Understanding High School Students' Science Internship:

At the Intersection of Secondary School Science and University Science

by

Pei-Ling Hsu
B.Sc, National Taiwan Normal University, 2000
M.Sc, National Taiwan Normal University, 2004

A Dissertation Submitted in Partial Fulfillment of the
Requirement for the Degree of
DOCTOR OF PHILOSOPHY
in the Department of Curriculum and Instruction

Understanding High School Students' Science Internship:

At the Intersection of Secondary School Science and University Science

by

Pei-Ling Hsu

BSc, National Taiwan Normal University, 2000

MSc, National Taiwan Normal University, 2004

SUPERVISORY COMMITTEE

Dr. Wolff-Michael Roth (Department of Curriculum and Instruction)
Supervisor

Dr. David B. Zandvliet (Department of Curriculum and Instruction)
Department Member

Dr. Eileen Van der Flier-Keller (School of Earth and Ocean Sciences)
Out of Department Member

Dr. Heidi B. Carlone (Department of Curriculum and Instruction)
External Examiner (The University of North Carolina at Greensboro)

Supervisory Committee

Dr. Wolff-Michael Roth, Supervisor
(Department of Curriculum and Instruction)

Dr. David B. Zandvliet, Department Member
(Department of Curriculum and Instruction)

Dr. Eileen Van der Flier-Keller, Out of Department Member
(School of Earth and Ocean Sciences)

Dr. Heidi B. Carlone, External Examiner
(Department of Curriculum and Instruction, The University of North Carolina at Greensboro)

ABSTRACT

In this dissertation I explore the nature of an internship for high school students in a university science laboratory and the issues that arise from it. The investigation of science internships is relatively new to science education; therefore, this exploration is urgently needed. Twenty-one participants were involved in the internship experience, including 13 students, one teacher, two research scientists, and five technicians. Data sources include observations, field notes, and videotapes. Drawing on four coherent and complementary research tools—cultural-historical activity theory, discourse analysis, conversation analysis, and phenomenography, I articulate a variety of phenomena from multiple perspectives. The phenomena identified in the dissertation include (a) the discursive resources deployed by a teacher for interesting and inviting students to participate in science; (b) the discursive resources high school students used for articulating their interests in science-related careers; (c) the natural pedagogical conversations for accomplishing the work of teaching and learning during the internship; (d) the theoretical concepts mobilized for describing the unfolding of science expertise in the internship; (e) participants' ways of experiencing the science internship; and (f) students' understandings of scientific practice after participating in the internship. The study identifies many useful resources for understanding the nature of the science internship and provides a foundation for future research. The findings reported here will also serve others as a springboard for establishing partnerships between high schools and science communities and improving teaching and learning in science education.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACKNOWLEDGEMENT

This work has been supported in part by the Centre for Research in Youth, Science Teaching and Learning (CRYSTAL) grant from the Natural Sciences and Engineering Research Council of Canada (NSERC) to Dr. Wolff-Michael Roth (Principal Investigator). Thanks are due to Dr. Asit Mazumder and all members in his biology laboratory for welcoming high school students into their laboratory and providing the internship opportunity. I am grateful to Dr. Anne Marshall and Francis Guenette for sharing their experience of conducting interviews about students' career orientations. Sincere thanks go to Ms. Karen Edwards and her students for participating in the internship project and allowing me to observe their high school class, field trips, and internship activities.

I am thankful to Dr. Roth's research group, CHAT@UVIC, for allowing me to learn in and through conversations with them. The members included Diego Machado Ardenghi, Leanna Boyer, Peilan Chen, Michiel W. van Eijck, Gholamreza Emad, Maria Ines Mafra Goulart, SungWon Hwang, Bruno Jayme, Mijung Kim, Jean François Maheux, Lilian Pozzer-Ardenghi, Giuliano Reis, Eduardo Sarquis Soares, and Ian Stith. The group has become my family in Canada because they not only provided insights in discussing research issues, but also supported me with warm care, support and friendship.

Special thanks go to Dr. Wolff-Michael Roth for his thoughtful mentoring and insightful supervision. Without his trust in me and allowance for my mistakes and autonomy in doing research, I would not have had the courage to conduct a research project, participate in conferences, and accomplish a dissertation in a foreign country and language.

In particular, I would like to thank my family in Taiwan for their encouragement and support. An especially BIG thank you goes to my husband Wen-Chun Ting for listening when I encountered breakdowns, for his funny tricks when I was sad, for his celebrations when miracles happened in my research life, and for his generosity in always being there for me.

To Wen-Chun

GLOSSARY

Apprenticeship: A context and process of learning in which newcomers become familiar with practice through the monitoring of experienced practitioners, and become members of the experienced practitioner's community.

Authentic science: The science practice of scientists, researchers, and technicians who work in a science laboratory or in the field.

Conversation analysis: A form of qualitative research designed to uncover the "mechanism" of turn-taking in everyday, mundane conversations.

Discourse: A social practice that includes many forms of talking and writing.

Discourse analysis: A qualitative research method for analyzing the actions participants in a setting performed by means of words.

Discursive device: A device to solve the conflicts or contradictions between two interpretative repertoires.

Discursive psychology: A field of inquiry and practice where psychological issues are discussed from a discourse analysis perspective. The main assumption is that language is not a medium or vehicle in peoples' minds but is a social practice in which people continually perform particular actions with interests or stakes.

Disinterested peers: Peers who can provide a more reflective and objective opinion on or feedback about analysis or assertions because they do not have stakes (personal interests) in the outcome of a piece of research.

Ethnomethodology: The study of how ("-methodology") people ("ethno-") use commonplace actions and tacit skills to interact in everyday life.

Ethnographgy: The research method of describing and interpreting cultural behaviour mainly through taking field notes and participant observation.

Formulating: The action of describing what is going to be done or what has been done.

Science internship: The context and practice of participating in science for outsiders to a scientific setting where they, for a short period of time, work with and under the guidance and monitoring of the insiders. In the dissertation, science internship refers to the science practices in a biology laboratory setting.

Interpretative repertoire: The chunks of verbal descriptions people usually take for granted as cultural language resources and tools, and which therefore can be used in support of arguments with little or no likelihood of being challenged. Interpretive repertoires therefore constitute ideologies, that is, forms of thinking that normally are not transparent to those who use them.

Member checking: A technique in qualitative research that serves to establish the credibility of the researcher's interpretation through participants' confirmation and checking.

Preference: An organization of conversation that operates such that a person will generally choose the preferred response (e.g., agree) rather than the dispreferred response (e.g., disagree). A dispreferred action generally requires an explanation, such as when a person rejects an invitation, which is normally followed by an explanation of why the invitation cannot be followed.

Progressive subjectivity: A technique in qualitative research that serves to avoid the researcher's prejudice through documenting the researcher's thinking trajectory.

Prolonged engagement: A technique in qualitative research that serves to establish the credibility of the researcher's interpretation through extensive involvement and understanding of the participants' culture and forms of action.

Persistent observation: A technique in qualitative research that serves to establish the credibility of the researcher's interpretations through regular and persistent recording activities and collecting of documents.

Systemic Functional Linguistic (SFL): A well-established linguistic system concerned primarily with the choices that grammatical systems make available to the speakers of the language.

Trajectory: The path that a practice takes, which involves changes in actions and activities over time.

Transaction: The term interaction is used to describe the exchanges of two subsystems (e.g., two participants in a conversation) when the subsystems can be modeled independently of one another. The term transaction is used when the two subsystems cannot be modeled independently, because they mutually constitute one another.

Phenomenography: A second-order and nondualistic approach aimed at describing, analyzing, and understanding peoples' experiences.

Cultural-historical activity theory: A multidisciplinary theory that integrates both material and ideal aspects of human activities for describing historically, culturally, and socially situated phenomena.

CHAPTER 1: PERSONAL COMMITMENT AND RESEARCH FOCI

In this chapter, I introduce my commitment to conducting the research project, and provide the rationale for choosing the research foci of my dissertation.

1.1. Personal Commitment

High school students face an important transition when deciding what to do after graduating: to go to work or to study, which requires a decision about the area(s) in which they want to major. In many cases, students are not aware of the entire range of options they have. Thus, "Too many students make career choices in an information vacuum" (American Association of University Women Educational Foundation, 1999, p. 115) and appear to lack information about pursuing higher education or careers in science (Madill et al., 2000). In the case of Taiwan, high school students seldom get a chance to explore their interests and, after some reflection, to choose a career. High school students usually "study hard" to get high grades on the entrance exams to a "better" (more highly rated) university or a "better" (more highly rated) university department. Only after the exam do students start to think about their reason for choosing the university and major: as a function of the grades they got.

The time from the exam to the decision is a mere one or two months. If they want to continue their post-secondary education, students have to decide on their major, which determines four years of life at university and their future career. Thus, students often hurriedly consult their teachers or parents to decide on a major. As a Taiwanese high school science teacher, I often encountered students' questions during this period. "Teacher Pei-Ling, do you know what it is like to be a scientist (biologist, chemist, physicist)? What kind of work they do? Do they work only in a laboratory? Or do they travel a lot like the ones in movies? Do you think it is a good career?"

These are but some of the questions students asked while I taught in Taiwan. Although I have had my own views about being a scientist, I hesitated in answering these questions directly.

I know that what a teacher says has, at least in the Taiwanese context, a crucial impact on students' thinking or even on their decision-making. Thus, I always encouraged students to research the issues a little more deeply. However, I thought one of the best ways for students to understand the life of a scientist is to work with scientists and experience life in science laboratories, that is, to engage in an internship (even a short one) in a science research laboratory while they are still in high school. This could assist students in better understanding science, for they generally do not appear to know what scientists and engineers actually do on a day-to-day basis (Lewis & Collins, 2001). With an internship, students could experience the particular occupational life and have space and time to reflect and make an informed decision when the time comes.

Fortunately, when I searched for an opportunity to study abroad during the spring of 2005, Dr. Wolff-Michael Roth introduced me to a high school students' internship project situated in a national project conducted to improve science education in Canada—the CRYSTAL project (Centers for Research on Youth, Science Teaching and Learning). When I received more information from him about the science internship, I was excited to learn that I could investigate a science internship program for high school students as my dissertation topic. It was an important element in my decision to come to Canada, related to my own interest in establishing a partnership between high schools and scientists' communities.

With mixed feelings of excitement and uncertainty, I came to Canada in the fall of 2005. At the beginning of the internship project, I had many questions. As a newcomer to Canada, how would I find my participants? How would I organize the project? How would I understand students' learning? Therefore, I tried to learn more about high school students' internships through a literature review and discussion with Dr. Roth and members of the laboratory for the study of human practices, which Dr. Roth had established. I found that the literature does not contain an examination of the nature of science internships. This being the case, I decided to frame my dissertation in terms of understanding the nature and relevant issues of a science internship. Before knowing how to improve internship education, I needed to understand the laboratory life of research scientists, high school students' life, their perception and expectation of each other, natural internship interaction and their internship experiences. I began this dissertation in the hope that it would create fundamental understanding and a basis for improving science education through internship experiences with potential implications for school science.

1.2. Research Foci

Many different types of research purpose exist within social research (Denscombe, 2002). The purposes include (a) forecasting an outcome (What will happen in the future?); (b) explaining the causes or consequences of something (Why do things happen?); (c) criticizing or evaluating something (How well does something work?); (d) developing good practice (How can it be improved?); (e) empowerment (How can it help those who are being researched?); and (f) describing something (What is it like?).

For my dissertation, I placed myself in the last category—describing the relevant phenomena of high school students' science internship, because the literature had not covered much terrain concerning this form of inducting high school students to science. Therefore, my dissertation serves as an *exploratory* research study that breaks new territory and explores and reports *how things are,* rather than how they *will* be, or how they *should* be, or *why* they are as they are (Denscombe, 2002). Based on my interest in understanding science internship, an area that is not yet theorized, I decided to use qualitative ways to describe the nature of science internship and salient structures that characterize it. Although my background in research was in experimental and quantitative methods (e.g., using questionnaires, pre-post tests, *t*-tests and factorial designs), I chose to learn a new set of methods generally found under the category of "qualitative" research. I am aware that my study would not generate findings for "causal explanation," "telling people what to do," or "teaching people how to design a science internship." Instead of making "causal" claims, I understand my study as being oriented toward "rich descriptions" that articulates the nature of a science internship. My intention was not to generate guidelines to follow, but to examine salient issues emerging from on implementation of a science internship program so that science educators could understand the forms of knowing and learning associated with science internships. The goal of this dissertation, therefore, is to identify and describe different science-internship-related phenomena rather than "finding factors or causal influences." This awareness led me to choose my research questions, methods for collecting data sources, and analysis. In the following section, I summarize my six research questions asked to understand the nature of a science internship and the conceptual framework in Figure 1.1, and then report my reflective strategies and considerations for choosing research foci for the dissertation.

