Transaction Structures and Natural Organizations of Apprenticeship in Authentic Science Laboratories

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Abstract

Educators and researchers have encouraged students' experiences of authentic science and their participation in activities in the science workplace. But little research has investigated the transactions between scientist/technicians and newcomers (high school students) to scientific settings. Without a pedagogical background or experience in teaching high school students, this study examines how scientists/technicians interact with students and how students interact with non-teachers in real scientific laboratories. Drawing on conversation analysis, we analyze the minute-by-minute transactions to investigate participation trajectories, transaction structures, and transaction organizations of apprenticeship in scientific laboratories. Through individual and collective analysis, our study found that demonstration-practice-connect (DPC) phases constantly recur in the process of "doing" science; initiate-clarify-reply (ICR) and initiate-reply-clarify-reply (IRCR) frequently happen in conversational transactions; preference organization is composed not only of preferred and dispreferred modes of responding but also personally dispreferred modes; the formulating organization not only includes self-formulating but formulating others. These findings allow us to understand the natural transaction between technicians and high school students in scientific laboratories where there is an authentic environment but formal school settings.

Key words: Participation trajectory, Transaction structure, Natural dialogue organization.

1. Introduction

The American Association for the Advancement of Science (AAAS) and the National Research Council (NRC) 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 (Soloway, Pryor, Krajcik, Jackson, Wisnudel & Klein, 1997). Authentic activities are important in promoting inquiry because they provide natural problem-solving contexts with a high degree of complexity (Lee & Songer, 2003). A number of studies investigated students' experiences in science laboratories. Existing studies include two main aspects (a) the examination of students' attitude toward science after participating in science activities (Gibson & Chase, 2002); and (b) descriptions of the impact of a science apprenticeship program on students' understanding of the nature of science and scientific inquiry (Bell, Blair, Crawford & Lederman, 2003). However, little research has been carried out on the minute-by-minute transactions of scientists/technicians and high students. The purpose of the study is to investigate the transaction structure and natural dialogue organizations of apprenticeship in authentic university science laboratories. As we know, in the university laboratory settings, most scientists/technicians have no pedagogic training and background. How they "teach" their scientific project to high school students and how high school students "learn" from non-teachers are the central issues we are interested in. Drawing on conversation analysis allows us to investigate the transactional structure and transactional organization of apprenticeship in practice.

2. Background and Method

In apprenticeship, novices advance their skills and understanding through participation with higher-skilled partners in culturally organized activities (Rogoff, 1990, p. 39). Apprenticeship offers direct exposure to the skills, problem-solving, knowledge, and language of practitioners in the context of everyday out-of-school practice (Roth, 1995). There are three major aspects of cognitive apprenticeship: modeling, scaffolding, and fading (Collins, Brown & Newman, 1989). In terms of the development trajectory in the study of navigation (Hutchins, 1993), most quartermasters learn what to do and how to do it while on the job. In order to advance to higher ranks, the novice must work through a set of formal 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 the Via tailor's apprenticeship (Lave &Wenger, 1991), learning does not merely reproduce the sequence of the production process, but is actually reserved, as apprentices begin by learning the *finishing stages* of producing a garment.

Conversation analysis (CA) is a method that allows us to find out what is being done in a particular setting by carefully attending to the semiotic resourced transaction participants

make available for one another and use to accomplish what they are in the process of doing (Roth, 2005). Following the principles of CA, that is: focusing on order in transaction; transactions are context-shaped and context-renewing; no order of detail can be dismissed a priori as disorderly, accidental or irrelevant; analysis is bottom-up and data driven; and we analyze the data individually and collectively to increase the credibility. Preference and formulating are two of the central analytical concepts in CA. As for *reference*, there is a "bias" intrinsic to many aspects of the organization of talk which is generally favourable to the maintenance of bonds of solidarity between actors and which promotes the avoidance of conflict (Heritage, 1984). When alternative responses are possible, the *preferred* action is frequently used to support social solidarity and *dispreferred* actions 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 agreement is the dispreferred action (Heritage, 1984). Furthermore, *formulating* is a pervasive 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.

3. Study Design

This study is part of a research program in one of five Canadian centres—the NSERC-funded Pacific Crystal project (www.educ.uvic.ca/pacificcrystal/main.html) concerned with developing scientific literacy. The purpose of this ethnographic study is to investigate the apprenticeship of high school students and technicians in university laboratories. Before inviting high school students to the science laboratories, we went to a high school class to observe their science lessons and build up trust in the research relationship. Meanwhile, we went to the laboratory to become familiar with the scientific projects which would take place for six months. We participated in scientists' weekly and monthly meetings and observed their work in the laboratory in order to understand their work and establish a trusting research relationship. The high school students who were interested in participating in the project voluntarily came to the laboratory in groups of three to four students. Each group followed one or two technicians to learn the respective scientific projects. Thirteen students were divided into four groups following different scientific projects and the apprenticeship activities were observed and videoed over two months. Researchers invited students who were interested in the project to come to the university, and then scientist/technicians discussed the scientific projects, organized scientific work for the students and negotiated suitable times to come to the university laboratory. Data were

collected by observation, field notes and science activities were videotaped in laboratories and in the field. In the study, we selected one group as an example to demonstrate the transaction of apprenticeship in a scientific project that utilizes scientific techniques (e.g., water sampling, bacteria incubating, antibiotic plating, etc.) to identify the fecal contamination in surface waters. In the group, three high school students (Cindy, Kelly and Joe) followed the technician (Nora) to learn and practice these techniques for five days (total 10 hours). [The paper uses pseudonym for all participants.]

4. Finding and Analysis

Through repeatedly watching the video tapes and reading the transcriptions, we found reasonable and manageable chunks of pattern for analysis. These patterns of variation and consistency in a range of features allowed us to map out the pattern of ways which technicians and students drew on to allow the process to move on. Two main transaction structures and two main natural organizations are discussed and demonstrated.

4.1. Transaction Structures

Based on analyzing turn taking and sequence, two main transactional structures were identified. The first observation was that technicians initiated the transaction structure: Initiate-Clarify-Reply (ICR). In ICR, “I” could be a description, gesture, body movement or formulating; “C” could be clarifying, confirming or a concern; and “R” could be description, gesture or body movement. The second observation was that students initiated an transaction structure: Initiate-Reply-Clarify-Reply (IRCR). Their structures are exemplified as episodes 1 and 2. (We use episode number and line number to refer to specific places to which the interpretative text pertains; thus, 1:03 denotes line number 3 in Episode 1.) In episode 1, Nora models using a pump for sucking water from a filter and Students stand beside her watching the demonstration to prepare their practice.

Episode 1

01	Nora	And then this is gonna get a little loud (5.08) ((turns on the pump))	**I**
02	Candy	Oh that is just like suck the water down [faster?] ((points to the filter	**C**
03		which sucking water down))	
04	Nora	[Ya (.)] what is this doing, is like it’s suctioning down	**R**

Before turning on pump, Nora formulates her actions and subsequent phenomenon “this is gonna get a little loud” (1:01) to *initiate* this conversation. After a long pause (5.08) which allows anyone to follow up on this conversation, without being informed by Nora, Candy watches Nora’s actions and the subsequent phenomenon (i.e., loud sound and water

sucking down through the paper filter) and *clarifies/confirms* the purpose of the action. Confirming Candy's reference "ya" (1:04), Nora supplements her explanation for her actions to *reply* to Candy's clarifying questions. In episode 2, one big water can attracts Kelly's attention and Nora tries to explain its nature.

Episode 2

01	Kelly:	what is this? (0.34) ((point 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) and her gesture (pointing at the water can). Nora *replies* to Kelly's question by naming the water inside the can as "double distilled water" (2:02). By asking a question again, Kelly *clarifies/confirms* her understanding of Nora's reply. Then, Nora *replies* to Kelly's question by using synonyms (i.e., "super" replaces "really" and "pure" replaces "clean").

As we can see, these two transaction structures have similar and overlapping portions. They both have ICR and the student-initiated structure has one more "R" after "I." These two transactional structures (ICR and IRCR) are very different from the IRE (initiate-reply-evaluate) that has been reported in the literature. The conversational sequence pattern in classrooms – Initiate-reply-evaluate (IRE) consists of the teacher posing or initiating through a question, the student responding and, finally, the teacher evaluating the student's reply (Mehan, 1979). The way students interact with initiation from technicians is different from their transaction with teachers. Responding to the initiation from technicians, students clarified their understanding to technicians to access more knowledge. When responding to the initiation from teachers, however, students usually gave their answers to the teacher to be evaluated.

4.2. Natural Dialogue Organizations

In the study, we find that two main organizations—*reference* and *formulating*—frequently exist in the transaction of apprenticeship. In terms of reference, besides *preferred* and *dispreferred* organizations, we find another reference organization—*personal dispreferred*— which is different from the preferred or dispreferred terms and indicates both functions of preferred and dispreferred. As for *formulating*, in addition to *self-formulating*, we also find *formulating other*, a category to describe a situation in which one participant formulates what another is doing. In episode 3, we demonstrate how these references and formulating are used in apprenticeship. After Nora's demonstration of filtering sample water

to collect bacteria, Candy volunteers to be the first person to practice the filtering.

Episode 3

01	Candy:	Is it easier like to take off the whole plastic part, and then (0.29) it doesn't rip?
02		Or (0.57) ((left hand holding the filter and right hand holding the tweezers))
03	Nora:	I don't (0.52) personally I don't find it that way, but=
04	Candy	=oh okay=
05	Nora	=if (0.85) I don't know=
06	Kelly:	=just hold on to the filter when you're trying to pull it out
07	Nora:	yea (.) like hold it very loosely (0.43) there you go now pull (1.38)
08	Candy:	yea:: (hhh) (0.81) okay so this part goes up, right?
09	Nora:	yea (0.61) print side up (4.90)
10	Candy:	cool (0.37)
11	Nora:	=and then (0.21) now (0.77) suck up twenty five mils (2.75)
12	Candy:	what a mess here ((laughter)) (.)
13	Nora:	that's okay (.) so am I

After ripping the paper filter and struggling to pull the paper filter from the slot, Candy offerred a suggestion for pulling out the filter: "Is it easier like to take off the whole plastic part, and then it doesn't rip?"(3:01-02). Responding to this offer, Nora doesn't say yes or no but "I don't personally; I don't find it that way" (3:03-05). Here Nora takes a dispreferred way personally to responds to Candy's offer. By saying, "but if…I don't know," Nora opens the possibility of implementing Candy's ideas. In this *personal dispreferred* way, Nora does not accept or refuse Candy's offer directly, but lightly accepts and refuses at the same time. Standing by Candy and not practicing yet, Kelly offers a suggestion to Candy: "just hold on to the filter when you're trying to pull it out" (3:07) while Candy concentrates on her pulling actions. Nora responds to Kelly's suggestion in a *preferred* way "yea, like hold it very loosely" (3:07). Besides this response, Nora also *formulates* Candy's actions: "there you go, now pull" (1.38) to describe what has been done (catching the filter paper successfully) and what is being done (pulling the filter out) by Candy. By celebrating this success, Candy cheers her actions with a long sound "yea" (3:08) and *assesses* her next actions: "okay so this part goes up right?" Again, by saying "yea" (3:09), Nora uses the *preferred* way to agree to Candy's assessment. This *preferred* action from Nora indicates Candy's understanding of Nora's demonstration, so she can get a preferred response from Nora. Without requesting anything from Candy, Nora automatically *formulates Candy's action* again by saying: "and then now suck up twenty five mils" (3:11). Reflecting self-actions in the filtering process, Candy comments, "what a mess here" to express her

awareness of *inadequacy or self-deprecation*. Here again, Nora uses personal dispreferred actions "that's okay, so am I" (3:13) to respond to Candy's comment rather than saying "no" (preferred) or "yes" (dispreferred).

5. Discussion and Implication

The study evidently shows that the transaction structure (ICR&IRCR) is very different from the transaction structure in the classroom (IRE). Without the training of a teaching or pedagogical background, these ICR and IRCR transaction structures allow a learning experience to happen in scientific laboratories. In ICR and IRCR transaction, students frequently clarify their understanding of what they see and what they hear. In IRE transaction, in contrast, students are expected to respond to the teachers' initiation and be evaluated. The actively clarifying action from students in ICR and IRCR has important implications for school. As we know, students do not always "understand" what teachers try to say or to teach. If students could actively clarify what they understand from teachers, these actions would not only help students but also teachers to understand and improve their teaching. From preference organizations, we found not only preferred and dispreferred but also personal dispreferred actions. These personal dispreferred actions in the apprenticeship open up possibilities for adopting students' ideas while they create some ideas for scientists/ technicians. It encourages students to practice more, even when they feel inadequate. Furthermore, through self-formulating and formulating others, tacit knowledge and skills are carried forward and are available for students to understand. This study not only supplies theoretical support for understanding the transaction and natural dialogue organizations in apprenticeship but also has practical implications for school teaching.

6. References

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