Lab Technicians and High School Student Interns—Who Is Scaffolding Whom?: On Forms of Emergent Expertise

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ABSTRACT: Apprenticeship and the associated support mechanism of scaffolding have received considerable interest by educational researchers as ways of inducting students into science. Most studies treat scaffolding as a one-way process, where the expert supports the development of the novice. However, if social processes generally and conversations specifically are dialogical in nature then we would expect to observe two-way processes. The purpose of this paper is to report the results of an ethnographic study of high school students' internships in a scientific laboratory. Data were collected through observation, fieldnotes, and videotaping. Drawing on discursive psychology and conversation analysis, we find that laboratory technicians and students draw on different forms of discursive strategies to articulate knowledgeability while transacting with each other. We put forth the notion of *emergent expertise* to describe new forms of expertise that are not a property of individuals but rather the product of collective transactions. Our study illustrates the importance of opportunities generated in the internship for both old-timers and newcomers to bring about knowledgeability. This study implies a rethinking of the role of the expert and the notion of scaffolding, which puts more emphasis on the transactional process rather than on learners as recipients. © 2008 Wiley Periodicals, Inc. *Sci Ed* **93:**1–25, 2009

INTRODUCTION

Both the American Association for the Advancement of Science (1993) and the National Research Council (1996) argued that K-12 science education needs to move beyond didactic instruction to more authentic science practice where students come to engage like

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scientists. The social studies of science and technology (e.g., Gilbert & Mulkay, 1984; Latour & Woolgar, 1979) have generated advanced understandings of scientists' practices that constitute not only empiricist (e.g., objective experiments) but also contingent components (e.g., subjective choices). These insights assisted many science educators in taking into account more than the substantive content of ready-made science (e.g., knowledge in textbooks). They started considering—in teaching and research—the importance of the social practice constituting science in the making, especially the discursive process in the creation of scientific knowledge (Crawford, Kelly, & Brown, 2000).

Authentic science activities are important in promoting inquiry because they provide ill-defined problem-solving contexts with a high degree of complexity that allow students to experience diverse aspects of science practices (Lee & Songer, 2003). To support students to experience and learn science more authentically, three models of learning activities were introduced (Barab, Squire, & Dueber, 2000; Resnick, 1987): the *simulation*, *partnership*, and *participation* models. First, the simulation model involves creating an open-inquiry environment (inside or outside schools) that is similar to the community of scientists for students to practice authentic science (Barab, Hay, Barnett, & Squire, 2001; Chinn & Malhotra, 2002). In the open-inquiry environment, students take ownership, experience the social nature of practice, and engage in various aspects of science practice. Second, the partnership model involves inviting both students and scientists to participate in a project or camp where they can work together (Lawless & Rock, 1998; Means, 1998). For instance, students collect real data (e.g., air temperature, clouds, precipitation, and so on) and scientists analyze these data to address real-world questions. Third, the participation model involves engaging students to work at the elbows of scientists in real laboratories or field sites (Bell, Blair, Crawford, & Lederman, 2003; Charney et al. 2007). For example, high school students participate in summer science programs where they work as apprentices in university research laboratories. The participation model requires that students leave school and interact directly with scientists in their workplaces. Projects following this model therefore are considerably more difficult to design than projects under the other models (Barab & Hay, 2001). These three models all support students in the process of investigating ill-defined problems (or real-world issues) that need comprehensive research to find solutions—rather than practicing science in a step-by-step fashion to see the "right" results described in textbooks.

In the present study, we invited high school students from a Canadian public school to work with scientists/technicians in a neighboring university's biology laboratory. One of the purposes of our project generally was to connect the resources in the community (e.g., between high schools and universities), as we believe that students should go beyond the walls of the school in learning science. Previous studies of authentic science were mainly concerned with what students "gain" or how they "change" after these authentic science activities (e.g., scientific knowledge, attitudes, views of the nature of science) and have used questionnaires, interviews, or autobiographical journals to collect these data. However, little research has been carried out concerning the transactional processes by means of which students come to participate in science practice in an authentic environment, that is, while they work at the elbow of research scientists and technicians. Here, the adjective "transactional" denotes the fact that the nature of subjects and their mutual roles (e.g., teacher–student, expert–learner) is not determined beforehand, that is, who is in the know, who teaches whom, or who has power over someone else is the result of the processes at hand (Roth & Middleton, 2006). The purpose of this study therefore is to investigate the transactions between students and scientific technicians and particularly to examine how students explore and create opportunities to guide and help scientific technicians to "teach" scientific knowledge in the laboratory. As a result of our analyses, we put forth the notion of *emergent expertise* to help us understand internship (apprenticeship-like) learning in science settings.

THEORETICAL BACKGROUND: LEARNING IN APPRENTICESHIP

Apprenticeship in science research settings and apprenticeship-like learning environments have received increasing attention as a means of helping students construct the appropriate understandings, practices, tools, and language used in scientific activities (Varelas, House, & Wenzel, 2005). In apprenticeship, newcomers advance their skills and understanding through participation with old-timers in culturally organized activities (Rogoff, 1990). Apprenticeship offers newcomers direct exposure to the skills, problem-solving abilities, knowledge, and language of practitioners in the context of everyday practice (Roth, 1995). Prior to the cultural-historical appearance of formal schooling, apprenticeship was the most common means of teaching and learning; and this traditional form provides many insights for teaching and learning in school. For instance, studies of the apprenticeship of midwives, tailors, and meat cutters allowed researchers to illustrate the *situated* nature of learning and to propose the concept of *legitimate peripheral participation* (Lave & Wenger, 1991). That is, learning could be defined as a process of participation in communities of practice, participation that is always legitimate peripheral but increases gradually in engagement and complexity as an individual matures from newcomer to old-timer. The term *cognitive apprenticeship* extends traditional apprenticeship to conceptual issues (i.e., problem-solving and metacognitive skills). Like traditional apprenticeship, it has as its components the phases of *modeling*, *scaffolding*, and *fading* (Collins, Brown, & Newman, 1989). During modeling, the more experienced person engages the practice, which the newcomer thereby experiences first hand; during scaffolding, the old-timer provides resources that allow the newcomer to engage in a practice at a level higher than unaided performance; and during fading, the old-timer withdraws the resources as the newcomer develops the knowledgeability to perform the practice without these. In the present study, we focus on the scaffolding phase, where transactions between old-timers and newcomers are most extensive.

Scaffolding involves a more experienced member who supports the first attempts of participation in a practice by a more junior member in the field (Wood, Bruner, & Ross, 1976). It essentially consists of the more expert individual “controlling” those elements of the task that are initially beyond the learner’s capacity, thus permitting him or her to concentrate upon and complete only those elements that are within his range of competence. For instance, six types of support in the scaffolding process were documented (Wood et al., 1976): recruiting the learner’s attention, reducing the degrees of freedom by simplifying the task, maintaining direction, marking critical features, controlling frustration, and demonstrating solutions to a task.

Whereas early conceptualizations focused on expert–learner transactions, the notion of *distributed scaffolding* implies multiple forms of social and material support that are provided through different means to address the complex and diverse learning environment (Puntambekar & Kolodner, 2005). Scaffolding-related studies mostly focus on developing different teaching strategies to scaffold students’ learning (Donovan & Smolkin, 2002; Kaste, 2004) and designing tools or resources (e.g., software) that provide the scaffolding (Davis & Linn, 2000; Quintana et al. 2004). The popularity of the scaffolding metaphor with researchers is indicative of its conceptual significance and practical value for teaching and educational research. However, the concept of scaffolding is mainly used to emphasize the roles of experts (e.g., teachers) and does not sufficiently address the transactional dimensions of teaching and learning, which, as one recent analysis involving an undergraduate student interviewing professors showed, may be continually shifting (Roth & Middleton, 2006). That is, apprenticeship studies emphasize how experts or teachers scaffold students, whereas little research illustrates aspects of mutuality in the apprenticeship, for example, how novices may actually help experts. In this study, we illustrate aspects of mutuality in laboratory technician–student intern transactions and argue that expertise does not belong to experts alone but requires the cooperation of all participants and mediation of tools.

Apprenticeship has been articulated and associated with the concept of the zone of proximal development (ZPD), that is, the distance between the actual developmental level, as determined by independent problem solving, and the level of potential development, as determined through problem solving under adult guidance or in collaboration with more capable peers (Vygotsky, 1978). However, educational researchers have interpreted ZPD in different ways. The metaphor of scaffolding is frequently used to articulate ZPD as a distance between learners' (novices) performance and the performance supported by more knowledgeable others (experts). In this study, we view the concept of ZPD from a more collective, societal perspective and characterize it as "the distance between current everyday actions of individuals and historically new forms of the societal activity that can be collectively generated" (Engeström, 1987, p. 174). Thus, to achieve the level of potential development from the actual development level, the historical and collective component is the crucial point rather than assistance from a more competent person (i.e., adults and experts).

To theorize forms of participation, the notion of legitimate peripheral participation (LPP) has been adopted and used by educators. To explicitly view learning through a participation metaphor, *a dialectic unit of margin and center* (Goulart & Roth, 2006) is used in the study to avoid the description of individuals moving from "peripheral" to "core" participation, a terminology that leads to the reification of a dualistic view of learning. So every moment of participation constitutes simultaneously marginal and central participation: In this way, any single perspective on participation is but a one-sided expression of the whole phenomenon. This internally contradictory articulation of participation leads to its dynamic possibility. Thus, from a dialectical perspective, the notion of being centered in the margin implies the ever-present possibility that marginal activity becomes central and central activity becomes marginal (Roth, Hwang, Lee, & Goulart, 2005). For instance, one student who seemed not to follow teachers' instruction (at the margin) generated a new way of actions to respond teachers' concerns about particular science topics and his action was followed by other students and acknowledged by teachers (in the center). In this study, we are particularly interested in how high school students, who are at the margin of the new practice (university science), engage in the center through participation (generating new cultural possibilities of science practice). The dialectic unit of margin and center is different from the concept of LPP in a sense that the dialectical unit considers "every moment" of participation as both marginal and central, whereas LPP addresses newcomers are from peripheral to core positions during the trajectory of participation from the periphery to the core of the community. To extend the notion of dialectic forms of participation, we see that each person as the center of their own world. In the case of teaching and learning, learners often know better what they know and do not know, and so can ask better questions or interact with teachers in the best way for their learning needs in each situation. In this view, learners become masters of their own learning and are put into a position where they teach others how to teach them. That is, we do not presuppose individuals' roles as experts or novices but focus on participants' transactions and see what has been produced in their transactions. We propose the notion of "emergent expertise" that helps us to elevate students' positions in teaching and learning and potentially leads us to achieve an equitable, student-centered, and empowered education.

RESEARCH DESIGN

Previous studies on students' authentic science experiences mostly focused on effect or change on students' attitudes or views on natures of science. Little research, however, reported on the ongoing process when students interact with authentic science practices. Concerned with high school students' experience of science in scientific research laboratories, the purpose of this ethnographic study is to investigate the teaching–learning transactions between high school students and technicians in a university–high school partnership program.

Participants

This project includes about 50 participants (13 high school students, 1 high school teacher, 2 scientists, 5 technicians, 25 laboratory members, and 5 educational researchers) in this internship. In this paper, our specific foci are the transactions between high school students and technicians who directly interact with students. In our study, the high school student participants were *like* apprentices in many respects, but their engagement was for a short period of time and without the economic relations (e.g., wage) that mediate traditional apprenticeships (Lave & Wenger, 1991). We therefore denote the experiences as "apprenticeship-like" or "internship" activities. Before inviting high school students to the university science laboratories, we observed high school science lessons (with a total of 28 students) and built a relationship of trust with the participants. The high school students attended a public school in a midsized Canadian city where they had enrolled in an 11th-grade honors biology course that also has a biology career preparation function to it. Usually, career preparation students use extra school time to participate in various science activities to complete the career preparation course, which requires 100 hours over the course of 2 years (Grades 11 and 12). The participation in the internship program serves as a means of accumulating hours for the career preparation course.

The researchers invited students who with an interest to participate in this internship and arranged the first meeting for high school students, scientists, and technicians to meet each other. After meeting with the scientists and technicians for a first time, students actively arranged their after-school time and took the bus to the university biochemistry laboratory. The 13 students who were interested in participating in the internship experience with our collaborating science laboratory included 2 male and 11 female students. Meanwhile, we conducted a 6-month ethnographic study of the laboratory to become familiar with the scientific projects before the high school students' arrival. We participated in the scientists' weekly and monthly meetings and observed their work in the laboratory to understand their work and establish a trusting research relationship.

Internship Context

Two scientists participated in and supervised the activities during this 2-month internship. Before the arrival of these high school students, scientists articulated the forms of internship they were ready to provide and the time schedule with the high school biology teacher and the educational researchers, and further communicated ways of guiding high school students with each technician in each project. Scientists directly interacted with high school students during the first introductory meeting and during the final presentation sections, whereas technicians were the principle "teachers" who were the contacts for the students throughout the internship. But it is not that students *merely* interacted with the technicians. Rather, they participated in laboratory practices practically realized in and through their interaction with a specific technician. When technicians needed instructions or help, they asked the scientists for advice. These five technicians (three females and two males; 22–30 years old; four Caucasian and one Asian; 4 months–2 years working on their projects) were either undergraduate or graduate students who are the main researchers on these four projects (one project has two technicians who take turns guiding high school students). As the main researchers, they would feature on the research articles issuing from the particular project. They all major in biology and have no pedagogical training. Each technician designed an internship plan beforehand and discussed the feasibility of the plan with the research scientists. The purpose of the internship from the scientists' and technicians' point of view is to demonstrate regular work in the laboratory, to show the connection and application of scientific knowledge with daily life, and to provide high school students with opportunities to engage in scientific practices. Four scientific projects closely related to everyday life were selected by the two scientists for the internship, they are projects focusing on (a) bacteria sources tracking in surface waters, (b) pharmaceuticals products determination in municipal wastewater, (c) chemicals tracking in aboriginal sea foods, and (d) household biosand water filter design.

The high school students who had an interest in participating in the project voluntarily came to the laboratories in groups of three to four students; each group followed around and worked with one or two technicians to learn relevant scientific knowledge and techniques in respective projects. These four groups of high school students followed different scientific projects for about 10–16 hours (original plans: 12–14 hours) in each group and the internship activities were observed and videotaped over the course of 2 months. The high school students started the internship by reading some relevant scientific papers selected by the technicians. They also participated in discussions and scientific seminars and practiced particular techniques in respective science projects or collected samples from the field (e.g., Figure 1). After the internship, each group of high school students presented their work and talked about what they learned during the internship to 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. Students' presentations were acknowledged and appreciated by the audience, particularly those scientists and technicians who expressed their surprises and amazements for students' deep understanding and proficiency of these scientific projects. Thus, one scientist stated, "It was done so well, it was done at such level as we would have done it here, very presentable and very kind of scientific in a way."

Figure 1. High school students interact with the scientific technician in the internship. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Theory of Method

In this study, we draw on discursive psychology and conversation analysis to analyze the high school student–technician transactions. Discursive psychology is concerned with how discourse accomplishes and is a part of social actions instead of explaining actions as a consequence of mental processes or of entities in peoples' minds delivered through language (Edwards & Potter, 1992). That is, discursive psychology focuses on how psychological phenomena are produced in talk rather than seeing this discourse as the product of psychological processes (Potter, 2003). Three theoretical principles in discursive psychology include (a) *action orientation*: to identify the business that is being done in talk; (b) *situation*: to notice that discourse is organized sequentially (e.g., turn taking and timing), situated institutionally (e.g., institutional tasks), and rhetorically (e.g., the way versions are put together to counter alternatives; and (c) *construction*: to be aware of how discourse is constructed (discourse itself is built from various resources) and constructive (discourse build the versions of worlds). In this study, we analyze the internship transaction in terms of these three principles rather than presupposing participants' mental states. For instance, when students mention some nonscientific statements, we do not interpret that students "have" particular conceptions, but focus on the available resources, situations, and transactions in that discourse. Likewise, we are less interested in what kinds of knowledge in these technicians' heads for teaching these students, but more in what kinds of concrete (social, material) resources they made available for them to realize the internship.

Conversation analysis, the analysis of naturally occurring talk in interaction, uses detailed transcription to analyze conversation moment by moment and takes turn-taking as the smallest unit for analysis. That is, the emphasis is on participants' transactions rather than on individuals' utterances. There are four fundamental assumptions of conversation analysis (Heritage, 1984): (a) interaction is structurally organized; (b) contributions to interaction are contextually oriented: action is context shaped (i.e., actions cannot adequately be understood except by reference to the context) and context renewing (the context of a next action is repeated renewed with every current action); (c) properties (a) and (b) inhere in the details of interaction so that no order of detail can be dismissed; and (d) the study of social interaction in its details in best approached through the analysis of naturally occurring data. Drawing on conversation analysis, we particularly use the internship's naturally video-recorded data sources, detailed transcripts, participants' real-time responses to support our analysis and claims. Both discursive psychology and conversation analysis have been used in research on how conversations are constructed and used in transactions rather than in trying to explain actions as a consequence of mental processes or entities. That is, expert knowledge and practice are seen not so much as located in the heads of individuals but as situated in the transactions among members of a particular community engaged with the material world.

Data Sources and Data Analysis

In the process of this internship project, we collected a total of 122 videotapes and hundreds of pages of fieldnotes. For this study, we are particularly interested in the teaching and learning transactions that happened during the internship. As these technicians are not teachers and have no educational training, "lay teaching" as it occurs in naturalistic settings is the main concern in this study. Data resources for this study constitute 2 months of observation, fieldnotes, and 15 videotapes (each about 50–90 minutes) of internship activities. We transcribed all the videotapes and adopted basic Jeffersonian system symbols (Atkinson & Heritage, 1984; see the appendix) to demonstrate the episodes for the study. Through repeated watching of the videotapes and reading the transcripts and fieldnotes, we found patterns of variation and consistency in a range of features that allowed us to map out the ways technicians and students draw on to make each other available to accomplish the internship activities. To validate our data analysis, we provide detailed transcripts allowing readers to assess as much data as researchers had to check or challenge our claims. For instance, we not only provide participants' utterances but also their body movements, gestures, laughter, etc. The detailed transcripts of ongoing conversations strengthen the ecological validity (i.e., whether the findings are applicable to people's everyday life) in our study, as our data consist mainly of naturally occurring talk in its authentic social setting. Thus its ecological validity is strong compared to other research methods (Seedhouse, 2005). We also pay extra attention to participants' orientations and responses (the emic point of view) to support our claims. To further establish the credibility of our data analysis, we adopted several techniques from fourth-generation evaluation (Guba & Lincoln, 1989). To satisfy the criterion of *prolonged engagement*, we interacted with technicians and students for at least 6 months, went to school to observe the class every day for 1 month, and observed scientific work in laboratories to build up a trusting relationship. We took fieldnotes in the university laboratory and the classroom, had conversations with technicians and students before and after their classes, and videotaped each classroom session. These techniques deepened our study through *persistent observation*. By discussing research questions and findings with peers who had no contractual interest in the situation (i.e., disinterested educational researchers who did not participate in the study), we tested working hypotheses through *peer debriefing*. After analyzing all the videotapes, and through continuous discussions with peers and conducting a literature review, the findings emerged and were constantly adjusted. The gradually developing process of generating research questions and findings allowed us to reduce privilege and satisfied the criterion of *progressive subjectivity*.

KNOWLEDGEABILITY IN SCIENCE INTERNSHIP: EMERGENT EXPERTISE

This study was designed to explore the learning *process* during high school students' science internship (apprenticeship-like) in a biology laboratory especially where the technicians, the students' main points of reference, have no educational training. Thus, our main focus is the question, "How do teaching and learning happen to accomplish the internship?" Usually, when newcomers arrive in a community, old-timers are presupposed to be experts relative to the newcomers. However, the following analyses of the discourse in science laboratories show that the transaction between scientific technicians and students is not just a one-way process in which the experts scaffold novices but that students actively engage in the activity to mediate technicians to help themselves make sense of scientific work. Interns continually exhibit their knowledgeability of learning and knowing, which assists them in understanding the scientific work of technicians. We show that not only do technicians orientate different strategies to guide students' learning but also students use different strategies to guide technicians' teaching. Both technicians and students help and scaffold each other to accomplish the internship. Thus, the question "Who is scaffolding whom?" seems to be unanswerable. Consequently, the role of expert seems not so "expert" and the role of novice seems not so "naïve."

The heterogeneous and hybrid nature of internship leads us to propose the idea of *emergent expertise* to characterize the apprenticeship-like transactions between experts and novices. In this study, we use the notion of *emergent expertise*—knowledgeability that is not a property of individuals but the educational emergence produced and reproduced during the dual transaction process between participants and mediated by different resources including language (verbal and nonverbal) and tools—as an approach to describe the apprenticeship-like learning process in authentic science laboratories. That is, we propose to think of *expertise* as "collective and knowledgeable achievements produced after (or during) the transacting process in particular situations (e.g., concrete practice or interactive knowledge)" instead of "individual and possessive knowledge in people's mind." To allow the emergent expertise exhibited in the internship transaction, participants drew on different kinds of discursive strategies to facilitate its emergence. These different discursive strategies are constituted in *transactions* between technicians and students; they therefore cannot be stated separately or attributed to individuals from one or the other groups. By watching videos and transcripts simultaneously and repeatedly (around 12 times) and following conversation analysis, that is, turn taking as analysis units and analysis supported by emic points of views (through participants' response in situations), these salient strategies patterns for facilitating scientific expertise reoccurred frequently among four groups of students as identified in Table 1.

TABLE 1
Knowledgeability and Its Discursive Strategies Used to Facilitate the Emergence of Scientific Expertise in the Internship

Knowledgeability	Dominant (Discursive) Strategies Initiated by Technicians	Dominant (Discursive) Strategies Initiated by Students	Frequency (in 120 Minutes)
Making tacit knowledge/ techniques available	Demonstrating techniques with body movements and orally explaining its purpose	Formulating technicians' tacit techniques beyond technicians' instruction through their observation	7 (3%)
Making linking relevant understanding available	Checking or commenting on students' understanding of technicians' instruction	Sharing relevant understanding from school science or everyday life	22 (9%)
Making assessment and clarification available	Opening space for students' assessments and providing immediate feedback to respond to students' assessments	Assessing or clarifying their understanding or adequacy of actions	155 (62%)
Making independent practice available	Supplying opportunities and achievable tasks for students to work independently	Engaging themselves in practice	28 (11%)
Making practice-improvement available	Sharing or considering possible solutions improve practices	Practicing or offering possible solutions for improvement	15 (6%)
Making connection between concepts or practice available	Supplying the whole picture of tasks and gradational results in tasks with visible tools and objects	Connecting the present technique to its purposes or next/precious steps	22 (9%)

In the following sections, we use five exemplary episodes that cover all these salient discursive strategies and exhibit the facilitating role of students *during* the transaction to support the notion of emergent expertise in the internship. These five episodes are relevant to opportunities for (a) *clarifying presuppositions*, (b) *reformulating retrospective instructions*, (c) *further explanations*, (d) *connecting previous and upcoming practices*, and (e) *reflecting science practices*. The first four episodes help us demonstrate how students draw on different strategies to guide and direct the teaching in the internship for different kinds of spontaneous needs and the last episode shows that students can also be the knowledgeable ones who justify solutions for improving science practice. They therefore allow scientific expertise to emerged in and from the transactional relation.

Although we also identified similar discursive strategies used by other technicians and students, for the purpose of illustrating our claims clearly, we selected one group as an example to demonstrate these different discursive strategies. As this group spent the longest period (i.e., 16 hours) in the internship and students in the group practiced almost every technique in the project and therefore allow their strategy patterns exhibited more explicitly. That is, numerous opportunities for students' practices in this group provided a salient "scaffolding" phase for us to investigate their transactions whereas other groups relatively more focused on "modeling" phase due to the nature of their scientific projects. The scientific project in this group is to utilize scientific techniques (e.g., water sampling, bacteria incubating, antibiotic plating, and so on) to identify sources of fecal contamination (i.e., *E. coli*) in surface water. In the group, three high school students (Cindy, Kelly, and Joe) followed the technician (Nora) to learn and practice these techniques of the scientific project (pseudonyms are used throughout.). To illustrate the typicality of these forms of knowledgeability, we selected 120 minutes of transactions randomly (40 minutes in the beginning, middle, and end stages of the internship) from this group to count the frequency for each form of knowledgeability. We watched videos and transcripts simultaneously and took turn taking as our basic unit to count the frequency. For instance, only when students accepted the technician's invitations for individual's practice and engaged themselves into practice, it constitutes a complete turn. If the technician invited students but students did not engage in the practice, we would not consider it as a complete unit. From the frequency results in Table 1, we find that "making assessment and clarification available" is the most frequent form (i.e., 155 times in 120 minutes, 62% among all) of knowledgeability. That is, in the internship, students asked a lot of questions to clarify their understanding and so this form of knowledgeability becomes the dominant discourse to facilitate teaching and learning happened in the internship. (In the following analysis, italicized words are used to indicate different strategies listed in Table 1, and we use episode number and line number to refer to specific places to which the interpretative text pertains; thus 1:06 denotes line number 6 in Episode 1.)

Opportunities for Clarifying Presuppositions

Teachers often presuppose students' relevant understanding of particular topics in terms of their grades or curriculum students have taken (Jarman, 1997). However, who can really know learners' knowing and not knowing about particular topics? Who can clarify specifically about learners' relevant understanding? The answer probably is that the learners themselves have a good sense concerning the answers. Our study shows the importance of the opportunities provided by both technicians and students to clarify their presuppositions and relevant understanding for each other. In the following episode, Nora initially appears to misunderstand students' relevant understanding about enzymes; we then show how students and Nora further help each other to achieve clarification about their presuppositions.

In Episode 1, Nora prepares to show students about working with a heat block. She describes her prospective actions and tries to explain the function of a heat block for the mechanism of enzymes.

Episode 1 (0403-1-4012)

Nora:	and now we are throwing these guys in the heat block (1.47)
	((left hand holds the tube box and right hand puts tubes
	into the heat block)) this is called a heat block. ((the
	right hand points at the heat block)) (3.66) and we're just
	leaving them there, (0.50) for a half hour ((putting more
	tubes into heat block))
	(4.62)
Cindy:	that just gonna like heat them up ↑ Is that ↑
Nora:	YA: the (1.06) u::the heat is gonna activate the enzymes
	(0.86) a::nd (0.75) I think (0.83) the confusion here
	(0.55) that you ((the right hand points to students)) might
	have had (0.66) was arising from um:: (1.28) ((after
	putting all the tubes into the heat block, Nora turn back
	to direct face students to explain)) when you guys were
	taught about enzymes you are taught about them (1.03)
	having two molecules ((two hands expand to the opposite
	direction)) (0.38) making one (two hands clap) (1.22) or
	something like that ↑ ((two hands open))
	(0.72)
Cindy:	heh ((laugh))
Nora:	no ↑ (1.07) [okay=
Cindy:	[I don't really remember enzymes heh heh ((laugh))
Nora:	Okay (0.62) um: ((goes back to the table and is looking for
	a pen and paper)) (4.39) have great draw a paper (0.94) so
	(0.89) um:: (0.55) basically enzyme (0.69) have molecule a
	(0.65) and molecule b (1.57) ((drawing diagram to assist
	her to explain)) an:::d you've got some sort of enzyme::
	that looks something like this ↑

After dropping enzymes into tubes that carry pure *E. coli* bacteria, Nora introduces the heating process for activating enzymes. Nora first introduces the technology called "heat block" (1:03) but does not formally introduce its purpose. So Cindy *clarifies her understanding* about the purpose of this procedure "that just gonna like heat them up?" (1:08). After Nora's *immediate confirmation* "ya" (4:09), she articulates thinking that students may have confusion here "I think the confusion here that you might have had was arising from um" (1:10–12) with her finger pointing to students. She exactly points out the possible confusing concept of "enzyme" and "two molecules making one" (1:15–17) with her hand movements to try to recall students' understanding about the function of enzymes. Nevertheless, following with a pause and students' embarrassed laughter (1:19–20), it shows that students have difficulties in understanding Nora's explanation. Thus, Nora further *checks students' understanding* of the concept of enzyme by asking "no?" (1:21). Cindy then *shares her relevant understanding* about enzymes "I don't really remember what an enzyme is" (1:22), and so Nora turns back to her desk and finds a paper and pen to assist her explanation about the function of an enzyme (1:23–28).

In this episode, one can see that Nora (the technician) presupposes that students may have confusions about some concepts arising from enzyme. But from the students' responses, they illustrate another difficulty for understanding the fundamental concept of enzyme. That is, the technician makes available her awareness of students' possible difficulties concerning some applied concepts arising from enzyme, but not the concept of enzyme itself. In students' responses (i.e., pause, laughter, oral statement), Nora notices their confusion and then has the opportunity to explain the fundamental concept of enzyme. This episode therefore shows that the knowledgeability about the function of an enzyme is emergent from the transaction between the technician and students. Without the technician's checking, students might not have the opportunity to point out the fundamental difficulty. Likewise, without students' sharing, the technician might not notice and would not have the opportunity to exhibit her knowledgeability about the fundamental concept of enzyme. Thus, the expertise to explain the fundamental concept of enzyme is not solely located in the technician but is negotiated between participants and emerged *in* and *from* the transactions among participants and resources (language and tools such as the paper and pen in this episode). Although students seem at the margin (did not know the function of enzyme), their knowledgeability to help the technician understand their real difficulty is the key action to improve the situation (in the center). This allows us to think about the importance of opportunities for both teachers and students to communicate their presuppositions for each other in teaching and learning. Especially while learning new concepts, units, and curriculum or entering into a new environment or classroom, these opportunities for clarification appear particularly important for both teachers and students, as they open up the possibilities for understanding each other better to further enhance better learning.

Opportunities for Reformulating Retrospective Instructions

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). Thus, it is important to address questions such as, "How do teachers know what kinds of difficulties students encounter?" and "How do teachers help different students in the ways suitable for different students?" Our study shows that the opportunities initiated by students allow teachers (technicians) to get the clues of these difficulties and then adjust or reformulate their previous instruction. In the following episode, we show how students help the technician to "reteach" in a way that fit for students' needs.

In Episode 2, students integrate their understanding of Nora's previous demonstration and formulate their ways of explanation to request a confirmation or comment from Nora for their understanding. *Formulating* is a pervasive conversation feature of talk in transaction and is about what is being done and what has been done (Roth, 2005). After demonstrating the procedure of putting bacteria on an agar plate to cultivate pure *E. coli* bacteria, Nora invites students to complete the remainder of the task. Cindy volunteers to be the first one *to engage the practice* of the cultivating procedure. Nora and the other student, Kelly, stand at the back to watch. When Cindy practices the technique, Kelly formulates her observation of Nora's retrospective demonstration in her own words and requests Nora's confirmation.

Episode 2 (0221-2-0150)

01	Kelly:	are you dragging it from the circle [when you]
02	Nora:	[YES=
03	Kelly:	=okay=

04	Nora:	=you picking up bacteria and you're drag it all along.
05		((moving hands in the air to imitate actual doing))
06		(1.35)
07	Cindy:	That's so cool:: (1.08) heh:: the guys ever seen in the
08		pictures it was like I'm so
09	Kelly:	=ya=
10	Cindy:	= intricate I was like how do they DO that like ↑
11		((hands are moving to do the cultivating on plates))
12		(0.94)
13	Kelly:	I thought it just the colonies like movie heh (hhh)
14	Cindy:	ya:: like just doing it themselves heh
15		(1.60)
16	Nora:	NO you are actually physically [moving it.
17	Cindy:	[ya (0.74) that's cool

While Cindy is sitting in front of Kelly and is actually putting bacteria on her agar plate, Kelly *formulates tacit techniques through her observation* to confirm with Nora the details of doing the cultivating procedure: "Are you dragging it from the circle?" (2:01). Nora immediately responds: "Yes" (2:02) and *demonstrates by virtual hand movements and oral explanation* to guide Kelly to understand Nora's retrospective demonstration. After a long pause (2:06), Cindy comments, "that's so cool" (2:07) while she is doing that technique. In the meantime, Cindy *shares the relevant understanding* and articulates her understanding about the agar plates from the pictures of textbooks with a high-pitched voice: "the guys ever seen in the pictures" (1:07–08). She also illustrates her confusion at that time "I'm so intricate" (2:10–11) about the bacteria-growing pattern on agar plates in textbooks and also talks about not knowing the reasons for the bacteria-growing patterns when she looked at the pictures in textbooks: "How do they do that?" (2:10). Kelly agrees and responds to Cindy's confusion by saying "Ya" (2:09). She produces an analogy to a similar phenomenon of that pattern on agar plates from her experience: "Just the colony like movie" (2:13). Furthermore, Cindy expresses her hypothesis for the reason of her own question "Just like doing themselves" (2:14) which responds to Kelly's comments about the phenomenon. After listening to the conversation between Cindy and Kelly, Nora *comments on their previous understanding*: "No, you are actually physically moving it" (2:16). Cindy then confirms her understanding of the reason behind the phenomenon of the bacteria-growing pattern and comments on the cultivating procedure: "Ya, that's cool" (2:19).

In this episode, we see Kelly reformulating Nora' previous demonstration in her own words and requesting confirmation from Nora. That is, Kelly provides Nora with an opportunity to clarify her previous actions and, at the same time, she also supplies an opportunity allowing Nora to help her (Kelly) to better understand how to do the technique. Here, Kelly's question exposes her knowledgeability in observing and supplying an opportunity for Nora to clarify. She is the center of her own learning; she asks a suitable question for herself to learn the technique. Nora never gives an instruction like "drag it all along" before, but recaps Kelly's way of formulating "you're drag it all along" (2:04). That is, Nora accepts Kelly's new formulation and now has a new way of introducing this technique.

In this episode, one can see that it is not just the technician who teaches students to do the practice, but the student also "teaches" the technician how to "teach" differently. Likewise, when Cindy shares her relevant understanding, she actually exhibits her knowledgeability about connecting the relevant understanding to the present technique. That is, Cindy's sharing helps Nora to realize the students' understandings about cultivating plates and so further emphasizes her explanation by saying "actually" and "physically." Before Cindy and Kelly's conversation about seeing the pattern in the textbook pictures, Nora never used the two words "actually" and "physically" to introduce the procedure of techniques. Here, Cindy and Kelly's conversation again supplies an opportunity for Nora to reformulate her retrospective demonstration by using different terms. From this episode, we learn that students do not just do what the technician wants them to do, but they observe, connect to their personal experiences with their present situation, and even generate new formulations to guide the technician's instruction (in the center). Students' conversations not only supply the opportunity for the technician to explain the retrospective introduction by using different and new terms but they also supply the opportunity for themselves to clarify their own understanding.

In sum, this episode illustrates the importance of the opportunities provided by students to reformulate or guide the technician's instruction in a way that students prefer or can make sense of. Consequently, these opportunities allow teachers to learn from students and adjust their teaching for different students' needs, so students can come to understand whether different ways of interpretation or instruction were formulated for them.

Opportunities for Further Explanations

Feedback or evaluation from students is generally regarded as an effective way to improve teaching (Boudett, Murnane, City, & Moody, 2005). However, these feedbacks are usually collected and utilized after teachers' instruction to improve further instruction. In the internship study, we find that students' immediate responses and questions during the transaction not only lead to improve teaching (e.g., adjust previous instruction in Episode 2) but also served as crucial resources for guiding the technician' teaching direction and depth of instruction at the first place. In the following episode, we show how students guide the technician's teaching directions and contents.

In Episode 3, Cindy contingently asks a series of questions until she solves her conflicts or confusion about Nora's demonstration and instruction. It shows that Nora and Cindy both hold the conversation's "remote control." That is, Nora instructs Cindy but Cindy also leads Nora and gives the technician clues about what to instruct. After Nora's demonstration of using the microcentrifuge, Cindy is curious about the running frequency of the microcentrifuge and asks relevant questions. Nora then answers Cindy's questions orally with her body movements in front of the microcentrifuge. In the following analysis, we focus on how Cindy responds to these answers and how she supplies opportunities for the technician to give further explanation.

Episode 3 (0403-1-0922)

Cindy: cool (1.53) this is how many times it's spinning ↑ ((the
right hand points to the screen of micro centrifuge))
Nora: that's how fast it's spinning. ((the left hand points to
the screen of centrifuge)) (1.21) um:: (0.38) what is that
measurement then (.hhh) (1.52) RPM (1.03) rounds per
minute(1.33) or revolutions per minute I guess::
(1.22)
Cindy: so every minute only goes around ten times ↑
Nora: UM:: ten thousands times.
(0.46)

11	Cindy:	OH::: ↑ OH [times a thousand.
12	Nora:	[times a - YA::: ↑
13	Cindy:	I was like that is <QUITE slow:::> like I thought it was
14		like sh:: ((right index finger whirl in the air))
15	Nora:	oh ya it's going fast.

When Nora operates the microcentrifuge, Cindy *assesses her understanding* of the meaning of the numbers showing on the screen of the microcentrifuge "this is how many times it's spinning?" (3:01) with her fingers pointing to the screen. Nora *immediately responds* to Cindy by saying "That's how fast it's spinning" and further explains the meaning of the sign "RPM" as " rounds (revolutions) per minute" (3:05–06). However, this answer from Nora does not satisfy Cindy and so makes Cindy further *clarify her understanding* and apply it by using exact numbers showing on the screen "so, every minute only goes around ten times?" (3:08). Nora immediately says "um, ten thousands times" (3:09). Here, we can see that Cindy may misunderstand the original explanation from Nora (i.e., 10 times per minute) if she does not ask further questions. After the response from Nora "um, ten thousands times," Cindy realizes the number showing on the screen (i.e., "10") needs to be multiplied by a thousand to be the exact running frequency of the spinning and so solves her confusion of the surprisingly low frequency "I was like, that is quite slow" (3:13).

In this episode, we see that Cindy asks a series of questions to guide and facilitate the technician's explanation until Cindy is satisfied. If Cindy were not to ask questions about the frequency of microcentrifuge, Nora might not be able to share the expertise of the concept of RPM. If Cindy did not clarify her understanding about Nora's explanation, Cindy might misunderstand that the microcentrifuge only runs 10 times per minute. That is, Cindy continually supplies opportunities for the technician to give further explanation and at the same time provides herself opportunities to make more sense of the microcentrifuge. These discursive strategies (e.g., assessing and clarifying) allow the student to bridge between herself and the technician to achieve a common understanding. Without Cindy's clarifying, the technician would not know Cindy's relevant understanding and would not have the opportunity to explain more scientific knowledge for Cindy's particular need. That is, the scientific expertise is achieved and illustrated with both the student's assessing and clarifying and the technician's responses. Meanwhile, Cindy's series of questions make us realize that students are the center of their learning, that they are the only ones who know when is the right time and what is the right question to clarify their understanding. These responsible assessing and clarifying actions from students make the technician (or teacher) have clues and better sense about how to instruct and teach for students' needs.

In sum, this episode shows that students do not just passively receive what the technician teaches but illustrates the students' roles as a facilitator, guide, or coach to help the technician in the internship transaction. In particular, students' initiative actions may open up more possibilities to lead teachers to "teach more" unexpected concepts or relevant experiences for different students.

Opportunities for Connecting Previous and Upcoming Practices

To advance efficient teaching, teachers are often encouraged to survey students' prior knowledge before classes and make connections between learners' prior knowledge and their present teaching (Myhill & Brackley, 2004). However, our study shows that students also need explicit connections between the previous and the upcoming practice "during" the instruction, and so connection should not only be addressed before the instruction but also during the instruction continually. Most importantly, students' initiation actions point out the need for connection immediately and so the technicians could have opportunities to notice when and how to enhance these connections. In the following episode, we show how students initiate these opportunities for the technicians to explicitly connect the previous and upcoming practice.

In Episode 4, Nora starts to demonstrate a new science practice called purification (referred to here as the second purification). Before this, students had finished their practice on a similar purification (referred to here as the first purification). However, when Nora demonstrates the second purification, she does not explicitly connect these two purifications. The procedure in the first purification is to put bacteria (*E. coli*) from a tube onto an agar plate (referred to here as the old agar plate) and the procedure in the second purification is to put bacteria from the agar plate produced in the first purification procedure onto another blank agar plate (referred to here as the new agar plate). Without explicit connection, students might not smoothly transit from the previous to the next step, and they illustrate their confusion about the purpose of the present technique. In Episode 4a, we show how students provide opportunities for connection while Nora starts to demonstrate the new science practice.

Episode 4a (0221-2-1344)

Nora: so this next step (1.01) is basically the same ((sterilizes her hands and then opens the old agar plate)) with the exception that you're gonna scrape off one of the isolated colonies

Cindy: mm

Nora: I put a black circle around them (.) so you guys knew what you were taking ((uses the scraper to scrape the E. coli on the old agar plate)) so you're just take it ((starts to scrap)) an::d (.) just drag it across the colony (.) you'll get some on the on the scraper ((the right hand holds the scraper and the left hand puts down the old agar plate and takes the new agar plate)) and again ((uses the scraper to pattern the E. coli down on the new agar plate)) a little circularly ((uses the scraper to draw some circles on the new agar plate)) with the lines and everything ((draws other lines and patterns and sterilizes the scraper periodically))

After students' individual practice on the first purification, Nora starts to demonstrate the next step for students to observe and learn. First, she refers to the first step as "basically the same with the exception that you're gonna scrape off one of the isolated colonies" (4:1) and prepares herself (i.e., sterilizes her hands) for the demonstration. Before the demonstration, Nora had already identified *E. coli* colonies and drawn black circles on the back of the old agar plate to identify them for students, so they could follow these black circles to mainly scrape *E. coli* from the old agar plates (4:6–8). Nora further demonstrates the process of putting the *E. coli* from the old to the new agar plate "so, you're just take it and just drag it across the colony, you'll get some on the scraper, and again, with the lines and everything" (4:8–16). Here, we notice that Nora uses the term "again" (4:12) to remind students that the present step is almost the same as the previous practice and so she shortens the other following procedure to "everything" (4:15). However, Cindy seems to have difficulty to understand Nora explanations, thus questions the purpose of the preset step in Episode 4b.

Episode 4b (0221-2-1344)

18	Cindy:	what's that doing
19	Nora:	pardon ↑
20	Cindy:	Like (.) what are you like
21	Nora:	this is purification
22	Cindy:	O::kay
23	Nora:	um:: ((drawing lines on the agar))
24	Cindy:	OH: so you're only taking out the E. coli or whatever and
25		then ((Nora continues drawing lines on the agar))
26	Nora:	EXACTLY ((drawing lines on the agar))
27	Cindy:	I see
28	Nora:	((sterilizes the scraper, continues and then finishes the
29		plating actions)) ya (.) because this stuff ((holds the new
30		agar plate)) here is a really good nutrient base ((puts
31		down the new agar plate)) whereas this stuff ((holds the
32		old agar plates)) isn't great, but you can just tell what
33		is and what isn't E. coli ↑
34	Cindy:	mm:
35	Nora:	um:: so (.) has to look like E. coli on here ((points to
36		the old agar plate)) and then it has to look like E. coli
37		on here ((points to the new agar plate)) and then we're
38		REDOING this step so we're taking the colony off here
39		((points to the old agar plate)) putting it onto another
40		one of these plates ((points to other new agar plates))
41	Cindy:	Oh, really ↑
42	Nora:	um: just to (.) make sure all the way along (.) we have E.
43		coli

After a long silence while Nora is finishing her plating, Cindy tries to *connect the present technique to its purposes* and asks questions "what's that doing," "like what are you like (doing)" (4:18–20) and Nora responds, "this is purification" (4:21). Here, we observe that the student seems not to understand the purpose of the present step although Nora mentions "the next step is basically the same (with the previous step)" (4:01). She then explicitly points out that the purpose of the present step is purification (similar purpose to the previous step). Cindy responds to Nora's explanation "oh, so you're only taking out the *E. coli*" (4:24) and got the confirmation from Nora "exactly" (4:26). Here, we see that Cindy uses the word "only," which indicates that she realizes that the last step not only plated *E. coli* but some other bacteria and so is different from the present step where Nora "only" plates *E. coli*. Although Cindy further confirms that now she understand the step after Nora's explanation "I see" (4:26), Nora continues to provide more detailed explanations that explicitly identifies the difference between the previous and the present steps. This time she does not explain in an abstract manner (4:01–04) but *uses concrete tools* (the old and new agar plates) and *supplies a bigger picture* to support her clearly pointing out the difference (4:28–43). That is, the first purification is to nurture by a normal agar material and roughly identify *E. coli* and the second purification is to further nurture the *E. coli* identified before by the better agar, and the purpose of these repetitive procedures is to make sure that what they got is pure *E. coli* (4:42–43) but not some other bacteria.

From Episode 4, one can see that although Nora states the present step is almost "the same" with the previous step that the students just practiced but with a little exception (i.e., scrape only one colony of *E. coli*). However, from Cindy's question about its purpose, we notice that Cindy cannot make sense of what is "the same" thing (i.e., the purification). Therefore, Cindy's question supplies the opportunity for Nora to recognize Cindy's confusion and to provide explicit explanation (i.e., contrast comparison) with concrete materials (i.e., new and old agar plates) to buttress herself and students to achieve the common understanding. Here, we notice that in the further explanation, Nora not only points out the "exception"—scrape the isolated colony (4:03) but also points out another difference—the different material of agars (i.e., the latter agar is richer than the former one). That is, if Cindy did not ask for the explicit explanation, students would not know the same part (the purpose of purification), and let alone the two differences between the two steps. Thus, although Cindy did not appear to understand the connections initially (at the margin), her questions played an essential role (in the center) to facilitate Nora's explicit and appropriate instruction for this particular situation. Cindy's questions and Nora's further explanation not only allow students to better understand the present step but also connect to a bigger picture (differences between steps) that help students to make sense of the local actions. Furthermore, these opportunities for connections between different techniques or concepts have important implication in science education in particular, as they help teachers and student to co-construct the semantic relationships (Lemke, 1990) between different scientific concepts that usually are implicit but have crucial roles in science teaching.

Opportunities for Reflecting Science Practices

A large body of research has demonstrated numerous differences between experts and novices (Chi, Glaser, & Farr, 1988). In general, an expert can be a person who is capable of providing strong justification for a range of claims in a domain or perform a skill well according to the rules and virtues of a practice, but novice cannot (Weinstein, 1993). Whereas the literature generally makes clear distinctions between experts and novices—for an exception, see Roth and Middleton (2006)—our analysis of the internship transaction shows that the boundary of experts and novices is not clear and so should not be predetermined. We find that the newcomers (the students) are knowledgeable persons who offer justifications (e.g., solutions) and opportunities for improving or reflecting science practices demonstrated by the old-timer (the technician). In the following episode, we show how students can offer their ideas generated through their repeated practices for the technician to reflect and possibly improve the science practice.

In Episode 5, it is the first day of the internship when Nora invites students to practice after her demonstration about filtering water samples. Students engage themselves in the practice and provide opportunities for reflecting the science practice for both the technician and students.

Episode 5 (0221-1-0525)

```
01  Nora:   So if there is anybody wants to try:: one of the other
02          (.)like the twenty five mil sample ↑ ((hands clap))
03  Cindy:  I'll give er a go=
04  Nora:   =OKAY:: give er a go
                                                  ...(continue)
05  Nora:   ((passes on the box full of paper filter packages))
06  Cindy:  okay ↑ ((picks up one paper filter package from the box and
07          then tears the plastic from the paper filter package))
08          focus just like the white part ↑
```

09	Nora:	The white part between the two blue
10	Cindy:	Oh: okay ((the left hand holds the paper filter and the
11		right hand picks up the tweezers, and then tries to use the
12		tweezers to grip the paper filter out of the package))
13		(10.12)
14	Nora:	it becomes an art form don't worry
15	Cindy:	alright (3.34) oh (1.38) okay
16		((The tweezers rips part of the paper filter))
17	Joe:	heh
18	Cindy:	I ripped it ((shows the ripped paper filter to Nora))
19	Nora:	that's okay we'll use another one
20	Kelly:	°heh heh°
21	Cindy:	WOW LA heh heh
22	PL:	heh heh heh
23	Nora:	((Passes another paper filter package to Cindy))
24	Cindy:	okay thanks (0.72) so if it is easier like to take off the
25		whole plastic part and then (.) it doesn't rip ↑ Or
26	Nora:	I DON'T (0.55) personally I don't find it that way but
27		(0.52) if (0.82) I don't know::
28	Kelly:	=just hold on to the filter when you're trying to pull it
29		out
30	Nora:	yea (.) like hold it very loosely (0.43)
31		there you go now pull (1.38)
32	Cindy:	((grips the paper filter and pulls it out of the package))
33		yeah:: (hhh)

Following Nora's demonstration of filtering, she *provides opportunities for students to practice individually* "if there is anybody wants to try" (5:01) and Cindy immediately volunteers to be the first one and expresses her willingness to *engage herself in the practice* "I'll give er a go" (5:02). After setting down all the equipment, Nora passes on the box full of paper filter packages to Cindy and Cindy picks up one package and tries to use tweezers to pull the paper filter out of the package (5:05–12). However, Cindy encounters difficulty in using the tweezers to grip the paper filter (tight between two blue papers), so this action lasts for 10.12 s (5:10–13). Nora notices Cindy's difficulty and so comforts and encourages her practice "it becomes an art form don't worry" (5:14). Cindy accepts this encouragement and continues her actions "alright" "okay" (5:15). During the practice, Cindy unexpectedly rips the paper filter (5:16) and Joe notices this phenomenon and laughs (5:17). Cindy tells Nora that she ripped the paper filter (5:18), and Nora comforts Cindy "that's okay, we'll use another one" (5:19). Kelly, Cindy herself, and PL (the researcher who holds the camera) all laugh to respond to this phenomenon (5:20–22). Nora then passes another paper filter package to Cindy. Before doing another griping action, Cindy *offers a possible solution* to improve the procedure of pulling the paper filter out of the package "if it is easier like to take off the whole plastic part and then, it doesn't rip" (5:24–25). Nora responds to this solution in an ambiguous way, that is, she neither accepts nor rejects "I don't, personally, I don't find it that way, but, if, I don't know" (5:26–27). Then, Kelly, the student standing beside Cindy, who has not practiced this procedure yet, offers another solution for improving Cindy's practice "just hold on to the filter when you're trying to pull it out" (5:28–29). Nora acknowledges Kelly's suggestion "yeah" (5:30) and *shares her experience* "like hold it very loosely" (5:31). Finally, Cindy grips the paper filter and pulls it out successfully with Nora's formulating and so follows with a celebration sound "yeah" (5:31–32).

In this Episode 5, we can see that Nora, the experienced technician who practices this procedure hundreds of times, considers Cindy's suggestion as a possible solution for improving the practice. The "but if" in Nora's utterance acknowledges the possibility of Cindy's solution. Surprisingly, Kelly, who arrives this laboratory with Cindy at the first time and has not practiced the technique in person yet, can "teach" Cindy how to do the scientific technique and can also get acknowledgement from Nora—the experienced old-timer. That is, newcomers' (i.e., high school students) suggestions have their own values and potentialities that are worth considering and adopting by the old-timer. As a result, this episode shows that the boundary between experts and novices are not clear and not necessary. Students are not always novices who only receive instruction from experts, and technicians are not always experts who teach their scientific knowledge to others. However, students also can "be in the know" (Roth & Middleton, 2006, p. 24) to teach peers or be the knowledgeable ones who offer solutions to professional personnel like Nora for improving practice. Therefore, the heterogeneous roles of high school students and the possibilities of students' contributions to old-timers' expertise assure us to propose the notion of emergent expertise that did not predetermine the roles of experts and novices for participants but focus on participants' transactions and its products of their transactions.

KNOWERS AND LEARNERS: BEYOND DETERMINISM

This internship (apprenticeship-like) study shows various forms of teaching and learning transactions that are very different from the report of previous studies. Over the past decade, numerous educators and researchers have used the concept of scaffolding as a metaphor to describe the role of adults or more knowledgeable peers in guiding students' learning. However, the scaffolding metaphor might lead to a narrow view of the child–teacher interaction and an image of the child as passive recipient of a teacher's direct instruction, which may distort the Vygotskian idea of the ZPD and the Piagetian view of the child as an active self-explorer (Verenikina, 2003). Furthermore, sometimes scaffolding can be seen as a one-way process wherein the scaffolder constructs the scaffold alone and presents it for the use of the novice (Daniels, 2001). For the purpose of avoiding predeterminations, in this study, we adopt a new way of seeing each person as a dialectic unit of center and margin, and extend the idea to see that all students are the center and master of their learning. This perspective helps us to identify different discursive strategies drawn on by students to learn in particular ways and make available opportunities for others to support them in the way they need. Thus, we learn that the apprenticeship-like activities are not constituted by one-way process in which experts pass knowledge to novices but through the dual transaction process where participants help each other and are mediated through all kinds of resources (e.g., language and tools).

Our analyses demonstrate different forms of knowledgeability (see Table 1) supported by different discursive strategies drawn on and shared by both technicians and students to produce different opportunities or space for learning in the internship. Five episodes were demonstrated in this study to illustrate five kinds of essential opportunities initiated by students allowing the teaching and learning happened in the internship: (a) opportunities for clarifying presuppositions, (b) opportunities for reformulating retrospective instructions, (c) opportunities for further explanations, (d) opportunities for connecting previous and upcoming practices, and (e) opportunities for reflecting science practices. The first four kinds of opportunities not only help technicians to notice students' learning situations but also guide technicians to teach in a way that students needed. The last kind of opportunities further allows technicians to reflect possibilities for improving their already-proficient practices. Therefore, these essential opportunities not only help students to learn but also to "teach" technicians. Likewise, they also help technicians teach and "learn." The dual helping mechanism benefits both newcomers (students) and new teachers (technicians) accomplish teaching and learning during the internship.

These teaching and learning opportunities, which are explicitly initiated by students and supported by both groups of participants (technicians and students), have important implication for both teaching and learning. They provide chances to illustrate students' understanding and clues for guiding technicians (teachers) to improve their teaching. Without these opportunities, technicians would not efficiently "scaffold" the scientific work to students, and students would not successfully learn in the internship. In this sense, these *opportunities* for "scaffolding" seem to have significant importance; precisely, these opportunities were ignored in previous studies. Thus, we argue that learning should not be taken as something that is scaffolded by teachers, as it presupposes the reification of a dualistic view of expert and novice and emphasizes mainly the learners' roles of receiving scaffolding from the more competent other. Rather, we see learning as a dynamic process that emerges from student–teacher transactions, where participants may take both roles not only in turn but also simultaneously. That is, learning is not just controlled and directed in the hands of "teachers" but also in the hands of "students." Students' guiding and directing actions allow students having opportunities to learn what they desire to learn individually and not just learn the same things that teachers want them all to learn.

We therefore suggest that educators and teachers provide the space and encourage students to question their observations or clarify their understanding as much as possible, as it may not only help both teaching and learning in schools but also help students to develop the habit of questioning throughout their lives for lifelong learning (Wiggins, 1989). This has important implications for new teachers in particular. For example, the technicians in our study did not have prior educational training. However, they successfully "taught" the high school students, as the space provided in the transaction allowed students to interact in a way that *guided* the technicians to teach. Thus, beginning teachers not only could learn from students about their personal interests or lives (Bianchini & Cavazos, 2007) but also the pedagogical guide and facilitation for individual students. In particular, with the need to teach in ways that fit students' diverse background in the classroom (Brownlie, Feniak, & Schnellert, 2006), it is important to create space and encourage students to speak out their different voices at anytime and anyway they need. Afterward, "authentic student voices" may then be able to consulted to create local and personalized curriculum to improve education (Thomson & Gunter, 2006).

In this study, we propose the notion of *emergent expertise* to emphasize the transactional nature of expertise. This notion allows us to rethink the presupposition of the institutional roles of experts and novices in the learning process. Unlike the notion of *legitimate peripheral participation* (Lave & Wenger, 1991), students were not deemed to be ignorant novices who engage and thereby move along a trajectory from peripheral to core participation; rather, they acted centrally and marginally in a simultaneous fashion. For instance, we can see that students who are usually deemed as novices sometimes could be, in the traditional sense, *experts* who offer solutions for improving science practice (e.g., Episode 5). Thus, we argue that expertise is not a property that belongs to individuals such as old-timers but is emergent in the transaction with others.

This proposal has significant potential (its fruitfulness) in education. If we do not presuppose the institutional roles of individuals, then students' potential as agents will not be underestimated. Without the predetermined boundary of experts and novices, it may open up more possibilities for students to surpass what teachers expect them to learn. That is, we will not see students as just passive novices—or worse, containers—who receive instruction, but as capable persons who may guide and help their own and even their teachers' teaching. Learners are not just students (margin) but teachers (center) at the same time. Meanwhile, we will not see teachers just as scaffold builders (center) but as learners (margin) who learn to teach differently and according to different students' needs. In a situationally appropriate way, students and teachers may be *experts* for each other and their collective expertise emerges in and from transactions that situationally assigns different roles on an as-needed basis. Expertise comes to be shared and distributed within the community where ideas are mutually negotiated (Brown et al., 1993). That is, expertise comes to be appreciated as the product of transaction, but not the predetermination before transactions. The notion of emergent expertise helps us to elevate the roles of students in science learning, as students now are not just deemed as receivers but as crucial contributors who could make their learning (and teaching) more efficient and successful. As a result, if teachers and students were educated and supported with the notion of emergent expertise, students would be encouraged to take more responsibility and be more autonomous in their learning in schools or even in their lifelong learning after schooling.

With this perspective comes a new sense for responsibility and autonomy in learning, which possibly leads to establish a community where students deem themselves as people who can make a difference in their education, schools, and neighborhoods. In fact, we support the perspective of seeing students as capable citizens who can contribute their opinions and voices to the society, rather than seeing them as passive receivers who accept the only "truth" from *experts*. Furthermore, the notion of emergent expertise also helps us to address equity in (science) education. Because expertise is emergent during the transaction but not belongs to individuals, "everyone" has the chance to allow the emergence of expertise during their transaction. Meanwhile, students are understood to be centers of their learning, so "everyone" is the master of their learning and has important contributions to their learning that may surpass to contributions from others such as teachers, higher achievement or different background peers. All voices are heard and valued to help co-construct the best of education.

According to the notion emergent expertise, we now argue that expertise is not constituted in individuals but emergent during participant's transactions with available resources. Therefore, how to create the space for essential transactions to bring out the best for each other is the crucial question for future research. Important research questions for further studies may include "What are the possible structures of the space to increase the depth and width of emergent expertise in the transactions?," "What types of transactions appear in these structures?," "How do resources mediate transactions in these structures?," and "How do the emergent expertise enhance the following learning and participation in their communities?" Furthermore, for the traditional view of scaffolding or zone of proximal development research it might be interesting to explore how "expert" could be "scaffolded" by "novices" to bring out the best of each other. These studies will help us to understand *how* to achieve an equitable, student-centered, and empowered education.

APPENDIX

Basic Jeffersonian Transcription Notation (Atkinson & Heritage, 1984)

Symbol	Name	Use
[text]	Brackets	Indicates 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
=	Equal sign	Indicates the break and subsequent continuation of a single utterance
(.)	Period inside single parentheses	A brief pause, usually less than 0.2 second
(# of seconds)	Numbers inside single parentheses	A number in parentheses indicates the time, in seconds, of a pause in speech
ALL CAPS	Capitalized text	Indicates shouted or increased volume speech
underline	Underlined text	Indicates the speaker is emphasizing or stressing the speech
>text<	Divergent greater than/less than symbols	Indicates that the enclosed speech was delivered more rapidly than usual for the speaker
<test>	Convergent greater than/less than symbols	Indicates that the enclosed speech was delivered more slowly than usual for the speaker
°	Degree symbol	Indicates whisper, reduced volume, or quiet speech
:::	Colon(s)	Indicates prolongation of a sound
(hhh)	"h" inside single parentheses	Audible exhalation
((text))	Double parentheses	Annotation of nonverbal activity

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