The six research questions are as follows:

1. Introducing science: How does an experienced teacher introduce authentic science activities to high school students? (chapter 4)
2. Talking about science careers: How do high school students articulate their preferred and dispreferred science-related careers? (chapter 5)
3. Internship transaction: How do teaching and learning happen naturally during a science internship? (chapter 6)
4. Science expertise: How does science expertise unfold in a science internship and what are suitable theoretical concepts to describe it? (chapter 7)
5. Internship experiences: How do participants experience a science internship? (chapter 8)
6. Understanding of science practice: How do students understand science practice after participating in a science internship? (chapter 9)

These research foci and questions were generated not overnight but through reading, discussion, and reflection over three years. To justify the various considerations of proposing these research questions for the dissertation, I summarize the rationale in the section. Five general considerations are illustrated in the following list. I did not consider them in a linear sequence but in heterogeneous and correlated ways. The details of the rationale for choosing each research question are discussed in the preface of chapters 4, 5, 6, 7, 8, and 9.

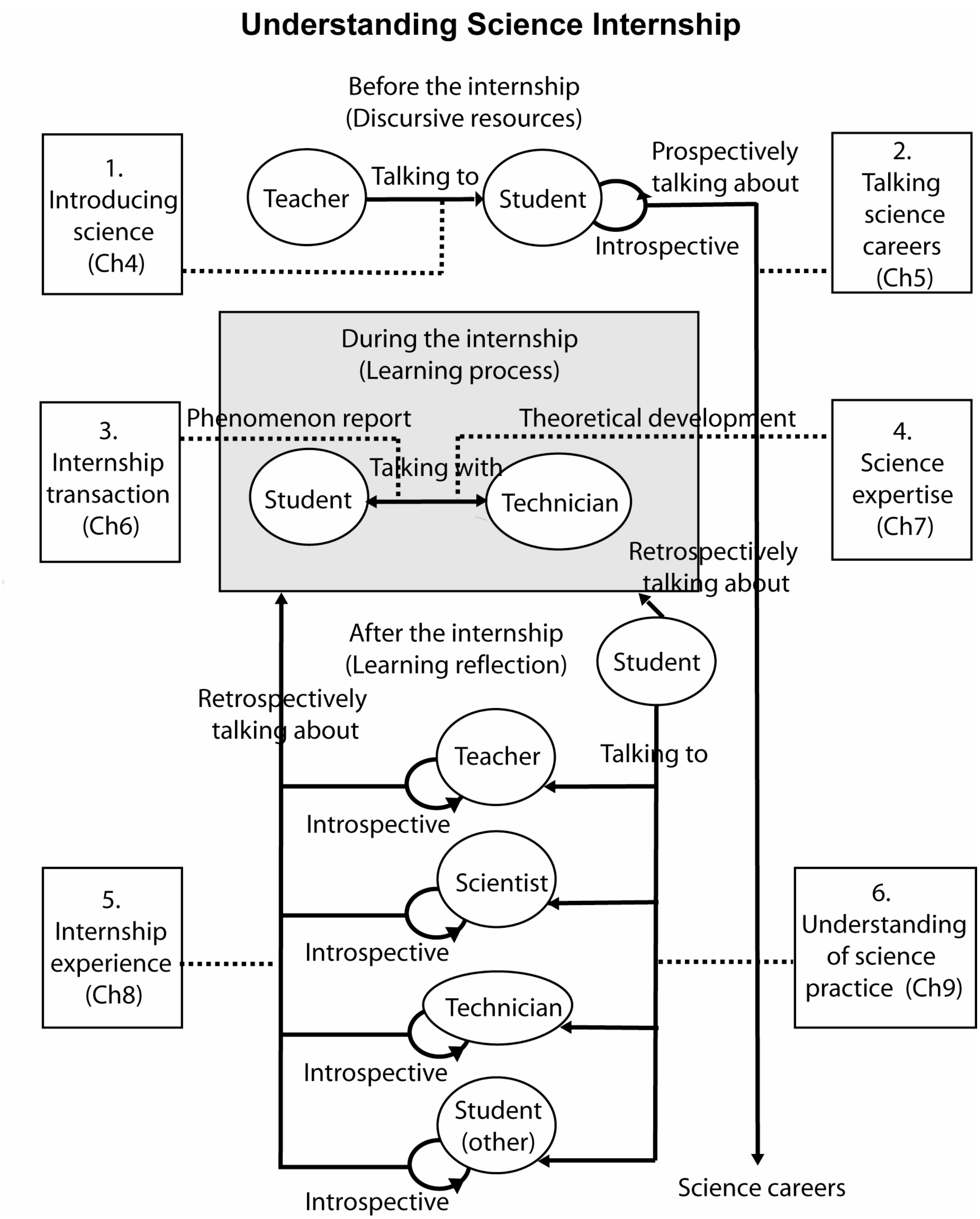

Figure 1.1. The conceptual framework of connecting six research questions in the dissertation.

1.2.1. "Understanding High School Students' Science Internship" as Core

As illustrated in Figure 1.1, understanding science internship constitutes the heart of this dissertation. The six research questions are asked to see how a school teacher "introduces science internships" (chapter 4); to understand how students "describe the personnel in science internships" (chapter 5); to understand how students "interact during a science internship" (chapter 6); to understand how "science expertise unfolds in a science internship" (chapter 7); to understand "participants' experiences in a science internship" (chapter 8) and students' "understanding of science practice after participating in a science internship" (chapter 9). That is, chapters 4 and 5 focus on *discursive resources* for talking about science internships (and its personnel), chapters 6 and 7 focus on the *learning process* in a science internship, and chapters 8 and 9 focus on the *learning reflection* about a science internship.

1.2.2. Cultural and Historical Considerations

From the viewpoint of cultural-historical activity theory, it is important for researchers to understand human activities (i.e., high school students' science internships in my case) in a cultural and historical manner. This means analyzing human activities across different timescales such as microgenetic (moment-to-moment), ontogenetic (individual development), cultural-historical, and phylogenetic timescales (Cole & Engeström, 1993). In choosing my research questions, I drew on two different timescales to analyze the science internship. First, in the cultural-historical timescale, the dissertation has a wide perspective and so includes internship-related issues in a historical manner. The goal is to understand the relevant discourses (a) *before* the internship (discourses of introducing science and talking science careers in chapters 4 & 5); (b) *during* the internship (discourses of conversations and interactions in chapters 6 & 7); and (c) *after* the internship (discourses about internship experience and understandings of science practice in chapters 8 & 9). Second, on a microgenetic scale analyses were conducted in chapters 6 and 7 to study the moment-to-moment unfolding of events during the science internship.

1.2.3. Considerations of Existing Studies

What counts as an educational research question worthy of investigation? Being able to provide new or different perspectives to address educational issues is an important consideration. Thus, before officially proposing a research question for my dissertation, I undertook a literature review on these questions. Following the literature review, the six research questions identified for the dissertation included essential "new" components in different chapters. That is, little was written about "introducing science discourse" (chapter 4), "students' ways of talking about science career choices" (chapter 5), "internship conversation and interactions" (chapter 6), and "internship experiential descriptions" (chapter 8). Likewise, little had been written on "the unfolding process of science expertise in a science internship" (chapter 7), and I wanted to provide "a new explanation to the debate on the influence of authentic science on students' understanding of science practice" (chapter 9).

1.2.4. Focusing on Discourse—Verbal Language

The dissertation examines cultural discourses in different situations related to a science internship. Chapter 4 discusses a high school class discourse; chapter 5 relates to high school students' science career discourse; chapters 6 and 7 are about discourses during a science internship; and chapters 8 and 9 are concerned about experiencing reflection and presentation discourses after a science internship. There are many reasons to focus on discourses, because it allows me to (a) understand one of the most important tools in human society for communication—language use; (b) illustrate the cultural essence through studying discourses; and (c) strengthen the ecological validity of the dissertation (i.e., whether the findings are applicable to everyday life). Although communicative acts include non-verbal language such as gestures and body movements, I chose to concentrate on verbal language because it is the dominant and natural form of language that was salient in the setting I studied and other forms of communication did not appear to play a major role.

1.2.5. Situated Experience Driven

An important characteristic of qualitative research is the "unstructured" nature of "research design." Unlike experimental types of research, researchers are "the controllers" who structure their research in terms of several variables and factors. However, in qualitative research, researchers are more like "mediators" who assist their participants to act naturally or speak out. Therefore, as a new qualitative researcher, I often felt that I lived in the flow and did not know where my participants and data sources would lead me.

At the beginning of the research, I was frightened by this new experience because "nothing was under my control." However, with the support of Dr. Roth and his research group, I gradually began to enjoy following my participants and learning from them. This moment gave me a different realization of "newness and innovation." That is, having no fixed research design led me to experience and understand something I did not expect. Choosing the research questions happened in the same way, when situated experiences helped me to adjust the questions and evolve them in new and different forms. For instance, one salient event occurred when I was in a high school class. I had strong motivation to investigate the research question "How does an experienced teacher introduce authentic science activities to high school students?" (See chapter 4). Sometimes interesting questions arose when I interacted with participants. Thus, the question "How do teaching and learning happen naturally during a science internship?" emerged during a conversation with scientists and technicians about the positive learning curve of these students in the internship (see chapter 6). Therefore, the emergent moments of situated research experiences played an important role in directing my research foci in the dissertation.

CHAPTER 2: THEORETICAL FRAMEWORK

This chapter provides the rationale for my theoretical framework. First, I introduce four main research tools identified for the dissertation—cultural-historical activity theory, discourse analysis, conversation analysis, and phenomenography. These research tools provide different ways of explaining and analyzing data sources. Therefore, they function simultaneously as theory and method because theoretical perspectives always structure the process, ground its logic and provide the criteria for the methods (Crotty, 1998). Finally, I justify my reasons for choosing these research tools at the end of the chapter.

2.1. Cultural-Historical Activity Theory

Cultural-historical activity theory is a multidisciplinary theory that describes human activities—farming, manufacturing, or schooling—as historically, culturally, and socially situated phenomena (Leont'ev, 1978). In this theory, human activity is described as a hierarchical structure consisting of four levels: network of activities; collective local, motive-driven activity; individual goal-driven and conscious acts; and routinized, condition-driven unconscious operations. In activity theory, actions play a special role, because this is what individuals do and what researchers observe. In addition to cognition, emotion plays an important role in mediating performance in human activities (Roth, 2007). From an activity-theory perspective, the activity is the minimum meaningful unit of human behavior. An activity therefore is the smallest unit of analysis that preserves meaning. Any smaller unit of analysis loses its constitutive aspects (Vygotsky, 1986). Therefore, we can only make sense of the context of an activity as a whole (Cole & Engeström, 1993). The structural relations in an activity are frequently depicted in a mediational triangle featuring six constitutive moments: subject, object, tools, rules, community, and division of labor (Figure 2.1). Consistent with the materialist dialectical approach underlying activity theory, which takes activity as its smallest unit, structures smaller than the unit are deemed as "moment." Moments cannot be understood on their own because they constitute and are constituted by other moments—any two moments therefore are in a *trans*actional rather than *inter*actional relation. None of these six constitutive moments can be studied in isolation and its generic representation reflects only one instant in time. That is, both the cultural and historical aspects of human activity play important roles in activity theory.

The relations between pairs of moments—e.g., subject and objects—are not direct but are mediated by other moments—e.g., tools, communities, rules, and the division of labor (Engeström, 1987). The *subject* refers to the individual or sub-group whose agency is chosen as the point of view in the analysis. The *object* refers to the material or problem at which the activity is directed and which is molded and transformed into outcomes with the help of physical and symbolic, external and internal mediating instruments, including both tools and signs. Subject and object mutually constitute each other, linked through the transitive action by means of which the former acts on or transforms the latter. Therefore, the object itself is constantly mediating the structural changes in and of the activity system (Saari & Miettinen, 2001). The *community* comprises multiple individuals or sub-groups who share the same general object and who construct themselves as distinct from other communities. The *division of labor* refers to both the horizontal division of tasks between the members of the community and the vertical division of power and status (as the relation between teacher and student, manager and worker). Finally, the *rules* refer to the explicit and implicit regulations, norms, and conventions that constrain actions and mediate transactions within the activity system.

Take my dissertation project as a concrete example (Figure 2.1), where I am a student researcher (subject) interested in high school students' science internship (object). Who I am and can be is informed and mediated by research methods and technology (instrument), research ethics and university regulations (rules), participants and collaborators (community), and partnerships with these communities (division of labor). Finally, the results of the internship project are produced in the form of the dissertation and reports (outcome). At the same time, these constitutive moments are strongly related and mediated and so cannot be articulated in isolated ways.

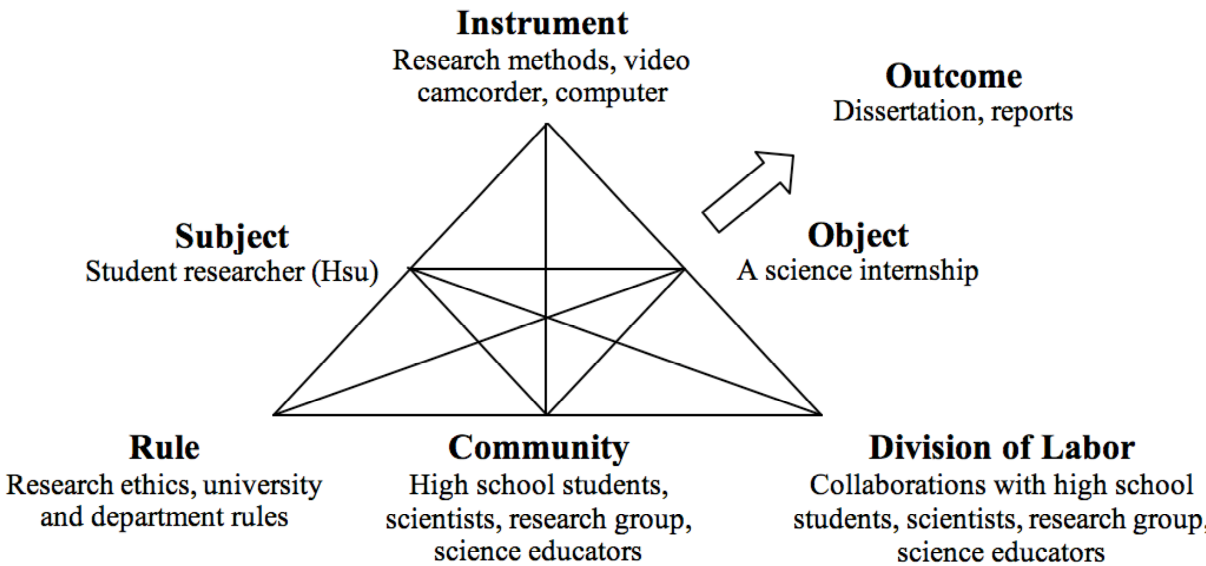

Figure 2.1. The moments of activity system and its respective elements of researching a science internship project.

The dialectical thinking in activity theory is important in explaining human activities such as the relationships of individual-collective, body-mind, subject-object, agency-structure, and material-ideal; that is, the opposites are theorized as nonidentical, one-sided expressions of the same category, which thereby comes to embody an inner contradiction (Roth & Lee, 2007). For instance, the outcome of the science internship research—the dissertation, is not just an *individual* contribution (e.g., Hsu's) but also a *collective* practice (e.g., supervision, partnership and collaboration of different communities). Without the *structure* of university, department, CRYSTAL project, etc., *agency* for conducting such a science internship would be impossible. The well-established activity-theoretic framework, therefore, provides a generic and useful tool to analyze human activity such as science practice.

2.2. Conversation Analysis

Conversation analysis (CA) studies the order/organization/orderliness of social action, particularly those social actions that are located in everyday contact between people, in discursive practices, in the saying/telling/doings of members of society (Psathas, 1995). Conversation analysis was influenced by the phenomenology of Alfred Schutz and the ordinary language philosophy of Ludwig Wittgenstein (Psathas, 1995). Developed during the 1960s, CA has developed into a prominent form of sociological and especially ethnomethodological work through the intense collaboration among Harvey Sacks, Emanuel Schegloff, and Gail Jefferson. It now exerts a significant influence on a range of social disciplines including linguistics, social psychology, and anthropology (Heritage, 1984).

Sacks in particular is *the* pioneer of CA. He was a graduate student of and mainly influenced by Erving Goffman and Harold Garfinkel. Goffman provided legitimacy to the study of the everyday face-to-face interaction order; but he mainly drew on data from observation, field notes, excerpted material from other reports and defined acts in a decontextualized way (Hutchby & Wooffit, 1998). Garfinkel proposed that members' commonsense knowledge should become a topic of study rather then simply a resource as the predominant sociological paradigm at that time. That is, people were viewed as internalizing norms and values through socialization, and then unconsciously reproduce them in their actions. However, for Garfinkel, "members" are capable of rationally understanding and accounting for their own actions in society. Thus, the aim of Garfinkel's ethnomethodology is to describe the methods that people use for accounting for their own actions (Psathas, 1995). At that time, Garfinkel used an experimental style of data to analyze how people conduct themselves in encounters with others. For instance, to response the everyday conversation "How are you?", the experimenter purposely creates trouble: "How am I in regard to what? my finances, my school work, my peace of mind, my…?" So, the person (subject) might react in an unusual way "Look! I was just trying to be nice. Frankly, I don't give a damn how you are." And then the researcher repeatedly requests the subject to clarify whatever he or she said. In this kind of "breaching" experiment—"breaching" because the experiment breaches social norms—we learn something about the structures of everyday activities and how they ordinarily and routinely are produced and maintained (Garfinkel, 1967). However, as Garfinkel himself realized, the possibilities of breaching experiments are essentially limited.

Thus, Sacks's most significant contribution is his approach—conversation analysis, the analysis of naturally occurring talk-in-interaction, has become one of the most fruitful means of doing ethnomethodological study. And Gail Jefferson further developed a systematic notation of transcription for representing verbal and non-verbal activities (Atkinson & Heritage, 1984, see Appendix).

Conversation analysis is the systematic analysis of the talk produced in everyday situation of human interaction: talk-in-interaction (practitioners do not engage solely in the analysis of everyday conversation but through interaction such as talk by examining available resources in that contexts). Its objective is to uncover the tacit reasoning procedures and sociolinguistic competencies underlying the production and interpretation of talk in organized sequences of interaction (Hutchby & Wooffit, 1998). Here I use an example to demonstrate how conversation analysis uncovers the tacit rules of turn allocation in everyday conversation. The paper "A simple systematics for the organization of turn-taking for conversation" (Sacks, Schegloff, & Jefferson, 1974) is a classic study in conversation. In this paper, the authors outlined a model for describing how speakers manage turn-taking in mundane conversation. The turn-taking model has two components: a turn construction (when the turn ends) and a turn distribution (who is the next turn speaker). A turn construction unit is built by participants who *project* the *transition-relevance places* where the possibility might exist for taking a turn at talk. As for the mechanism for distributing turns between participants, Sacks, Schegloff, and Jefferson (1974) proposed a simple set of rules that describe how turns come to be allocated at transition-relevance places.

Rule 1(a): *If the current speaker has identified, or selected, a particular next speaker, then that speaker should take a turn at that place.* As the excerpt below illustrates that S select O (Oscar) as the next speaker, so O has the right to speak.

(From Sacks, Schegloff, & Jefferson, 1974, p. 717)

```
S:  Oscar did you work for somebody before you worked for Zappa?
O:  the, many many. (3.0) Canned Heat for a year.
```

Rule 1(b): *If no such selection has been made, then any next speaker may, but need not, self-select at that point.* As the following excerpt, L did not select the next speaker and D is self-select for the right to speak.

(From Sacks et al., 1974, p. 707)

```
L:  Bertha's lost on our scale, about fourteen pounds.
D:  oh[::no::
J:    [twelve pouns I think wasn't it?
```

Rule 1(c): *If no next speaker has been selected, then alternatively the first speaker may, but need not, continue talking with another turn constructional unit, unless another speaker has self-selected.* As in the excerpt below, A did not select the next speaker and no one self-selected for speaking after A, so after a 0.7 second pause, A continue the talk.

(From Sacks et al., 1974, p. 704)

```
A:  He, he'n Jo were like on the outs, yih know?
    (0.7)
A:  [so uh,
B:  [they always are
```

Rule 2: *Whichever option has operated, then rule 1(a)-(c) come into play again for the next transition relevance place.*

These rules provide for the allocation of a next turn so as to minimize gap and overlap, capture most turn-taking practices and display an actions' orientation that does not mean the rules precede the action but the rule is discoverable in the actions. As the rules of turn allocation, the discovery of a turn-by-turn sequential organization of interaction was the crucial point of conversation analysis.

2.2.1. Adjacent Pair and Intersubjectivity

One of the widely sequences of conversation is adjacency pair (Schegloff & Sacks, 1973, p. 295) such as “Question-Answer”, “Greeting-Greeting” or “Offer-Acceptance/Refusal.” It constitutes several features including (a) two-utterance length; (b) different speakers producing each utterance; (c) these two utterances are relevant and usually adjacent; (d) relative ordering of parts (i.e., the first pair part precede the second part); and (e) discriminative relations (i.e., the pair type of which a first pair part is a member is relevant to the selection among the second pair part). In term of the concept of adjacent pair, we may now better understand the way people act in everyday conversation. For instance, in the following excerpt, A performs the first part of the adjacent pair (i.e., a question) and he expects the second part (i.e., an answer) responded by the other person.

(From Atkinson & Drew, 1979, p. 52)

```
A:  is there something bothering you or not?
    (1.0)
A:  yes or no
    (1.5)
A:  eh?
B:  no.
```

However, B does not answer immediately and thus not complete the second part of the adjacent pair yet. So after a one-second pause, A asks further questions “yes or no” and “eh?” until the second part of the pair is completed by B (“no”). Here, there is *noticeable absence* in the conversation, so A continually request for B's response to fill the absence. Although the two parts of the adjacency pair usually appear very closely, that is, the second part closely follows the first part of the pair. However, conversation is not necessarily adjacently ordered but it is *sequentially* ordered in a *relevant* way (the discussion is based on that found in Hutchby and Wooffit (1998). For instance, the following except demonstrate how one adjacent pair could embed into another adjacent pair.

(Levinson, 1983, p. 304)

A:	can I have a bottle of Mich?	Question
B:	are you over twenty-one?	Ins Question
A:	no	Ins Answer
B:	no	Answer

From this expert, we can see that an adjacent pair is sequentially ordered but not necessarily adjacent. Thus, the adjacency-pair concept has to do not simply with the fact that some utterances come in pairs but has a fundamental significance for one of the most basic issues in CA: the question of how mutual understanding is *accomplished* and *displayed* in talk. This issue related to the concept of *intersubjectivity,* it refers to the production and maintenance of mutual understanding in dialogue, of mutual intelligibility between participants (Drew, 1995, p. 77). By means of turn-by-turn basis, a context of publicly displayed and continuously up-dated intersubjective understanding is *systematically* sustained.

As a matter of fact, four fundamental assumptions of conversation analysis can be noted (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) these two properties 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 is best approached through the analysis of naturally occurring data. About the development of CA studies, in general, it could be categorized into five main types of studies (Heritage, 1989): (a) preference organization: to characterize basic differences in the ways that alternative responses are routinely accomplished; (b) topic organization: to see how different topics flow into peoples' conversations; (c) the use of non- or quasi-lexical speech objects: to study the use of non-lexical speech objects such as response tokens (e.g., "mm" or "oh") and laughter; (d) the integration of vocal and non-vocal activities: to investigate the use of both vocal and non-vocal (e.g., gaze or body movement) interaction; and (e) interaction in institutional settings: to see how conversation flow in institutional settings where constitute particular social roles.

2.2.2. Procedures and Validation of Conversation Analysis

There are two perspectives on any social situation: the *emic* viewpoint results from studying behavior as from inside the system, whereas the *etic* viewpoint studies behavior as from outside of a particular system, and as an essential initial approach to an alien system (Geertz, 1973; Pike, 1967). The aim of CA is to portray social action in interaction from an emic perspective. To achieve the emic perspective, CA typically uses *next-turn proof procedure* to support the analysis. That is, CA not analyzes the conversation only depending on solely and independent utterance, rather CA use participants' contextually response to support the analysis. For instance, the following excerpts demonstrate that one utterance could be responded as question or a pre-announcement just depending on the next person's response (the discussion is based on that found in Heritage, 1984, and Hutchby and Wooffit, 1998).

(Terasaki, 1976, p. 45)

```
Mother:  do you know who's going to that meeting?   Question
Russ:    no, I don't know.                           Answer
```

Mother: do you know who's going to that meeting? Pre-announcement

Russ: Who? Receive

Sometimes misunderstanding even happens between participants at that time of talk. As analysts, we therefore have to be careful and study how participants *repair* the gap between them. For instance, in the following excerpt, Russ misunderstood Mother's utterance as a pre-announcement, so he further asks "who" for preparing the reception of the announcement. But Mother responds to Russ's question by "I don't know" to respond Russ's question and repair the gap. When receiving the response form Mother, Russ just realized that Mother's first utterance "do you know who's going to that meeting?" is a question rather than a pre-announcement and then provide the second part of the adjacent pair (question-answer)-the answer "probably Mr. Murphy and Mrs. Timple".

Mother: do you know who's going to that meeting?

Russ: Who?

Mother: I don't know!

Russ: Oh, probably Mr Murphy and Dad said Mrs Timple an' some of the teachers

Thus, by using the next-turn proof procedure, analysts strengthen the credibility and support of an emic (insider) perspective. CA is interested in how social acts are packaged and delivered in linguistic terms. The fundamental CA question "Why this, in this way, right now?" captures the interest in talk as social action which is delivered in particular linguistic formatting, as part of an unfolding sequences (Seedhouse, 2005). Six methodological principles of doing conversation analysis of talk-in-interaction are sorted as follows (Drew, 1995, 70–72):

(a) Turns at talk are treated as the product of the sequential organization of talk, of the requirement to fit a current turn, appropriately and coherently, to its prior turn.

(b) Focus on participants' analyses of one another's verbal conduct.

(c) To address two distinct phenomena: the selection of an activity that a turn is designed to perform (e.g., invitation or complaint) and the detail of the verbal construction through which the turn's activity is accomplished (e.g., short response or long explanation).

(d) To identify those sequential organizations or patterns.

(e) The recurrence and systematic basis of sequential patterns of organizations can only be demonstrated and tested through collections of cases of the phenomenon under investigation.

(f) Data extracts are presented in such a way as to enable the reader to assess or challenge the analysis offered.

Furthermore, considering the methodological issue, several techniques to construct CA's reliability and validity are discussed as below (Seedhouse, 2005):

(a) Reliability (whether the results of a study are repeatable or replicable): to display the raw data (e.g., detailed transcripts) and analysis in reports, make them transparent for readers to follow or challenge the researcher's claims.

(b) Internal validity (whether the data prove what the researcher says): to supply the detailed transcripts and use participants' perspective to construct the emic point of view; to avoid using existing theories to explain the interaction as it may go against the emic point; to avoid using context (e.g., gender or race) directly into account unless supported by the detail analysis to prove that is actually procedurally relevant.

(c) External validity (whether the findings can be generalized beyond the specific research context): the aim of CA is to explicitly generate the conversation machinery that possibly generalizes to different settings in the sense.

(d) Ecological validity (whether the findings are applicable to people's everyday life): CA practitioners typically record naturally occurring talk in its authentic social setting, so its ecological validity is strong compared to other research methodologies.

2.3. Discursive Psychology and Discourse Analysis

Discourse analysis (DA) is the study of how talk and texts are used to perform actions and also with the sort of resources that people draw on in the course of those practices; discursive psychology (DP) is the application of ideas from discourse analysis to issues in social psychology (Potter, 2003). Discursive psychologists reject to see language as a medium, providing clues as to what is going on inside people's minds but to examine how people deploy language to construct everyday life or institutional settings.

A number of studies indicate that the ways in which researchers attempt to detect structures in peoples' minds are quite debatable. For instance, Schoultz, Säljö and Wyndhamn (2001) found that by modifying the interview situation through the introduction of a globe as a tool for thinking, the outcomes are radically different from previous studies reported before. That is, in the previous studies, researchers interviewed children and concluded that many children have difficulties of understanding astronomical concepts, such as the shape of the earth and gravitation. However, Schoultz and colleagues also use interviews as the research method but had a globe available in front of the children while asking them the same (kinds of) questions as in the previous studies. In this new situation, most children surprisingly had no difficulties of answering these interview questions scientifically. Thus, the authors suggest that interview studies should be regarded as situated and as dependent on the tools available as resources for reasoning instead of viewing understanding as the overt expression of underlying mental models. There therefore is no neutral ground on which children's understandings of concepts can be studied. Likewise, as a school discourse episode (Edwards, 1993) indicated, when a teacher tries to access students' understanding of a scientific concept taught during a field trip, children might merely have been reproducing what the tour guide said without understanding what the latter meant. That is, even if students could scientifically answer the teacher's question, this does not mean that students understand these concepts but only repeat what they heard.

These and similar findings inform us that many studies—those whose methods are designed to detect peoples' minds or mental models—are highly problematic, because peoples' reactions are always situated rather than stable across situations. It is therefore almost impossible to detect peoples' mind—which tends to be thought as stable entity. In discursive psychology, on the other hand, we are not concerned with *what* people "have" in their minds but we are concerned with bringing these contextual and peripheral phenomena into analytical focus to see how discourse accomplishes and is a part of social actions.

2.3.1. Theoretical Principles in Discursive Psychology and Discourse Analysis

Being sociologists of scientific knowledge, Gilbert and Mulkay (1984) developed *discourse analysis* as an approach to study scientists' discourse in biochemistry. Later, one of Mulkay's post-graduate students, Jonathan Potter, who had a psychology background, used discourse analysis to examine the issues within social psychology (Wooffitt, 2005). Edward and Potter (1992) subsequently coined the term "discursive psychology" to denote a relatively new perspective in the area of language and social psychology. Its ideas were influenced by Wittgenstein's (1958) later philosophy on language games, ethnomethodology (e.g., Garfinkel, 1967), rhetoric (e.g., Billig, 1985), sociology of science (e.g., Gilbert & Mulkay, 1984), conversation analysis (e.g., Atkinson & Heritage, 1984), and discourse analysis (e.g., Potter& Wetherell, 1987).

Following Jean Piaget's pioneering studies in developmental psychology, children's understanding of the world have been taken to be coherent, internal cognitive representation, whose nature can be examined via careful experiments and interviews (Edwards, 1993). Through experimental manipulations and procedures in traditional psychology, language has been treated as an apparently neutral means for getting at presupposed underlying cognitive states. Researchers took language as a window through which one could look at the thoughts in and of peoples' minds. In contrast, discursive psychology (DP) took discourse *as a topic* investigating, among others, the techniques interaction participants use to manage their talk. Psychologists traditionally attempted to produce a psychology of people trying their best, in a disinterested manner, to remember events or adduce causal responsibility, whereas discursive psychologists treat people as agents who have a *stake* or *interest* in their talk while performing particular actions. For instance, rather than seeing people use language to recall their memory of the past events, remembering is understood as the situated production of versions of past event, while attributions are the inferences that these versions make available (Edwards & Potter, 1992).

As for attitude, traditional research usually ignores and suppresses variability by means of restriction during experiments (e.g., forced choice responses), gross coding, and selective reading (Potter & Wetherell, 1987). In discursive psychology, variability is expected as people perform different actions with their talk. Thus, rather than treating attitudes as inner entities that drive behavior, discursive psychologists study attitudes as a family of evaluations that are performed rather than preformed (Potter, 1998). For instance, it was found (Pomerantz, 1984) that when people make a comment during a conversation, other interlocutors often return a similar view (e.g., A: it is a great challenge, isn't it? B: yes, the challenge is terrific!). In the conversation, can we say that both A and B have positive attitudes? Does B really have a "natural positive attitude" or just avoid offending A's comment? Thus, to better understand psychological phenomena, we should always take conversation situations as a whole instead of simply attributing interests or attitudes to one or more individuals. DP is not a matter of proving or disproving the nature or existence of real minds or what people really think, but rather is a matter of taking a different perspective altogether on language, one that examines verbal conceptualizations as flexible components of situated talk (Edwards, 1993). Thus, DP does not ask questions like "What does this talk tell us about underlying conceptions?" but concerns itself with questions such as "What is the contextually situated action being done here?" In DP, discourse is defined as talk and text, which are studied in and as of social practices (Potter & Edwards, 2001). Discourse work typically asks questions of the form "How is X done?" The focus on how-questions leads to a focus on interaction rather than cognition, a focus of concrete setting rather than abstract scenarios, and a focus on processes rather than outcomes (Potter, 2003).

There are three theoretical principles that guide discourse analysis in DP (Potter, 2003):

(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 (i.e., institutional identities or tasks) and rhetorically (e.g., the way versions are put together to counter alternatives). For example, people tend not argue the virtues of gravitational force, as it is taken to be something that simply exists. However, people do argue over the virtues of a federal Europe, and in so doing may be treated as arguing against particular nations (Billig, 1995). That is, evaluations are rhetorical, people produce evaluations where there is at least the possibility of argument and expressing an evaluation for something is often simultaneously the expression of an evaluation against something else (Billig, 1989).

(c) Construction: to be aware of discourse is constructed (discourse itself is built from various resources) and constructive (discourse build the versions of worlds).

In fact, discourse analysis has a twin focus. It is concerned with what people do with their talking and writing and also with the sort of resources that people draw on in the course of those practices (Potter & Wetherell, 1995). Specifically, DA is concerned with how the content of talk is designed for the context in which it occurs (Edwards, 1993). In the following sections, I list three examples from previous studies to demonstrate how people draw on discursive resources to support their claims and how discourse was used to perform actions in talk. In an analysis of accounts of violent political protest, the use of personality and role could be used as an indirect device for attributing blame (Wetherell & Potter, 1989).

Excerpt 1

I think the police acted very well. they're only human. If they lashed out and cracked a skull occasionally, it was, hah, only a very human action I'm sure. (Edward & Potter, 1992, p. 159)

Excerpt 2

> [I]n a way they don't have much choice . . . they've got to do their job . . . a lot of people tend to forget that. (Wetherell & Potter, 1989, p. 213–215)

In the first excerpt, police action is constructed as natural, only human, and therefore excusable. Anybody, as long as you are human being, might have done the same thing in the circumstances. However, in the second, it is role behavior that removes responsibility: "they" acted not as universal human being, but as policemen, legitimately and under orders. The deployment of group membership categories, whether universalizing (i.e., only human) or specific role descriptions (i.e., doing their job), is an indirect way of performing important attribution work (Edward & Potter, 1992).

Another device to make a version factually robust is *counter-dispositional construction* (Potter & Edwards, 2001, p. 112). An interview as below was concerned a controversial immigration issue-should the government have the restrictions on immigrations or not?

```
I:   d'you think there should be restrictions on immigration? how do you feel
     about that?
R:   oh yes, there's got to be
I:   yeh
R:   unfortunately
I:   Yeh
R:   I would love to see the whole world y'know, just where you:: go where
     you like
```

Whereas the interviewer (I) asks about the issue of restriction of immigrations, the interviewee's (R) position is agreement of the restriction "oh yes, there's got to be". However, he further talk about his another preference ("unfortunately, I would love to see the whole world"), which is a psychological counter (disjunctive)-disposition (disagreement) to construct the version as he reluctantly arrived at his position (agreement). In this way, R expressed his opinion in an indirect way and prevented the possibility of receiving strong opposition.

Another prevailing rhetorical device is *footing* (Goffman, 1981), which refers to the range of relationship between speakers and what they say, enables distinctions to be made between people making their own claims (e.g., "I think . . .") or reporting the claims of other (e.g., "My doctor said . . ."). In a focus group interview, women with breast cancer talk about cause in the following episode (Wilkinson, 2000, p. 449).

G: My sister was a nurse, way back in the 1920s, she, and she, she was at what is Springfield General now, she did her training there an there was a Doctor Patterson at the time, who used to lecture to the nurses and he told them nurses in his lectures that everybody has a cancer, and, it's a case of whether it lays dormant

F: Yes, I've heard that

D: Mm

G: Have you heard that?

F: Mm

G: Well, yes, that, she told us that, and that came in her lectures, and according to him, anything could wake it up

G articulates the dormant cancer theory as not her own but someone else's opinion and even specifically points out from a expert who is a doctor working at a professional organization "Dr. Patterson at Springfield General Hospital." She also carefully monitors the response from F, D and even checks that she has their support "Have you heard that?" The effect of all this footing is to emphasize that these ideas are not her own, increasing the likelihood that she cannot be held accountable for the cancer theory. In this study of women experiencing breast cancer, it was discovered that footing for speakers had served certain functions, namely to avoid challenge, or ridicule potential arguments or occasions that might be problematic to self-identity.

2.3.2. Interpretative Repertoire

Interpretative repertoire is an important concept in DA. The concept first appeared in Gilbert and Mulkay's (1984) sociological study of biochemistry laboratories in UK and USA. These researchers found that scientists employ certain stable interpretative forms and repertoires, but that these recurrent interpretative resources are used with great flexibility to generate radically different accounts of social phenomena. They mainly identified two interpretative repertoires: an *empiricist* and a *contingent* repertoire. The empiricist repertoire usually happens in the formal discourse (e.g., papers of conference) where scientists use impartial and objective words to support their articulation like "the experiment confirmed . . ." or "the results show. . . ." Whereas the contingent repertoire often happens in the informal settings (e.g., interviews) or when things go wrong where scientists uses many interpersonal words (e.g., "Dr. Smith believes that . . ." or "the result must result in human errors . . ."), Gilbert and Mulkay found that the empiricist repertoire represent scientists as objective and as following particular experimental procedures which lead to the factual results. The contingent repertoire, on the other hand, represents scientists as social beings whose work could be affected by their desire, beliefs and prejudice.

We therefore can define an interpretative repertoire as a lexicon or register of terms and metaphors drawn upon to characterize and evaluate actions and events (Potter & Wetherell, 1987). Because discourse is designed for recipients, interpretative repertoires fundamentally constitute shared discourse features. Interpretative repertoires denote forms of talk that discourse participants unquestioningly (a) take for granted for the purpose at hand and (b) draw on to buttress other aspects of talk that are contentious and uncertain. Interpretative repertoires also are part of any community's common sense and are available to the members of a culture, providing a basis for shared social understanding. They can be thought of as books on the shelves of a public library, permanently available for borrowing by the members of a discursive community

(Edley, 2001). Existing studies have utilized a discursive psychological orientation and discourse analysis to identify interpretative repertoires in different contexts, for instance, investigating students' discourse of ontology, epistemology and sociology of scientific knowledge (Roth & Lucas, 1997), students' talk about physics concepts such as rotational motion (Roth, Lucas, & McRobbie, 2001), people's discourse on masculinity (Edley, 2001), articulating environmental education designers' discourse about why and how they design environmental education (Reis & Roth, 2007), investigating people's discourse about racism and culture (Wetherell & Potter, 1992), and analyzing people's discourse about marriage (Lawes, 1999).

Interpretative repertoires are pre-eminent ways of understanding the content of discourse and how that content is organized. When two repertoires lead to contradictions, special discursive devices are invoked to resolve them. Thus, when in the same interview scientists say that science both reveals the truth and is contingent and subjective, then the *truth-will-out device* (TWOD) allows them to talk themselves out of the contradiction (Gilbert & Mulkay, 1984). In high school students' talk about scientific knowledge, researchers also found students drawing on another discursive device *as-long-as-it-works-take-it-as-truth* device to solve their conflict (Roth & Lucas, 1997). This occurred, for example, when a student felt his ontological claim (e.g., the nature is inherently structured by laws and a prior to human apperception) conflicted with his epistemological claim (e.g., scientific knowledge does not describe nature as it really is).

2.3.3. Stages and Validation of Discourse Analysis

In practice, discourse analysis could be generally split the process into several stages that are not sequential steps but phases (Potter & Wetherell, 1987).

(a) Setting research questions: give priority to discourse and ask about its construction in relation to its function.

(b) Sample selection: the sample size depends on the specific research question. A success of discourse studies is not dependent on its sample size, many classic discourse studies have only concentrated on a single text, with the goal of showing how a certain effect can be achieved.

(c) Collection of records and document: by collecting documents from many sources, it is more possible to build up a much fuller idea of the way participants' linguistic practices are organized compared to one source alone.

(d) Interviews: interviews have the virtue of allowing the research room for active intervention and question an entire sample of people on the same issues. However, discourse analysis is different from conventional interviews in three ways: variation in response is as important as consistency; techniques and room for diversity conversation is important; and interviewers are seen as active participants rather then like speaking questionnaires.

(e) Transcription: in general, the ratio of tape time to transcription time is about one to ten. However, it also depends on how detailed the transcription you need, so it is important to think what information is required and what level the analysis will proceed.

(f) Coding: the goal of coding is not to find results but to squeeze the large body of discourse into manageable chunks. The categories of coding are related to the research question and it need to move back and forth between analysis and coding.

(g) Analysis: a lot of careful reading and rereading is necessary and analysts need to constantly ask: why am I reading this passage in this way? What features produce this reading? Furthermore, there is the search for pattern in both variability (differences in either the content or form of accounts) and consistency (the identification of features shared by account) sense and there is the concern with function and consequence.

(h) Validation: four main techniques for validation are (a) *coherence* (show how the discourse fits together and how discursive structure produces effects and functions), (b) participants' *orientation* (not only show analyst's views but also show how participants' views), (c) *new problems* (the existence of a secondary system acts as a validity check on the existence of the primary system), and (d) *fruitfulness* (the scope of an analytic scheme to make sense of new kinds of discourse and to generate novel explanations).

(i) Report: the goal of report is to present data, analysis and conclusion in such a detail way that the reader is able to access the researcher's interpretations, so each reader is given the possibility of evaluating the different stages of the process and hence agreeing with the conclusion or finding grounds for disagreement. Thus, discourse analysts leave the reader to take on trust rather than having inter-rater reliability as traditional content analysts need for their numerical summary.

To support new scholars for avoiding doing non-discourse analysis, discourse analysts (Antaki, Billig, Edwards, & Potter, 2003; Burman, 2003) also continually identify nine common analytic shortcomings for newcomers to adjust and improve their analysis. They are:

(a) Under-analysis through summary: summarizing might prepare for analysis but not analysis itself and might risk losing detail information from discourses.

(b) Under-analysis through taking sides: adding sympathy and scolding utterance from the analysts are not analysis but enlistments that risk simplifying the complexity of talk and social action.

(c) Under-analysis through over-quotation or through isolated quotation: only leaving quotations alone without going beyond texts and explaining is not analysis either. Analysts should do analysis such that it allows readers to follow analysts' points.

(d) The circular identification of discourses and mental constructs: some analysts only take similar quotes together to prove there is a common theme between different speakers and then use the common theme to explain what is happening in the situation. If that is all an analyst is doing, then she only summarizes. Analysts should go further and supply an extra elements or explanation for the common theme. Especially from a discursive psychological perspective, analysts should not use some terms (e.g., think, feel or believe) indicating mental states (e.g., schema, attitude, belief) to circularly explain what is going on in the discourse.

(e) False survey: some discourse analysts intend to report survey but might risk over-generalizing their findings.

(f) Analysis that consists in simply spotting features: discourse analysts should not only be able to recognize rhetorical features in previous findings, but should be able to have further detailed analyses, set in new materials, or find new features.

(g) Under-analysis through uncontested readings: rather than formulating a singular account, good discourse analysis acknowledges the multiple and contest character of the interplay of discourses by showing how different discursive representations are built to interact with and ward off others.

(h) Under-analysis through decontextualization: good analyses explicitly supply social, historical, cultural and political components of discourses- a meaningful context and discourse for readers to follow.

(i) Under-analysis through not having a question: to indicate a research question in analysis allows readers to know why the analysis is being done and is worth doing.

2.4. Phenomenography

To identify different ways of experiencing in learning situations, phenomenography was developed from an empirical educational framework by Ference Marton and his coworkers in the 1970s in Sweden. Phenomenography constitutes a second-order and nondualistic perspective to aim at description, analysis, and understanding of people's experiences (Marton, 1981). The analysis is of the second-order type (statement-about-perceived-reality) in a sense that phenomenography focuses on describing people's experience of various aspects of the world rather than describing various aspects of the world (first-order perspective: statements-about-reality, e.g., ethnography). To use a second-order perspective, researchers not only investigate the world but also peoples' perceptions about it. They can thus provide a wider understanding about people's experience and supply the pedagogical potentiality. Phenomenography is nondualistic in the sense that it understands that objects and subjects cannot be separated: the world is what we perceive and experience it to be. The results of phenomenographic studies are neither mental entities nor physical things but consist of internal relationships between the subject and the world—*intentionality*.

The basic analytic unit in phenomenography is "a way of experiencing something," which indicates an internal relationship between the experiencer and the experienced. For instance, two people become a husband and a wife respectively because of their marriage—an internal relationship between them. Without one of them, the internal relationship would not exist and without this relationship, one would not be seen as a husband or a wife. Phenomenography and phenomenology both are influenced by the phenomenological philosophy (e.g., intentionality), however, phenomenography purports to describe the different ways of experiencing phenomenon and phenomenology aims to capture the typical essence or structure of a range of experiences (Giorgi, 1999). Phenomenology asks for the very nature and richness of a phenomenon, for that which makes a something what it is, whereas phenomenography is interested in how people perceive a phenomenon differently. That is, phenomenography's interest is not the phenomenon per se (neither actors per se), but concerns the relationship between the actors and the phenomenon. Phenomenologists usually ask "How does the person experience her word?" and phenomenographers would ask "what are the critical aspects of ways of experiencing the world that make people able to handle it in more or less efficient ways?" (Marton & Booth, 1997, p. 117). According to gestalt theory, these different experiences are based on the relationship between figure and ground.

To demonstrate different students' learning experiences, Marton (1981) takes a study by Johansson and Lybeck (1978) as an example. In their study, the latter investigated how students solved physics problems. A problem is as follows: "a car moves at constant speed and in 3 second it travels 6 meters. What distance does it travel in 9 seconds?" Two possible ways of calculation can both produce the same answer. On the hand, the student may focus on the relationship within the variables: "9 is 3 times 3, thus I have to multiply 6 by 3, which makes 18." On the other hand, the student may concentrate on the relationship between the variables: "6 is two times 3, thus I have multiply 9 by 2, which make 18." From the point of view of mathematics, both solutions make sense. However, in physics, it is a big matter about which solution the student used. Because "relating two different qualities to each other in terms of a quantified relationship is central to the use of the conception in physics." In the case, the second approach illustrates the concept of "velocity," and therefore is a more fruitful solution.

A fundamental assumption underlying phenomenographic research is that there are finite numbers of qualitatively different understandings of a particular phenomenon—*categories of descriptions*. These categories of description (the collective level of ways of experiencing a phenomenon) and the logical relationship between them constitute the results of phenomenographic studies—*the outcome space*, which provides a framework for better understanding participant's variations of the collective. Thus, phenomenography takes a different perspective in qualitative research to investigate phenomenon. Take the topic of "social power" as an example. Phenomenography would aim at learning about "people's different ways of experiencing political power," whereas phenomenology would focus on "what political power is," and psychology would be interested in "why people have particular experience about political power."

A structure-of-awareness approach has been used to articulate how experience has a structural aspect and a referential (or meaning) aspect (Marton & Booth, 1997). The structural aspect includes the discernment of the whole from the context (i.e., external horizon) and discernment of the parts and their relationships within the whole (i.e., internal horizon). The boundary between the external and internal horizons delimits the theme of awareness—the phenomenon. And through the relationship between the parts/whole and the context, we sense the meaning (referential aspect) of the phenomenon. In addition to the different ways of experiencing (the first face of variation), the variation that corresponds to the critical aspects of the phenomenon (the second face of variation) has become an important component in the recent studies in phenomenography (Pang, 2003).

2.4.1. Validation of Phenomenography Analysis

In phenomenographic research, the preferred method of data generating is the semi-structured, individual, oral interview using open-ended questions, and researchers need to step back consciously from their own experience of the phenomenon and illuminate others' ways of experiencing (Marton & Booth, 1997). After transcribing interviews verbatim, researchers read transcripts repeatedly to discern participants' different ways of experiencing a phenomenon. Several useful techniques are identified as followings (Dahlgren & Fallsberg, 1991): (a) *familiarization* (reading transcripts repeatedly); (b) *condensation* (identifying significant answers by informants); (c) *classification* (grouping similar features within or between participants); (d) *preliminary comparison* (establishing borders of initial categories); (e) *naming* (giving essential names for each categories); and (f) *contrastive comparison* (describing unique characters in each category and its resemblances and relationship between categories).

Furthermore, three indicators identified to assess the significant elements in participants' descriptions (Sjöström, & Dahlgren, 2002): (a) *frequency* (how often a meaningful statement is articulated); (c) *position* (very often the most significant elements are to be found in the beginning stage of answers); and (c) *pregnancy* (when participants emphasize certain aspects are more important than others).

To establish the validity of data analysis, three criteria are used to justify the basic quality of phenomenographic studies (Marton & Booth, 1997, p. 125): (a) each category of description should be distinct with each other and stand in clear relation to the phenomenon; (b) these categories of descriptions should stand in a logic relationship with one another; (c) the system should be parsimonious for capturing the critical variation in the data.

Furthermore, there are eight criteria to establish the credibility for phenomenographic studies (Cope, 2002).

(a) The researcher's background should be acknowledged. Describing the researcher's scholarly knowledge of a phenomenon is a means of providing a reader with the context within which the analysis took place.
(b) The characteristics of the participants should be clearly stated, providing a background for any attempt at applying the results in other contexts.
(c) The design of interview questions should be justified.
(d) The steps taken to collect unbiased data should be included.

(e) Attempts to approach data analysis with an open mind rather than imposing an existing structure should be acknowledged.
(f) The data analysis method should be described.
(g) The researcher should account for the process used to control and check interpretations made throughout the analysis process.
(h) The results should be presented in a way that permits informed scrutiny. Categories of description should be fully described and adequately illustrated with quotes.

2.5. Why Use These Research Tools for Analysis?

> The search for method becomes one of the most important problems of the entire enterprise of understanding the uniquely human forms of psychological activity. In this case, the method is simultaneously prerequisite and product, the tool and the result of the study. (Vygotsky, 1978, p. 65)

As Vygotsky indicated, methods play an important role in social sciences because they not only serve as mediational moments in and to the research process but also constitute determinations of the results that will issue from the research process. Therefore, searching for appropriate methods and tools is crucial for social-science researchers. However, in qualitative research, there is no "one right way" to find a theoretical framework. Some people count on "total chance," "a suggestion from a colleague," "putting two heads from two different fields together," or "being well-read in education and other fields of study" (Mertz & Anfara, 2006). For my dissertation, I found salient two major considerations guiding me in the choice of research tools: (a) proper tool(s) for addressing the research questions; (b) coherent and complementary tool(s) for the dissertation.

2.5.1. Searching Proper Tool(s) for Addressing Research Questions

"Judgments about the scientific merit of a particular method can only be accomplished with respect to its ability to address the particular question at hand" (Feuer, Towne, & Shavelson, 2002, p. 7). Therefore, choosing tool(s) that help me to address the research question is the key consideration for the dissertation. Four primary research tools—discourse analysis, conversation analysis, phenomenography and cultural-historical activity theory, are identified to examine each research question as illustrated in Table 2.1. As the first four research questions are closely related to discursive approaches, I first discuss the rationale for choosing tools for the first four questions (1-4) and then address the choice of method to find answers to questions 5 and 6.

Table 2.1. Six research questions and corresponding tool(s)

No	Focus/ Research Question	Primary Tool for analysis
1	How does an experienced teacher introduce authentic science activities to high school students? (chapter 4)	Discourse analysis
2	How do high school students articulate their preferred and dispreferred science-related careers? (chapter 5)	Discourse analysis
3	How do teaching and learning happen naturally during a science internship? (chapter 6)	Conversation analysis
4	How does science expertise unfold in a science internship and what are suitable theoretical concepts to describe it? (chapter 7)	Conversation analysis
5	How do participants experience a science internship? (chapter 8)	Phenomenography
6	How do students understand science practice after participating in a science internship? (chapter 9)	Cultural-historical activity theory

2.5.1.1. Proper Tool(s) for Research Question 1, 2, 3 and 4

One of the important foci in the dissertation is to investigate discourses related to science internships, because it allows me (a) to understand one of the most important tools in human society for communication—language use; (b) to illustrate the cultural essences through studying discourses; and (c) to strengthen ecological validity of the dissertation. As illustrated in Table 2.1, the first four research questions concern issues of discourse. So, how did I choose the proper tools to address these questions among the numerous discourse-related tools?

Discourse means many forms of social practice like talking and writing. The literature describes many approaches for analyzing discourse. According to Schiffrin (1994) and Wooffitt (2005), many ways of analyzing discourse and its main contributors and foci are listed below:

(a) *Speech act theory* (e.g., John Austin & John Searle): concerning how meaning and actions are related to language and claim language is used to perform actions (focus on communicative acts performed through speech), e.g., "I promise to be there tomorrow" perform the act of "promising" and "the grass is green" performs the act of "asserting."

(b) *Interactional sociolinguistics* (e.g., John Gumperz & Erving Goffman): the analysis of the ways in which how interpretation and interaction are based upon the interrelationship of social and linguistic meanings (focus on the social and linguistic meaning created during interaction), e.g., the phenomenon of speaking for another—C uttered "she's on a diet" after A invited B for dinner.

(c) *The ethnography of communication* (e.g., Dell Hymes): to discover and analyze the structures and functions of communicating that organize the use of language in a speech situation, event and acts (focus on language and communication as cultural behavior), e.g., identify several functions (seeking or checking) of questioning.

(d) *Pragmatics* (e.g., Paul Grice, Stephen Levinson, & Charles Morris): the study of the relation of signs to interpreters, and its focus on meaning, context and communication (focus on meaning, context, and communication of constructed utterances in hypothetical contexts), e.g., the phenomenon of speaking for cooperation and inference "A: Smith doesn't seem to have a girlfriend these days. B: He has been paying a lot of visits to New York."

(e) *Conversation analysis* (e.g., Harvey Sacks, Emanuel Schegloff & Gail Jefferson): to discover the methods by which members of a society produce a sense of social order (focus on sequential structures in conversations), e.g., adjacent pair.

(f) *Variation analysis* (e.g., William Labov): to discover patterns in the distribution of alternative ways of saying the same things (focus on structural categories), e.g., different text structures (i.e., "narrative" tell what happened and "lists" describe a category).

(g) *Discourse analysis* (e.g., Nigel gilbert, Michael Mulkay, Jonathan Potter, Derek Edwards & Margaret Wetherell): focus on how people perform actions and draw on cultural resources in an interest manner in discourse, e.g., interpretative repertoires.

(h) *Critical discourse analysis and Foucauldian discourse analysis* (e.g., Michel Foucault, Norman Fairclough, Teun A. van Dijk, & Ruth Wodak): the analysis of the relations between power and discourse, e.g., injustice and the hierarchy of power.

As illustrated in the list above, different discursive approaches have a different focus. To address research questions 1 and 2, I chose discourse analysis as my method to analyze the discourse of "introducing science" and "talking science careers." In question 1, I wanted to understand how a teacher uses discursive resources to present science opportunities to her students through her introductions and how she uses words to promote these opportunities (i.e., how she performs the promoting actions in her introduction). In question 2, I wanted to understand how high school students draw on discursive resources to help them articulate science-related careers. That is, my purpose in asking these two questions is to understand discursive resources in the high school class culture, rather than addressing power relations in school, identifying different functions of language use, or comparing language use across different groups. Thus, discourse analysis is a good choice for this purpose because it allows me to understand cultural resources of science related discourses shared in the high school class.

As for questions 3 and 4, I wanted to see how students and technicians interacted with one another in the science laboratory. I chose conversation analysis because the aim of this method is to examine the social order created by participants during face-to-face interaction. Although the social order is also a concern for interactional sociolinguistics, conversation analysis seeks generalizations within the progression of utterances themselves rather than judge participants' interpretation with the help of contextual information (Schiffrin, 1994). That is, conversation analysis refuses to take external aspects (e.g., cultural or social identity) into account "since there are an indefinite number of external aspects that could be potentially relevant to any given instance of talk-in-interaction . . . and analysis can only show these innumerable, potentially relevant characteristics through analyzing details of the interaction" (Seedhouse, 2005, p. 255). Therefore, conversation analysis is a more objective method of choice for analyzing interactions. To illustrate the similar and different orientation of conversation analysis (CA) and discourse analysis (DA), Wooffitt (2005) has an excellent discussion, which I summarize in Table 2.2 as a brief comparison.

Table 2.2. A comparison of CA and DA.

		CA	DA
Similarities	Talk as a topic for analysis	Examine discourse as a topic in its own right, not as a reflection of wider structural conditions.	
	Attention to the properties of data	Data-driven research questions, not theory driven	
	The influence of Ethnomethodology	Mainly by Harold Garfinkel and Erving Goffman	
	Accusations of triviality	Both are accused of dealing with the trivial and adding little to existing knowledge.	
Differences	Influence	Mainly from Harvey Sacks's unique way of doing research	From various disciplines: Ethnomethodology, sociolinguistics, structuralism, speech act theory
	Concern	Actions (i.e., interaction)	Action orientation (i.e., accounts in talk and texts)
	Terminology	Many technical terms	Few
	Demonstrate	Turn design	Rhetorical force
	Data kind	Verbal interaction	Verbal and visual (text)
	Data source	Mundane and routine	Disputes or controversial events
	Transcription	Very detail	Less detail
	Analysis	Formal procedure (e.g., next turn proof procedure)	Repeatable & consistent analysis

2.5.1.2. Proper Tool for Research Question 5

Research question 5 aims to understand internship "experience." In the literature, phenomenography and phenomenology are two primary ways of investigating people's experience. Phenomenography and phenomenology are both influenced by the phenomenological philosophy (e.g., intentionality); however, phenomenography purports to describe the different ways of experiencing phenomena and phenomenology aims to capture the typical essence or structure of a range of experiences (Giorgi, 1999). Phenomenology asks for the very nature and richness of a phenomenon, for that which make a thing what it is, whereas phenomenography is interested in how people perceive a phenomenon differently. That is, phenomenography's interest is not the phenomenon per se (nor actors per se), but the relationships between the actors and the phenomenon. Phenomenologists usually ask, "How does the person experience her world?" where phenomenographers would ask, "What are the critical aspects of ways of experiencing the world that make people able to handle it in more or less efficient ways?" (Marton & Booth, 1997, p. 117). A fundamental assumption underlying phenomenographic research is that a finite number of qualitatively different understandings exist of a particular phenomenon. Thus, for phenomenology, data sources are usually collected from "rich and deep" experiences from "few" participants, whereas phenomenography are often collected data sources from many people to discern different ways of experiencing. In fact, previous phenomenographic studies show that the variation of a phenomenon reached saturation at around 20 research participants, after which no new conceptions emerged (Sandberg, 2000).

For my dissertation, I choose phenomenography as the tool to answer question 5. The reasons include: (a) the science internships project is relatively new research in science education; therefore, to understand different ways of participants' experiences is an urgent need for researchers (i.e., the study can serve as a foundation or referent for a phenomenological study); and (b) my internship project had involved different groups of participants (high school students, high school teacher, scientists, technicians), so phenomenography allows me to illustrate experiences from these participants to see a broader experiential pattern.

2.5.1.3. Proper Tool for Research Question 6

Question 6 asks about students' understanding of (the nature of) science practice after they had participated in the science internship. In previous studies, the research concentrated on students' views of the nature of science. However, in my dissertation, I decided to choose a different way to ascertain students' views of (the nature of) science practice. In the following section, I justify my reasons for choosing cultural-historical activity theory as a tool to understand students' views of science practice.

Most of the previous studies on students' image of science enterprise depended on conventional instruments to detect conceptions such as questionnaires (e.g., Aikenhead & Ryan, 1992), interviews (Ryder, Leach, & Driver, 1999), or the Draw-A-Scientist Test (e.g., Chambers, 1983). However, these approaches are not without their critics. The debate involves assessment instruments that are often interpreted in a biased manner and appear to be poorly constructed (Lederman, Wade, & Bell, 1998); existing assumptions of no ambiguity between researchers' statements in instruments and students' interpretations (Aikenhead, Fleming, & Ryan, 1987); students' responses on questionnaires have little consistency across survey items and contexts (Leach, Millar, Ryder, & Séré, 2000); interview questions are ill-addressed in most studies (Lederman, Wade, & Bell, 1998); and methodological issues (e.g., students' different drawing abilities, the request to draw scientists rather than other occupations) exist in Draw-A-Scientist Test (Losh, Wilke, & Pop, 2008). In particular, disagreements exist in the literature about the tenets of the "nature of science," outlined in previous studies (Alters, 1997).

These discussions in literature show that there is no consensus about (a) the definition of the nature of science; and (b) the proper tools for detecting students' views on the nature of science. Therefore, I decided to find an alternative way to understand students' understanding about science practice after their participation in the science internship. I drew on the cultural-historical activity theory as a tool (a) to analyze students' public presentations and (b) to debate the influence of authentic contexts on students' views of science practice. The well-established activity-theoretical framework suggested itself as a useful tool for analyzing human activity generally, including science practice. It opens another possibility for science educators to examine students' understanding of science practice.

2.5.2. Searching for Coherent and Complementary Tool(s)

It is common to use multiple frameworks for qualitative studies to be based on more than one theory or method, as researchers often find that no single theory or method explains all their data (Fowler, 2006). It is the same case with my dissertation. To understand the issues of science internship, I chose a multiple approach to explain and analyze the data sources. In addition to considering the compatibility of the research questions, I chose tools for the dissertation in coherent and complementary ways (i.e., discourse analysis [DA], conversation analysis [CA], phenomenography, and cultural-historical activity theory [CHAT]).

"Coherent" here is meant in the sense that these four research tools have a congruent philosophy of doing and analyzing social research. That is, they all

(a) *Focus on discourse in natural settings* (either in everyday life or open-ended/semi-structured interviews) rather than in a experimental design setting; and

(b) *Consider conversations and practice as products at both individual and collective levels* rather than attributing them solely to individuals.

The methods are "complementary" in the sense that the four research tools allow me to understand different aspects and dimensions of the science internship. That is, they assist me to investigate the science internship

(a) *For different timescales of phenomenon* (e.g., DA and CA focus on the microgenetic scale and CHAT focuses on the cultural-historical level);

(b) *With both emic and etic perspectives* (e.g., DA & CA provides the emic perspective and CHAT provides the etic perspective); and

(c) *With both the first-order and second-order understanding* (e.g., phenomenography provides the second-order approach that aims to understand "statement-about-perceived-reality" and CHAT provides the first-order approach that aims to understand "statement-about-reality").

CHAPTER 3: EMERGENT RESEARCH DESIGN

This dissertation was designed to examine the nature and relevant phenomenon of high school students' science internship in an effort to identify relevant and salient aspects (factors, variables) rather than as an "experimental" study that examines known factors or variables. Thus, "doing what comes naturally" (Lincoln & Guba, 1985) became one of the main principles of the research design. That is, "I" am not the only one who participates in the internship design, but so do scientists, technicians, and the high school teacher who participated in my study. Therefore, the research design is an "emergent" product of participants' discussions, collaborations, and negotiations. In the following sections that introduce the overview of the emergent research design, I report how I collected data sources, gathered background information about participants and the internship, and decided on the main principles to establish the credibility of data collection and analysis.

3.1. Data Sources Collection

To understand the related issue of internship, I started the project by conducting ethnography studies in both the university science laboratory and the participating high school class prior to the actual internship experience. I used the following techniques: video recording the activities, taking field notes, and collecting relevant, available documents. This research project was carried out in cooperation with a grade 11 honors biology class at one high school and with a biology laboratory at UVic. For the research in the high school, ethics approval from UVic, the support of the principal in a high school, authorization from the school district are obtained to be present in the high school biology class. I obtained consent from the teacher, the students in her class, and the students' parents. I observed the class from January 5 to February 3, 2006. During that period, I videotaped 22 lessons, took extensive field notes, interviewed 13 students about their career aspirations, and interviewed the teacher about her teaching experience.

In terms of the biology lab ethnography, I obtained consent from the scientists, technicians, and graduate students in the lab. I attended the weekly and monthly lab meetings from September 2005 to May 2006, and observed the scientists at work in the lab from November 2005 to May 2006. The high school students and their teacher were invited to a meeting at UVic with scientists and technicians on February 17, 2006 to discuss scheduling the high school student science internship in the biology lab.

The students were divided into four groups, each group led by one or two technicians working in the lab. The high school students came to UVic to participate in four scientific projects outside school hours. The students spent about 4–5 days (total 10–16 hours) on campus working with these technicians assigned to these projects. Each scientific project represented different scientific knowledge, techniques, and use of technology and equipment. Each technician arranged the work to be conducted by his or her group. The science work carried out in the groups included but was not restricted to demonstration, leading students doing science, fieldtrips, and attending in seminars and discussion. During the internship, I followed their actions to record the process of the internship. On April 19, 2006, at the end of the internship, the high school students in each group presented what they had learned from the internship for 10–15 minutes to a group of their peers, their biology teacher, the laboratory members, and educational researchers (in total about 50 people). After the completion of the internship, I carried out another round of individual interviews with all high school students, the teacher, and all these technicians and scientists about their experience of the internship. The research framework of the internship project is graphically shown in Figure 3.1.

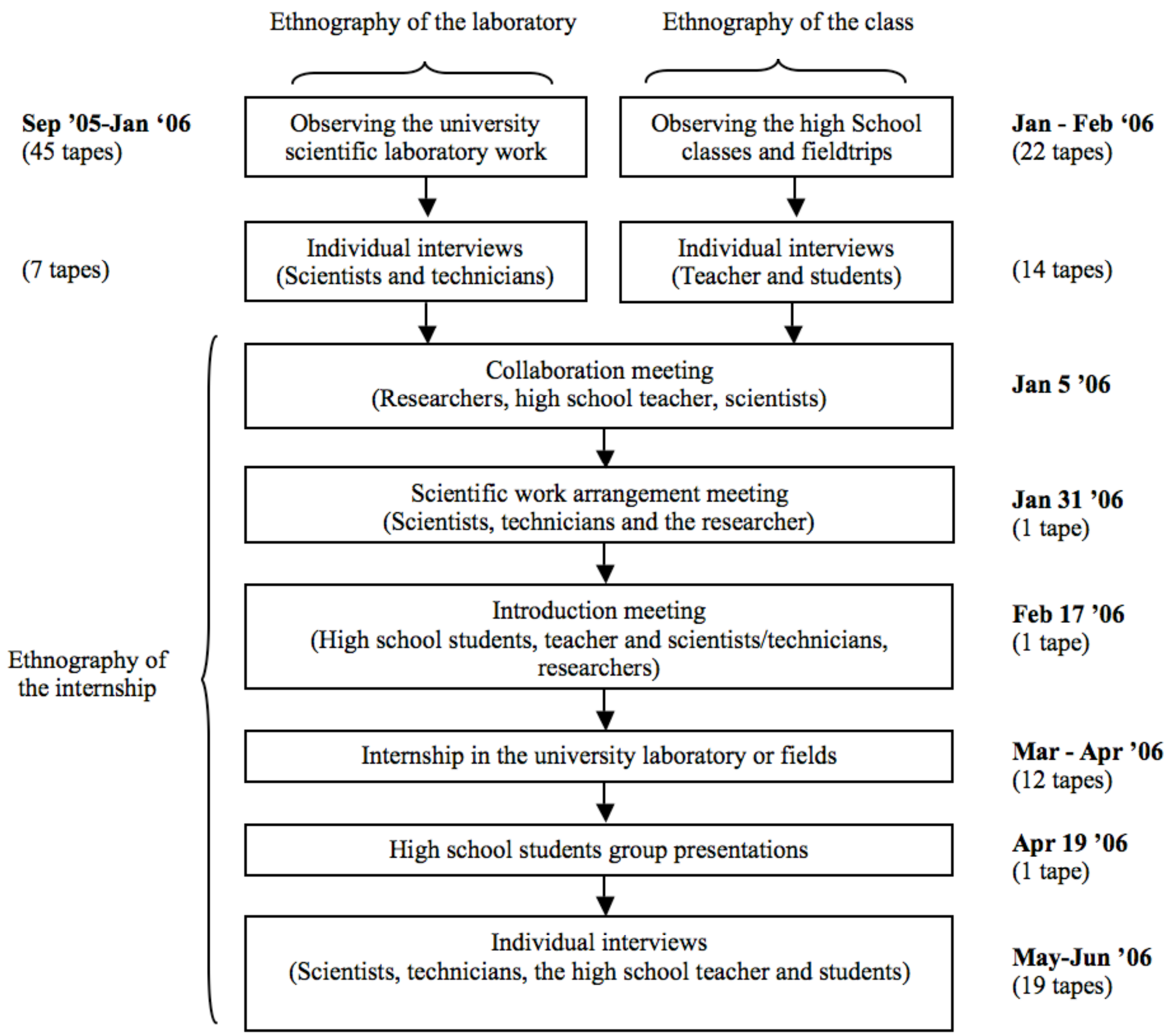

Figure 3.1. Research design, timeline and data source collection of the project.

3.2. Ethnography of School Science and Career Preparation

To understand what and how students learn during authentic experiences, I conducted an ethnographic study in the school prior to offering them the internship opportunity. I observed their biology lessons and career-preparation course for a period of twenty-two lessons (one month). The high school students attended a public school in a mid-sized Canadian city where they were enrolled in an eleventh-grade honors biology course that includes a biology career-preparation function. Usually, the career-preparation students used extra school time to participate in various science activities to complete the career-reparation course, which requires 100 hours over two years (grades 11 and 12). Students normally relied on the biology teacher to get information about science activities and counted on her to arrange participation in them. The internship activity in this study was one of their career-preparation course activities.

The teacher involved in this study has 26 years of experience and was the head of the high school science department. In this course, the teacher guided students to learn biology through lectures, experiments, and demonstrations. She used multiple resources to aid her teaching, including videos, microscopes, dissection equipment, textbooks, overheads, chalkboard, and newspapers. In addition to teaching eleventh-grade biology, the teacher arranged and conducted a variety of scientific activities in which students could participate (the school released her from one course). This school had many career-preparation courses, including art, carpentry, human services and music. The biology career-preparation course in this study was the only academic career-preparation course that relates to fundamental science (e.g., biology, physics, chemistry, and math) in the city. The career preparation course was funded by the school district, allowing the school to finance some student-learning resources, such as science magazines, microscopes, and bus tickets for visiting science laboratories.

3.3. Ethnography of the Scientific Laboratory

Meanwhile, to understand what would happen when the students joined the laboratory, I conducted a six-month ethnographic study of the laboratory. I participated in scientists' and technicians' weekly and monthly meetings and observed their work in the laboratory for six months to understand the work and establish a trusting research relationship. In addition, I followed the four scientific projects that the students would participate in later to understand the science work. The biology laboratory cooperated with many partners (e.g., the city, funding agencies, and researchers at other universities) to investigate the environmental parameters of drinking-water supplies. The laboratory members included the chief scientist and head of the research program, a laboratory manager, three scientists, five postdoctoral fellows, one administrative assistant, thirteen technicians (field managers, research assistants etc.), fifteen graduate students, and a variable number of undergraduate co-op students. At the beginning of each week, the lab manager hosted a discussion of administrative issues, troubleshooting, equipment arrangement, working reports of the previous week, and schedule reports for the following week. The administrative assistant and technicians normally participate in these meetings. They discuss many instances of collaboration that occur between the different projects conducted in the laboratory and the organization of special events and activities during the weekly meetings. The meeting minutes were sent to every member to update the news about the laboratory. Scientific events such as graduate students' presentations were discussed monthly, involving all members of the laboratory and some of the external collaborators.

For this team, there was a cubical office for administration and computer work, and several scientific laboratories with equipment such as an isotope ratio mass spectrometer, an electron microscope, centrifuge, fume hoods, glassware, and so on. Technicians were the key people to contact the high school students in the study. Most technicians were in their 20s or 30s and had biology-related majors. Technicians usually worked in the laboratory for eight hours a day, had lunchtime and coffee breaks, and sometimes went into the field to collect samples. Many different projects were going on at the same time and these technicians in each project cooperated with graduate students while being supervised by the responsible scientist. Technicians went back and forth in the laboratory to use different equipment and instruments for their work, or even went to other laboratories to use their instruments if necessary. The atmosphere in the scientific laboratory was energetic and collaborative. For instance, they had music in the background while working in the laboratory; they chatted together at break times and had celebrations on special days such as dressing up at Halloween and holding a Christmas party.

3.4. Participants and Participation

The high school students who were interested in participating in the project voluntarily came to the laboratory in groups of three or four. I organized the first meeting for the students, scientists, and technicians to discuss the science projects, negotiate time schedules and discuss the work in preparation for the internship in the university science laboratory. After meeting with the scientists and technicians, students arranged their after-school time and took the bus to the university biochemistry laboratory. This group of 13 students participating in the internship was composed of two male and eleven female students. Each group followed one or two technicians to learn about science and to practice science techniques for the ongoing scientific projects. They spent ten to sixteen hours in the laboratory during the two-month period. Students usually started the internship by reading some relevant scientific papers selected by these technicians. They participated in discussions and scientific seminars, and practiced particular techniques in science projects in laboratories or collected samples from the field. After the internship, each group of high school students presented their experiences and what they had 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 center for scientific literacy.

The chair scientist and the laboratory manager (scientist) participated and supervised the internship activity during the two months. Before the arrival of the students, the scientists communicated the forms for the internship and time schedule to the biology teacher and discussed the ways of guiding the students with each technician in each project. When technicians needed instruction or help, they approached the scientists for advice. These technicians were undergraduate or graduate students majoring in biology and had no pedagogical training. These technicians designed an internship plan beforehand and discussed the feasibility of the plan with the scientists. The purpose of the internship from the scientists' and technicians' point of view was to demonstrate regular work in laboratories, to show the connection and application of scientific knowledge with daily life, and to provide some scientific practice for high school students.

3.5. Trustworthiness

Specific techniques validated different methods, as described in chapter 2, to establish the quality of qualitative research. Several techniques from fourth-generation evaluation (Guba & Lincoln, 1989) were also considered in the dissertation. Trustworthiness is the criteria for establishing the quality of naturalist inquiries that aim to "do what comes naturally" for social research. Naturalist inquires have a different philosophy and way of doing social-science research from the conventional way (e.g., experimental study or natural science studies). To illustrate the difference, I summarized the general philosophy and different criteria for evaluating the quality of social-science research in Table 3.1. For instance, the fundamental assumptions of "reality" are very different between the two. In conventional studies, researchers generally assume the existence of "one real reality"; therefore researchers can use techniques such as "repeatable experiments" to seek this "fixed reality." However, in qualitative research, researchers assume that the "reality" is not fixed but constructed differently by different people and so there is no such a "real reality" for researchers to look for. These different assumptions lead researchers to have different criteria for validating their research. As illustrated in Table 3.1, parallel criteria are identified and compared. In particular, strategies and techniques to establish trustworthiness are thoroughly discussed in the following chapters to address specific research questions.

Table 3.1. Different philosophy and criteria for doing social-science research.

Conventional Evaluation	Trustworthiness (naturalist inquiry)
• Philosophy: o Reality is single, tangible, and fragmentable o Knower and known are independent o Time and context-free generalizations are possible o There are real causes, temporally precedent to or simultaneous with their effects o Inquiry is value-free	• Philosophy: o Realities are multiple, constructed, and holistic o Knower and known are interactive and inseparable o Only time and context-bound working hypotheses are possible o All entities are in a state of mutual simultaneous shaping, so that it is impossible to distinguish causes from effects o Inquiry is value-bound
• Internal validity (between findings and a "real" reality)	• Credibility (between findings and the constructed realities of respondents) o Techniques: (a) activities in the field that increase the probability of high credibility such as prolonged engagement, persistent observation and triangulation; (b) peer debriefing; (c) negative case analysis; (d) progressive subjectivity; (e) member checks
• Generalization (between samples and populations)	• Transferability (between sending and receiving contexts) o Techniques: thick descriptions; reflective journals
• Reliability (the stability of data over time: repeatable data)	• Dependability (the stability of data over time: tracked and trackable data) o Techniques: dependability audit; reflective journals
• Objectivity (objective interpretations: mainly by methods)	• Confirmability (objective interpretations: mainly by data) o Techniques: confirmability audit; reflective journals

CHAPTER 4: AN ANALYSIS OF TEACHER DISCOURSE THAT INTRODUCES REAL SCIENCE ACTIVITIES TO HIGH SCHOOL STUDENTS

Preface

Based on cultural-historical activity theory, researchers understand human activities more thoroughly because they have a greater sense of its "historical" and "cultural" aspects. Thus, although the project is an internship activity in a university setting, I decided to conduct an ethnographic study in the high school class. It was my first time entering a foreign high school class and everything was eye opening. The first thing I saw while sitting at the back of the classroom taking field notes was the chalkboard on which there words were written densely in grids. These words occupied one-forth of the chalkboard and students often went to that area. "That must be something very important to the class," I said to myself. When I had a chance to approach the chalkboard (see Figure 4.1), I realized that each grid represented an opportunity for students to participate in some science context—after school, because this is a career preparation course that requires 100 hours of authentic science experiences over two years to complete the course. Their teacher introduced various activities, invited students to participate and wrote down the information on the chalkboard for students seeking further information. "What a unique course!" I thought. In Taiwan, most high school students only study hard to gain better grades and do not have a special course like this to encourage them to go off campus to explore. During the month in the classroom, the chalkboard always got my attention and invited me to check updated information about the exciting authentic science activities. It had become an integral part of my being in the classroom. My internship project, of course, was written in one of the grids on the chalkboard for career preparation students!

My purpose in entering the class before their arrival in the internship project was to understand the students and their class culture. The special chalkboard and its discourse begged to be investigated, because I realized that these high school students relied ONLY on the teacher's introduction and the information on the chalkboard to decide which activities to take. The special culture in the class provided me with a perfect opportunity to investigate how the teacher "introduced science" to her students. In fact, the "experienced" teacher had taught for 26 years and the high school students were "experienced" students who participated in various kinds of science activities and reported back to the teacher. The "introducing science" discourse in the classroom likely exemplified an "experienced" discourse that served to interest students in participating in science. Therefore, if I could understand how authentic science activities are introduced to interest students, it would help me to understand "how" a science introduction discourse encourages students to participate in the internship project. Furthermore, the special discourse in the class would likely exemplify a condensed version of science discourse that aims to interest and invite students into science activities for other science teachers and educators. Therefore, the big question I want to answer in this chapter is:

"How does an experienced teacher introduce authentic science activities to high school students?"

This chapter is based on collaboration with the following authors and has been accepted in the journal of Research in Science Education.

Hsu, P.-L., & Roth, W.-M. (in press). Introducing science: An analysis of teacher discourse that presents real science activities to high school students. *Research in Science Education*. DOI: 10.1007/s11165-008-9094-9.

Abstract

Most academic science educators encourage teachers to provide their students with access to more authentic science activities. What can and do teachers say to increase students' interests in participating in opportunities to do real science? What are the discursive *resources* they draw on to introduce authentic science to students? The purpose of this ethnographic and discourse-analytic study is to investigate the ways in which the activities of scientists are discursively presented to high school students in a biology/career preparation course. Data sources were collected by means of observation, field notes, interviews, and videotaped lessons in an eleventh-grade biology/career preparation course. Drawing on discourse analysis, I investigate the discursive resources—or, more specifically and technically, the *interpretative repertoires*—teachers used to explain and promote opportunities to engage students in real science activities. My analysis identifies and characterizes six types of interpretative repertoires: specialized, a-stereotypical, relevant, empirical, emotive, and rare-opportunity. To better understand the big picture of how these discursive resources are drawn on in the classroom, I also report on the frequencies of the repertoires in the discourse and the ways in which repertoires changed in the course of teacher-student interactions. The findings of this case study offer teachers and researchers with a better understanding of how specific forms of discourse—i.e., the interpretative repertoires—can serve as resources to enhance teacher-introduction of authentic science to students and provide students a bridge between school and authentic science.

4.1. Introduction

The American Association for the Advancement of Science (AAAS) and the National Research Council (NRC) suggest that K–12 science education needs to move beyond didactic instruction to a more constructivist, inquiry-based pedagogy that allows students to engage in "authentic," long-term science investigations (Soloway et al., 1997). The term "authentic science" generally is used to denote family resemblances with scientists' science (Uyeda, Madden, Brigham, Luft, & Washburne, 2002). "Authentic science" activities are important, it is claimed, in the promotion of inquiry, because they provide natural problem-solving contexts with high degrees of complexity (Lee & Songer, 2003). Science teachers are challenged to present students with opportunities to experience science as it "really is" rather than promote a mythic, textbook-based science (Martin, Kass, & Brouwer, 1990). Due to limited resources, however, there often is a gap between science as practiced (e.g., in university research laboratories and offices) and school science. How may this gap be bridged? The following example from my database illustrates the discourse Elizabeth (pseudonyms are used throughout), a biology and career-preparation teacher, used to encourage students to take up opportunities of participating in internship in real science settings. Elizabeth taught an honors biology class which also has the function of career preparation for students who want to be better informed about their career orientations and possibilities by participating in different kinds of science activities (e.g., science internships & fieldtrips). In an interview, Elizabeth articulates how and what she does to introduce these science activities to her students and to build a bridge between school and science in the outside world.

```
Interviewer: So how do you introduce the opportunities for THEM? So they will have
          the willing or: have the: um [DESI:RE want to]
Elizabeth: [well:, I tried to be] you know: I tried to be: enthusiastic and promote,
          whatever the opportunity is let them know, the benefits, what they can
```

> get out of it, and how much they will enjoy it those kinds of things like, so for instance the FOREST lab tour, forest lab doesn't have a whole lot of appeal, to most of them, doesn't, NO. so I mention, well there are a couple of guys there keep tarantulas in the office you know(.hhh) and you know, OR and they have an electron microscope up there.

In this interview excerpt, Elizabeth articulates her attempt at promoting real science activities by talking to students about the benefits and the joys such opportunities may provide. In this excerpt, Elizabeth also intimates knowing about student interests ("forest lab doesn't have a whole lot of appeal") and points out specific students' interests in particular activities ("guys keep tarantulas or have a electron microscope") that lead her to address those kinds of activities. From a discourse perspective, the teacher does not use language plain and simply but she draws on several *interpretative repertoires*, which can be defined as "forms of (shared) talking that discourse participants take for granted for buttressing their contentious and uncertain statements" (Roth, 2005, p. 323). Speakers draw on these resources presupposing both that they are understood and go unchallenged by the audience; that is, interpretative repertoires constitute ways of talking that speakers presume to be shared (unless, of course, the presupposition is challenged in and through interaction). Repertoires constitute something like "common knowledge" and "common sense." They often remain constant even if speakers defend radically different claims, for example, social constructivist and realist epistemologies; and the kind of repertoires that students use to talk about epistemology does not appear to change even when their epistemological position changes (Roth & Lucas, 1997). It is the shared nature of these repertoires that allows different speakers to take different positions and to defend them in ways acceptable by the opponent because they draw on the same repertoire.

The purpose of this study is the identification of interpretative repertoires in teacher discourse that presents science internship opportunities. That is, I am less interested here in *what* teachers like Elizabeth (a career-preparation teacher) claim but *how* they support these claims, in particular by means of interpretative repertoires. I achieve a better understanding of how an experienced teacher may utilize interpretative repertoires to introduce authentic science opportunities to students by (a) identifying the interpretative repertoires teachers use and by counting frequencies of these and (b) demonstrating the interaction by which repertoires change. Understanding the interpretative repertoires drawn on in school discourse to interest students in real science is important, as these constitute a possible bridge between where students currently are in their understanding and authentic science as practiced. This is so because these interpretative repertoires have to be intelligible to student audiences and have to interest them (a) in something they are currently not interested in and thereby (b) in going beyond their current positions and understandings.

4.2. Background

In this section, I briefly review science educators' interest in "authentic science" and the theoretical/method-related grounding in discursive psychology and discourse analysis.

4.2.1. Authentic Science

Authentic science has become an important term in the current science education reform movement, but what authenticity implies is often unclear (Rahm, Miller, Hartley, & Moore, 2003). Since a gap has been noted to exist between authentic (real) science and school science—though there are some notable exceptions (e.g., Roth & Bowen, 1995)—a major issue of any reform is the question of how to attract students' attention to participate in science *as it is* really *practiced*. The mediation of teachers' promotion of authentic science in school may be a way to bridge this gap, especially in contexts such as mine where students are provided with several internship opportunities among which they can choose as part of a career-preparation course integrated with their biology course. Because teachers are the front-line personnel in the educational system, what they say constitutes the resources for students to form first impressions and images of science. Over the past decades, researchers have become more interested in making authentic science accessible to students (Bencze & Hodson, 1999; Cunningham & Helms, 1998). Some research investigates how teachers use problem-based learning (PBL) activities in the classroom (Uyeda et al., 2002); other research creates software and resources for teachers and students to engage in more authentic science activities (Lee & Songer, 2003). These studies show how teachers use different strategies, tasks, or teaching tools to make science accessible to students in ways that bear family resemblance with science. However, little research has investigated systematically how teachers use language to introduce, describe, and promote opportunities for students to participate in real science at the very beginning and prior to an experience that allows students to spend some time with scientists at their workplace. This situation motivated my investigation of how *interpretative repertoires* (discursive resources) are deployed to introduce and promote authentic science opportunities in a science discourse.

4.2.2. Discursive Psychology and Discourse

In the past, psychologists typically treated language as a resource and a medium, providing clues as to what is going on inside people's minds. In experimental manipulations and procedures, language has been treated as a *neutral* means for getting at presupposed underlying cognitive states; the same is the case for science education research on conceptions and conceptual change (Roth, 2008b). Discursive psychology uses rigorous analytical procedures to examine how people deploy language to construct everyday life or institutional settings (Edwards & Potter, 1992). In discursive psychology, language is not considered to be neutral but essential to *how* views, beliefs, and attitudes are constituted in each situation (Edley, 2001). The term "discourse" here denotes all forms of talking and writing in context (Gilbert & Mulkay, 1984). Discursive psychology provides a novel account of the relationship between human psychology and shared discourse by inverting a traditional assumption: it focuses on how psychological phenomena are produced in talk rather than seeing this discourse as the product of these underlying psychological phenomena (Potter & Wetherell, 1987). Discursive psychology is concerned with bringing these contextual and peripheral phenomena into analytical focus to see how discourse accomplishes and is a part of social action.

Discourse Analysis Originating in the UK, discourse analysis is the study of how talk and texts are used to perform social actions; *discursive psychology*, also a British invention, is the application of ideas from discourse analysis to issues in psychology (Potter, 2003). Research questions in discourse analytic research typically take the form of "How is X done?," where X may be the mediation between scientific and religious discourses (Roth & Alexander, 1997); and the analyses of discursive work participants do focus on interaction, concrete settings, and process. Discourse analysts' interests have been in how mentalist discourses are constructed and used in interactions rather than in trying to explain actions as a consequence of mental processes or entities (Potter, 1996a). The core features of discourse analysis emphasize (a) *action orientations*, which discourage the one-to-one relationship between discrete acts and certain action verbs; (b) *situations*, which are sequentially, institutionally and rhetorically organized; and (c) *constructions*, which illustrate that discourse is both constructed and constructive. Discourse analysis is concerned with the sorts of discursive resources people draw on and what they *do with* language rather than with the content of this language and the (material, ideal [conceptual]) objects it denotes. Key theoretical principles in discourse analysis include: how discourse is constructed to perform social actions; treating content literally where the action is (rather than looking for cognitive entities behind the content); the rhetorical or argumentative organization of talk and texts; stake and accountability in social actions; and how cognition is played out in action (Potter & Wetherell, 1995). Furthermore, analyses are conducted by searching for patterns, sequential turns, deviant cases and other kinds of materials in verbal and written texts. The validation of analysis is established by focusing on participants' orientations, noting deviant cases, establishing coherence with earlier studies and considering readers' evaluation. The investigation of discourse therefore requires and presupposes the researcher's cultural competence in and with the situations where the talk occurs; they are then in the same situation as the participants who do not have to stop and interpret what has been said but take any utterance at its face value (Roth, Lee, & Hwang, 2008). Talk presupposes a lot of stage setting and unquestioned, mundane, and commonsense statements that function as background against which the talk becomes a salient figure. By using discourse analysis, I explicitly identify these unquestioned background utterances—interpretative repertoires.

Interpretative Repertoires The concept of interpretative repertoires first appeared in Gilbert and Mulkay's (1984) sociological study of biochemistry laboratories. These researchers found that natural scientists employ certain stable discourse patterns—interpretative forms and repertoires—but that these recurrent patterns are used with great flexibility to generate radically different accounts of social phenomena. Basically, an interpretative repertoire is a lexicon or register of terms and metaphors drawn upon to characterize and evaluate actions and events (Potter & Wetherell, 1987). Because discourse is designed *for* recipients, interpretative repertoires fundamentally constitute what speakers take to be discourse features shared with their audience. Interpretative repertoires denote forms of talk that discourse participants unquestioningly (a) take for granted for the purpose at hand and (b) draw on to buttress other aspects of talk that are contentious and uncertain. