different actions were not totally rejected in the first place by the expert of these science techniques. That is, science practices not always are objective or ''scientific'' but also are constituted by uncertainty and subjective choices (Roth, 2008).

Formulating. Formulating is a pervasive feature of talk to focus participants' attention on what is going on (Roth & Middleton, 2006). For instance, in the sentence ''May I ask you a question?,'' before I ask a question, I formulate my own action in the next seconds, that is, to ask a question. In terms of this conversational feature, we found three different kinds of temporal characteristics in the internship: (a) prospective, (b) simultaneous, and (c) retrospective formulating. Our ethnographic work shows that these three characteristics have different functions. In addition to *self-formulating*, we also find *other-formulating*, a category to describe a situation in which one participant formulates what another is doing or has done. Further, both self-formulating and other-formulating have prospective, simultaneous, and retrospective features in the internship. The respective functions of each feature are listed in Table 2, and characteristic episode featuring are exemplified and described in the following subsections.

Table 2
Self-formulating and other-formulating conversation features in the apprenticeship between students and technicians

Conversation feature	Self formulating		Other formulating	
	Technician	Students	Technician	Students
Prospective	Guide	Assess	Guide	Assess/[a]Guide
Simultaneous	Guide	Inform	Guide	Assess/[a]Share
Retrospective	Confirm	Share	Evaluate	Assess/[a]Assess

[a]Students formulate peer' actions (between students).

Self-Formulating. Many scientific techniques were demonstrated and practiced with self-formulating actions in the internship to illustrate what is going to be done or has been done by themselves. When the technicians demonstrated their actions to students, self-formulating features occurred frequently. In Episode 7 involving the featured students, we see how Nora formulated herself in the demonstration phase of the filter water example.

Episode 7 (022110426)

```
01   Nora:   and then we're gonna scrape this guy off (2.64) ((right hand uses
02           tweezers to pick out the paper filter)) one of you guys wanna
03           to open one of those ↑ ((left hand points to plates on the desk))
04           I'm sure I have done that before (0.63)
05   Cindy:  okay (2.28) ((opens one of the lids))
06   Nora:   and we'll just (0.66) put the filter paper (0.5) ((puts filter
07           paper on the open plate)) right on (1.11) and make sure it's
08           (1.07) fully down there's no little air bubbles underneath
```

After "sucking" water down the filter paper, Nora is going to pick up the bacteria-carried filter paper. Before this action, she *prospectively formulated herself* about what was going to be done: "And then we're gonna scrape these guys off" (7:01) to *guide* the students' observation of her actions. After she uses tweezers to pick the filter paper from the pump bottle, Nora asks students to help her open one of the plates on the desk and *retrospectively formulates herself* about the action (i.e., opening the lid of the plate) which she has done before: "I'm sure I have done that before" (7:04) thereby *confirming* her previous actions. Cindy responds to the request in the preferred way and opened one lid of the plates. After Cindy helped her open the lid, Nora *formulates herself prospectively* again about her future action "And we'll just put on the filter paper" (7:06). While putting the filter paper on the pump bottle, she *simultaneously formulates her actions* putting the filter paper "right on" (8:07) the open plate to *guide* students of her current action. In the self-formulating actions, the technician is doing publicly for everyone to perceive, both visually and orally (her "doing aloud"), that is, demonstrating not only by actions but also in words.

We identified self-formulating in other groups as well. For example, the technician in the aboriginal project demonstrated how to extract meat samples from a fish "So when we work on this fish, we skin it, this one is small so makes it a little bit hard. I often do this (using a knife to cut a fish), it (the skin of the fish) gonna come off. . . so after I cut the skin" (031512400). Here we can see how the technician used self-formulating prospectively ("it gonna come off"), simultaneously ("I often do this") and retrospectively ("after I cut the skin") to lead students to observe her actions.

In this way, technicians formulated students to observe what they wanted students to observe as students might see other trivial parts of the demonstration that the technician did not intend to show. Otherwise, in the practice phase, students also frequently used self-formulating to confirm their understanding before, simultaneously or after their actions. Such self-formulating supplied opportunities for participants to achieve common views of target goals of actions. As we know, sometimes what teachers intend to teach is not equal to what students learn in that lesson. Self-formulating allows teaching and learning more likely having same focus and same understanding.

Other-Formulating. Besides self-formulating, technicians and students explicitly formulated others' actions about what was going to be done or had been done. Different features of other-formulating by different people served different functions in the internship. In Episode 8, Nora and Kelly formulated Cindy's action of picking up and pulling out the filter paper.

Episode 8 (022110730)

```
01  Kelly:  just hold on to the filter when you're trying to pull it out
02  Nora:   yea (.) like hold it very loosely (0.43) there you go now pull
03          (1.38)
04  Cindy:  yea:: (hhh) (0.81) okay so this part goes up, right↑
05  Nora:   yea (0.61) print side up (4.90)
```

In this episode featuring a moment of first practice, the newcomer Cindy experienced difficulties catching and pulling the filter paper from a plastic wrap. Standing by Cindy and observing, Kelly provides a description that *guides* Cindy and *prospectively formulates* what her peer may do: "Just hold on to the filter when you're trying to pull it out" (8:01). While Cindy concentrates on her pulling action, Nora responds to Kelly's suggestion in a preferred way "Yea" (8:02) and *prospectively formulates Cindy's action* "like hold it very loosely" (9:02) to guide Cindy's action. When Cindy successfully catches the filter paper with tweezers, Nora also *simultaneously formulates Cindy's action* "There you go" (8:02) to inform her of what had been done (catching the filter paper successfully) and "now pull" (8:02) to *prospectively formulate Cindy's action* again. In celebrating this success, Cindy cheers her action with a loud "Yea" (8:04) and assesses and prospectively formulates her next action: "Okay so this part goes up, right?" Again, by saying "Yea" (8:05), Nora uses the preferred way for agreeing with Cindy's assessment. This preferred action from Nora indicated Cindy's understanding of Nora's demonstration, so she could get a preferred response from Nora.

In the following episode, we demonstrate the retrospective characteristics of other-formulating. The episode exhibits other-formulating by a technician, here Nora. Cindy sat on the lab stool and put her hands in the fume hood, using a pipette to suck nutrient broth from one tube to another. Nora and Kelly stood behind Cindy and discuss Cindy's actions.

Episode 9 (033113730)

```
01  Nora:   SEE (0.72) notice HOW (.) her hands are all the way inside the
02          flow (.)
03  Kelly:  ya (0.37)
04  Nora:   that's GOOD (1.0) you kind of get used to having the glass in
05          front of your face after for a while
```

After observing Cindy practicing in the fume hood, which is made of glass, Nora says to Kelly: "See, notice how her hands are all the way inside the flow"(9:01). This *retrospectively formulates* what Cindy has done; she then *evaluates* and comments on Cindy's action "That's good" (9:04). Further, Nora formulated

Cindy's condition—Cindy got used to working in front of the glass (9:04). In the other-formulating actions, technician and students guide and formulate the way for others about how things could be done by others. That is, participants are more likely to accomplish the practice successfully when they recognize that the other-formulation articulates what they currently do; and they have a resource for retrospectively establishing the quality of their own actions in terms of what the other-formulating action has established.

The phenomena of other-formulating also occurred in other groups, for instance, when one student practiced to use a pipette to suck liquid into a flask and the technician guided the student's actions ''not touching it (flask) (the student is touching a flask through the pipette), it is okay just add it (liquid), (the students successfully add liquid into the flask without touching the flask) yeah, like that, and do the wash'' (031533257). Here, we can see the technician used other-formulating simultaneously (''not touching it''), prospectively (''just add it,'' ''and do the wash''), and retrospectively (''yeah, like that'') to guide students' practices.

These self-formulating and other-formulating actions in the internship by technicians and students served different functions (Table 2). The technicians formulated their actions prospectively and simultaneously, which guided students to see what the former wanted them to see and formulated their own actions retrospectively, which provided and confirmed descriptions for what has been done. Technicians also formulated students' actions prospectively and simultaneously to guide their practices and retrospectively formulated what students has done to evaluate their actions. As for students, they formulated themselves prospectively to assess the accuracy of their oncoming actions. They formulated themselves simultaneously to inform others about their actions and formulated themselves retrospectively to share their experience with others. In addition, students formulated the technician's actions to assess their understanding of what they were seeing. Moreover, students formulated peer's actions prospectively to guide, simultaneously to share experiences and retrospectively to assess peer's accuracy of actions. Through these different formulating actions, we observed the participants' dynamic roles in and during the internship. The technicians sometimes were guides, at other times they were evaluators; and students were assessors, informers, guide, or experience sharers. That is, students were not just students who learn from the technician but could be a guide or teachers for their peer or experience sharer for either the technician or peer.

Prevalence of Observed Patterns

In the internship, students had numerous opportunities to practice ''doing'' science, their dynamic transactions provided a great resources for the purpose of finding tendency and patterns. To overview these transactional structures, natural conversation organizations, and features in the 5 days long internship, we pick the beginning, middle, and closing stage in the internship to represent different stages in the internship. Each stage extends for about 40–45 minutes and all three stages include the participation of the technician (Nora) and three students (Cindy, Kelly, and Joe). During the three stages, we indicate who initiates the conversation by using ''T'' to represent technician and ''S'' to represent student. Following the turn-taking principle in conversation analysis, all these frequencies are counted by the unit of turn taking no matter how many sentences the participants said. That is, one turn may have ten sentences or only one word or just a gesture or body movement. For I-C-R and I-R-C-R transactional structures, we usually identified the C (clarify, confirm or concern) first and then extendedly found the surrounding turns. As for preference organization, the forms of response are the cues for coding in terms of turn taking too. With regard to formulating, we coded these different types of formulating by watching videos and transcript together to ensure their orientation and timing of formulating and the boundary is the different forms of formulating. For instance, in demonstration phases, Nora used a lot of self-formulating, and the defining feature of self-formulating would be whether it is prospective, simultaneous, or retrospective.

Table 3 shows the frequencies of transaction structures, natural conversation organizations, and features in different stages of the 5-day internship that totaled about 10 hours. Meanwhile, transaction structures are represented in terms of I-C-R and I-R-C-R structures, natural conversation organizations are represented in terms of different contexts (offer/invitation, assessment and self inadequacy) and natural conversation features-formulating were represented by different orientations (self-formulating and other-formulating) and different timing (prospective, simultaneous, and retrospective).

Table 3
Frequencies of transaction structures, natural conversation organizations and features

	Stages									
	Beginning (40:40)		Middle (41:50)		Closing (45:00)		Three stages			
	T	S	T	S	T	S	T	S		Total
Initiate-Clarify/Confirm/Concern-Reply (ICR)	21	—	6	3	9	2	36	5	41	70
Initiate-Reply-Clarify/Confirm/Concern-Reply (IRCR)	—	10	—	15	2	2	2	27	29	
Preference										
Preferred										
Offer/invitation	6	7	4	—	3	1	13	8	21	
Assessment	4	43	5	19	3	11	12	73	85	113
Self inadequacy	—	4	—	2	—	1	—	7	7	
Obvious dispreferred										
Offer/invitation	1	2	—	—	—	—	1	2	3	
Assessment	1	15	2	17	3	3	6	35	41	47
Self inadequacy	—	1	—	1	—	1	—	3	3	
Ambiguous dispreferred										
Offer/invitation	—	2	—	—	—	—	—	2	2	
Assessment	1	7	—	3	1	—	2	10	12	19
Self inadequacy	—	2	3	—	—	—	3	2	5	
Formulating										
Self formulating										
Prospective	20	27	14	34	15	7	49	68	117	
Simultaneous	22	6	6	3	8	5	36	14	50	201
Retrospective	7	5	6	11	4	1	17	17	34	
Other formulating										
Prospective	38	3	42	2	11	—	91	5	96	
Simultaneous	13	5	7	2	2	2	22	9	31	148
Retrospective	3	4	6	4	4	—	13	8	21	

T, technician[Q3] initiate; S, student initiate.

These frequency results of transactional structures, natural conversation organizations and features are described in the following paragraphs in terms of different stages (beginning, middle, and closing) of the internship and demonstrated with bar graphs.

Transactional Structures. The investigation of transaction structures allows us to see the conversation structures in the internship, and further to see the changing dynamic transaction between technicians and students over time. Two issues in particular are salient in transaction structures. First, *I-C-R structures are more frequent in T-initiated transactions; I-R-C-R structures are more frequent in S-initiated transactions*. During I-C-R structures ($N = 41$) in the three stages, T-initiated transactions occurred 36 times (88%), meanwhile in I-R-C-R structures ($N = 29$), S-initiated transactions occurred 27 times (93%). This result shows that T-initiated transactions are dominant in I-C-R structures, but S-initiated transactions are dominant in I-R-C-R structures. That is, students adopted a lot of clarifying actions in the internship. Second, *diverse transaction structures tendency.* By looking at the frequency from the beginning to the closing stage, we found that the transaction structures have a diverse tendency (see Figure 3). That is, in the beginning stage, I-C-R was only initiated by the technician but in the end of the internship, I-C-R could also be initiated either by the technician or by the students. Namely, at the end of the internship, the technician used more clarifying actions to respond to students' initiation. Likewise, I-R-C-R was initiated not only by students in the end, but the technician also initiated some issues, and had further clarifying actions, in order to get responses from students.

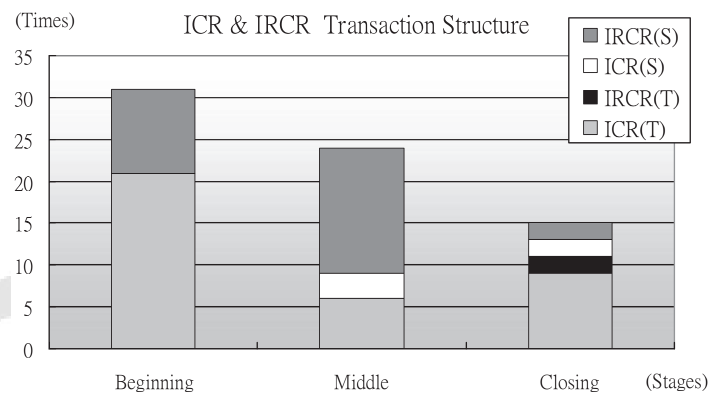

Figure 3. Frequency of ICR and IRCR in different stages of the apprenticeship. ICR (T) and IRCR (T) indicate that the technician initiated these transaction structures; ICR (S) and IRCR (S) indicate that students initiated these transaction structures.

Natural Conversation Organizations. Studying the conversation organizations allows us to better understand how participants interact or respond each other. For instance, from the response of students to technicians' previous introduction or response of technicians to students' previous questions, we can realize how well the teaching and learning unfold in the internship Five phenomena in particular are salient in the conversation organizations. First, *preferred responses occurred more frequently than obvious dispreferred and ambiguous dispreferred*. In total frequency, we can see preferred responses are the most frequent preference ($N = 113$ [63%]) and same phenomenon occurred in each stage as well (See Figure 4). That is, the technician and students both generally acted intelligibly for the other so that a preferred response could happen all the time.

Second, *assessment contexts happened more frequently*. In the three frequent contexts (i.e., offer/invitation, assessment, and self inadequacy/deprecation), assessments are the most frequent context in the internship ($N = 138$ [77%]). The assessment discourse allowed the technician and students to assess the other's actions and make them intelligible to each other. In assessment contexts, 62% (85 out of 138) of responses are preferred. That is, students generally had an understanding of what was going on, because, to

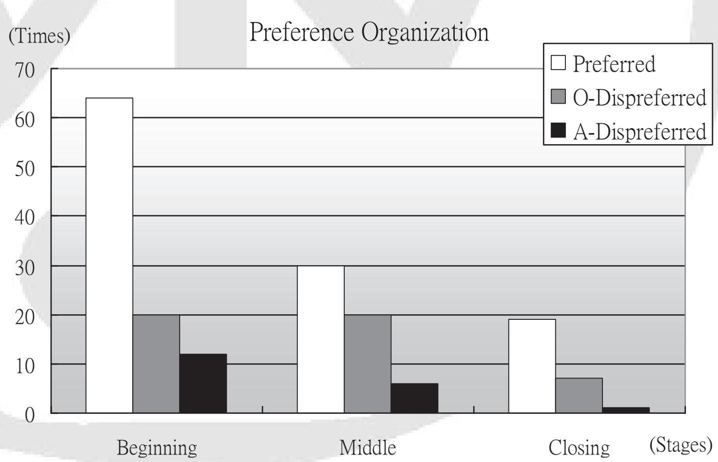

Figure 4. Frequency of different preference organizations in different stages of the apprenticeship.

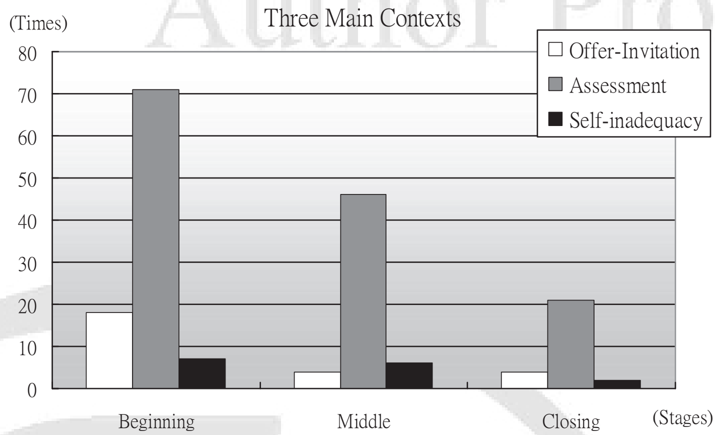

Figure 5. Frequency of different contexts in different stages of the apprenticeship.

get a preferred response, students needed to understand the demonstration or knowledge explained by the technician. For instance, the assessment question from students: ‘‘Should I sterilize the tweezers now?’’ To get a preferred response from the technician ‘‘Yes,’’ students needed to be aware that they should sterilize the tweezers beforehand.

Third, there was a *decrease in assessment tendency*. We can see the times of assessment decrease from the beginning ($N = 71$ [52%]) to the end ($N = 21$ [15%]) of the internship (see Figure 5). This result shows that with time went by, the technician and students were more familiar with each other and the tacit knowledge of scientific work so that they did not need to assess others’ actions so often.

Fourth, *student-initiated self-inadequacy is often responded to in preferred ways*. When students showed their self-inadequacy, the technician frequently responded to them in preferred ways ($N = 7$ [58%]). That is, saying ‘‘that’s not a problem or that’s okay’’ encouraged students to move on in their practice.

Fifth, *T-initiated self-inadequacy is responded to with ambiguous dispreferred organizations*. When the technician revealed her inadequacy in the internship, students always ($N = 3$ [100%]) responded to her in an ambiguous way—‘‘silence.’’

Natural Conversation Features. Investigating conversation features-formulating, we could see how participants articulated their own or others’ actions to direct others for their target behaviors. Two issues in particular were salient in the conversational feature formulating (See Figure 6). First, *there were frequent self-formulating actions*. We found that self-formulating actions were used a lot by both the technician and students in the internship ($N = 201$ [58%]). Technicians and students frequently used this way to make sure that their actions are intelligible to others. Second, we observed *prospective formulating is more than*

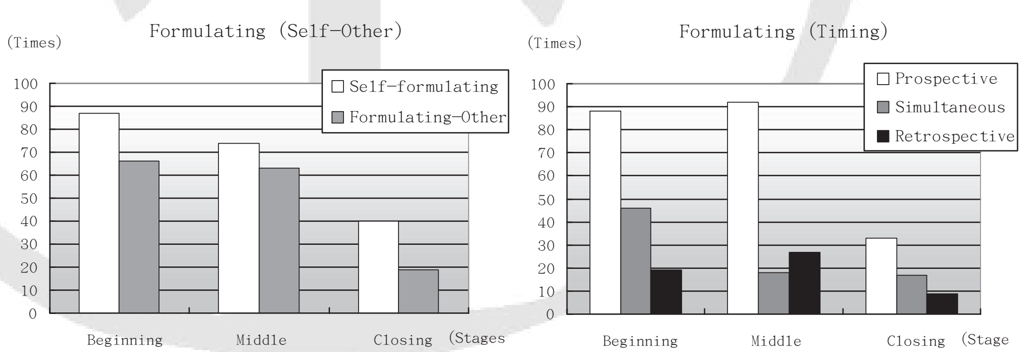

Figure 6. Frequency of different formulating actions in different stages of the apprenticeship.

simultaneous and retrospective. According to the timing, prospective formulating is the most frequent formulating action ($N = 213$ [61%]) in the internship. With this organization, a technician prepared students to see what she wanted to be observed and students could assess the correct actions in their practice.

From the beginning stage to the closing stages of the internship experiences, these natural ways of teaching and learning (e.g., transactional structures and natural pedagogical conversations) generally decreased as time went by. One possible reason for this is that students became more familiar with what they learned—the scientific project—and that they knew more of the tacit skills and knowledge required to do the work. In this way, both technicians and students did not need to expend the same amount of effort as they did when they first met and thus there was a lot that went without saying toward the end of the internship. In addition, the higher rates of preferred response actions (62%) in assessment contexts indicates that students generally experienced positive understanding in the internship by using these natural ways of teaching and learning.

Discussion and Implication

The purpose of this study was to investigate the learning trajectories and natural pedagogical conversations that guide high school students to learn in a university-based scientific research laboratory. With a goal of connecting school science to everyday life and exhibiting the everyday work in the science laboratory, leading technicians—who had majored in biology but did not have pedagogical training—introduced and demonstrated scientific projects in the biology laboratory. How these technicians "taught" students and how students learned science from these non-teachers are our central interests in this paper. We describe and theorize three major dimensions of the processes by which high school biology students came to be introduced to scientific laboratory work: participation trajectories, transactional structures, and organization of natural pedagogical conversations. Drawing on conversation analysis in the study, we identify several natural ways of teaching and learning through microscale transactions and macroscale trajectories that characterized the internship experiences.

First, in the internship, the trajectories mainly were led by the technician in terms of the sequence of step-by-step techniques. In each practice task, we identified typical patterns continually happen in the participation trajectories: demonstration, practice, and connection (D-P-C) in which each task was connected to other tasks showing gradual results. In Vai and Gola tailor apprenticeship (Lave & Wenger, 1991), apprentices first learn to make informal garments and then move on to more external and formal garments. In the process of producing formal garments, they begin by learning the finishing stages of producing a garment, go on to learn to sew it, and only later learn to cut it out. Reversing the production steps has the effect of focusing the apprentices' attention first on the broad outlines of garment construction as they handle garments while attaching buttons and hemming cuffs. Here, comparing these tailors' participation to the internship in our study, students first were directly directed to practice the formal science activities and moved on in a step-by-step fashion to the finishing stage unlike the reverse learning process of these tailors. However, to illustrate the effect of outlines of activities, the technicians supported the gradual emergence of results and pointed out the purposes of each task. In this way, the relation between different tasks and between the present task and the purpose of whole science project was exhibited and made salient. These connections—go back and forth to the previous, the next task and even the whole purpose of the internship—allowed students to "get the big picture" while practicing the microlevel details of the present task. Furthermore, reducing assistance was critical for encouraging students to take responsibilities for their learning and performance—the reason being that students must use their inner resources rather then depend on external help (Corno, 1992). In this study, offering opportunities for individual practices (practice phases) to students was one of the components for them to act as autonomous learners.

Second, drawing on conversation analysis, specific interaction patterns emerged and became salient from the data collected during the internship. Salient dialogue structures during the internship were initiate-clarify-reply (I-C-R) and initiate-reply-clarify-reply (I-R-C-R) transaction structures. Normally technicians initiated I-C-R transaction structures and students usually initiated I-R-C-R transaction structures. That is, students produced many clarifying actions and, as other research suggested (e.g., Scharle & Szabó, 2000), thereby acted as responsible and autonomous learners who make efforts and use available opportunities to monitor their own understanding and learning. Students' clarifying contributions increase the possibility of successful learning in the internship as learning can only happen if learners were willing to contribute. Further, both structures displayed a change in the initiation phenomenon tendency from the beginning to the closing stage. This tendency illustrates that as time went by, the more complex mechanism between technicians and students occurred and their roles in the internship were dynamically changed. For instance, technicians also started to adopt clarifying actions for exploring students' reply in the end of the internship.

Our study shows that the transaction structures that occur in an authentic scientific setting (I-C-R and I-R-C-R) are very different from the transaction structure in the classroom (I-R-E). This pattern of initiation-response-evaluation is distinctive and very common in high school classrooms (Scott, Mortimer, & Aguiar, 2006). Even for technicians without a teaching background, these I-C-R and I-R-C-R transaction structures allow learning experiences to emerge in a scientific laboratory. In I-C-R and I-R-C-R transactions, students frequently clarified their understanding of what they see and hear. In I-R-E transactions, in contrast, students are expected to respond to the teachers' initiation and be evaluated. Such I-R-E sequences dealt with procedural and declarative knowledge, but did not deal with situated practical understanding, which is always relational (Roth & Middleton, 2006). The students' clarifying actions in I-C-R and I-R-C-R structures often related to the particular situation and to their understanding at that moment. This has important implications for school since teachers or instructors often teach in ways they plan; but despite planning, students may still encounter learning difficulties after teachers' instruction (Lee, Buxton, Lewis, & LeRoy, 2006). If students could clarify frequently what they understand from teachers, these actions would help not only students but also teachers to understand and improve their teaching. In this way, students might be encouraged to suspend disbelief or belief as the situation may warrant, which is an important ingredient in fostering meaningful learning (Wiggins, 1989).

Third, with respect to preference organizations, we found not only preferred and dispreferred actions occurred in the internship but also ambiguous dispreferred actions. These ambiguous dispreferred actions contain both preferred and dispreferred functions and open up possibilities for adopting students' different voices from dominant (scientists/technicians) discourse. That is, these ambiguous actions allowed the expression and retention of students' voices even if these voices were different from the dominant voice. Learning to question is important, as questioning releases a range of possibilities that dominant opinions would restrict (Gadamer, 1988). Therefore, these ambiguous actions likely encouraged students to think and practice more, even when they acted differently from normal laboratory practice. Furthermore, through the processes of self-formulating and other-formulating, tacit knowledge and skills were articulated and exhibited and thereby made available for students to understand. As we know, what teachers teach might not necessary be what students learn; therefore, these explicit natural ways of formulating actions might likely serve a useful pedagogical conversation features for students and teachers in teaching and learning.

These transactional structures, organizations and features of natural pedagogical conversations identified in the study serve as resources for teachers concerned with understanding the nature and structure of the conversations they have with their students in the teaching of science. Do conversations supply and increase the opportunities for students' clarifying actions and different voices? Do teachers' actions make available to students resources that allow the latter to follow and focus on the current events? Further more, the findings of this study also allow us to discuss some critical issues: Why do these differences of transaction structures (e.g., I-R-E vs. I-C-R) exist in the different settings? Is it related to differences of power relationships in formal and informal settings? Or it is related to the different purposes of learning? And why do these natural ways of learning and teaching not exist often in the classroom? All of these are important issues and research questions that future studies should pay attention to and seriously take into consideration. After knowing and basing on these natural ways of teaching and learning in the internship, we now also consider the possibilities of working with these scientists and technicians to exchange some theoretical and pedagogical training ideas for improving the internship. Some of the things we intend to share include (a) emphasizing opportunities for shared responsibilities for learning (i.e., having more students' practices without explicit assistance), (b) having more space for students' different voices (e.g., ambiguous organizations), and (c) creating a more open-inquiry environment for students to investigate their desiring topics.

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Appendix: Basic Jeffersonian Transcription Notation (Atkinson & Heritage, 1984)

Brackets ([text]) indicate the start and end points of overlapping speech; Period (.) indicates falling pitch or intonation; Up arrow (↑) indicates rising pitch or intonation; Comma (,) indicates a temporary rise or fall in intonation; Hyphen (-) indicates an abrupt halt or interruption in utterance; Equal sign (=) indicates the break and subsequent continuation of a single utterance; Period inside single parentheses (.) indicates a brief pause, usually less than 0.2 seconds; Numers inside single parentheses (# of seconds) indicates the time, in seconds, of a pause in speech; Capitalized text (ALL CAPS) indicates shouted or increased volume speech; Underlined text (text) indicates the speaker is emphasizing or stressing the speech; Convergent greater than/less than symbols <test> indicate that the enclosed speech was delivered more slowly than usual for the speaker; Colons (:::) indicates prolongation of a sound; "h" and period inside single parentheses (.hhh) indicate audible inhalation; Text in double parentheses ((text)) indicates annotation of non-verbal activity.

References

Abraham, L.M. (2002). What do high school science students gain from field based research apprenticeship programs? The Clearing House, 75, 229–232.

American Association for the Advancement of Science (AAAS). (1993). Benchmarks for science literacy. New York: Oxford University Press.

Atkinson J.M. & Heritage J. (Eds.), (1984). Structures of social action: Studies in conversation analysis. Cambridge: Cambridge University Press.

Barab, S.A., & Hay, K.E. (2001). Doing science at the elbow of experts: Issues related to the science apprenticeship camp. Journal of Research in Science Teaching, 38, 70–102.

Bell, R., Blair, L., Crawford, B., & Lederman, N. (2003). Just do it? The impact of a science apprenticeship program on high school students' understandings of the nature of science and scientific inquiry. Journal of Research in Science Teaching, 40, 487–509.

Collins, R. (2004). Interaction ritual chains. Princeton, NJ: Princeton University Press.

Corno, L. (1992). Encouraging students to take responsibility for learning and performance. Elementary School Journal, 93, 69–83.

Gadamer, H.G. (1988). Truth and method (G. Barden & J. Cumming, Trans.). New York: Seabury Press.

Geertz, C. (1973). The interpretation of cultures: Selected essays. New York: Basic Books.

Gibson, H.L., & Chase, C. (2002). Longitudinal impact of an inquiry-based science program on middle school students' attitudes toward science. Science Education, 86, 693–705.

Goody, E.N. (1989). Learning, apprenticeship and the division of labor. In M.W. Coy (Ed.), Apprenticeship: From theory to method and back again (pp. 233–256). Albany, NY: State University of New York Press.

Goulart, M.I.M., & Roth, W.-M. (2006). Margincenter: Toward a dialectic view of participation. Journal of Curriculum Studies, 38, 679–700.

Guba, E., & Lincoln, Y. (1989). Fourth generation evaluation. Beverly Hills, CA: Sage.

Heritage, J. (1984). Garfinkel and ethnomethodology. Cambridge: Polity Press.

Hutchby, I., & Wooffit, R. (1988). Conversation analysis: Principles, practices and applications. Cambridge: Polity Press.

Hutchins, E. (1993). Learning to navigate. In S. Chaiklin & J. Lave (Eds.), Understanding practice: Perspectives on activity and context (pp. 35–63). New York: Cambridge University Press.

Jefferson, G. (1989). Preliminary notes on a possible metric which provides for a ''standard maximum'' silence of approximately one second in conversation. In D. Roger & P. Bull (Eds.), Conversation: An interdisciplinary perspective (pp. 166–196). Clevedon: Multilingual Matters.

Krange, I. (2007). Students' conceptual practices in science education. Cultural Studies of Science Education, 2, 171–203.

Lave, J., & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. New York: Cambridge University Press.

Lee, H.-S., & Songer, N.B. (2003). Making authentic science accessible to students. International Journal of Science Education, 25, 923–948.

Lee, O., Buxton, C., Lewis, S., & LeRoy, K. (2006). Science inquiry and student diversity: Enhanced abilities and continuing difficulties after an instructional intervention. Journal of Research in Science Teaching, 43, 607–636.

Lemke, J.L. (1990). Talking science: Language, learning and values. Norwood, NJ: Ablex.

Mehan, H. (1979). Learning lessons: Social organization in the classroom. Cambridge, MA: Harvard University Press.

Nassaji, H., & Wells, G. (2000). What's the use of 'triadic dialogue'? An investigation of teacher-student interaction. Applied Linguistics, 21, 376–406.

National Research Council. (1996). National science education standards. Washington, DC: National Academy Press.

Psathas, G. (1995). Conversation analysis: The study of talk-in-interaction. Thousand Oaks, CA: Sage.

Rasmussen, I., Krange, I., & Ludvigsen, S.R. (2003). The process of understanding the task: How is agency distributed between students, teachers and representations in technology-rich learning environments? International Journal of Educational Research, 39, 839–849.

Richmond, G., & Kurth, L.A. (1999). Moving from outside to inside: High school students' use of apprenticeships as vehicles for entering the culture and practice of science. Journal of Research in Science Teaching, 36, 677–697.

Rogoff, B. (1990). Internship in thinking: Cognitive development in social context. New York: Oxford University Press.

Roth, W.-M. (1995). Authentic school science: Knowing and learning in open-inquiry science laboratories. Dordrecht, Netherlands: Kluwer Academic Publishers.

Roth, W.-M. (1996). Teacher questioning in an open-inquiry learning environment: Interactions of context, content, and student responses. Journal of Research in Science Teaching, 33, 709–736.

Roth, W.-M. (2005). Doing qualitative research: Praxis of methods. Rotterdam: Sense Publishers.

Roth, W.-M. (2008). Radical uncertainty in[Q4] scientific discovery work. Science, Technology & Human Values, 10.1177/0162243907309627.

Roth, W.-M., & Lee, S. (2004). Science education as/for participation in the community. Science Education, 88, 263–291.

Roth, W.-M., & Middleton, D. (2006). Knowing what you tell, telling what you know: Uncertainty and asymmetries of meaning in interpreting graphical data. Cultural Studies of Science Education, 1, 11–81.

Sacks, H., Schegloff, E., & Jefferson, G. (1974). A simplest systematics for the organization of turn-taking in conversation. Language, 50, 696–735.

Scharle, Á., & Szabó, A. (2000). Learner autonomy: A guide to developing learner responsibility. Cambridge: Cambridge University Press.

Scott, P., Mortimer, E., & Aguiar, O. (2006). The tension between authoritative and dialogic discourse: A fundamental characteristic of meaning making interactions in high school science lessons. Science Education, 90, 605–631.

Seedhouse, P. (2005). Conversation analysis as research methodology. In K. Richards & P. Seedhouse (Eds.), Applying conversation analysis (pp. 251–266). Basingstoke: Palgrave Macmillan.

Sinclair, J.M., & Coulthard, M. (1975). Towards an analysis of discourse: The English used by teachers and pupils. London: Oxford University Press.

Soloway, E., Pryor, A.Z., Krajcik, J.S., Jackson, S., Stratford, S.J., Wisnudel, M., et al[Q5]. (1997). ScienceWare's model-It: Technology to support authentic science inquiry. THE Journal, 25(3), 54–56.

Strauss, A.L. (1993). Continual permutations of action. New York: Aldine de Gruyter.

ten Have, P. (1999). Doing conversation analysis: A practical guide. London: Sage.

Varelas, M., House, R., & Wenzel, S. (2005). Beginning teachers immersed into science: Scientist and science teacher identities. Science Education, 89, 492–516.

Wiggins, G. (1989). The futility of trying to teach everything of importance. Educational Leadership, 47(3), 44–48.

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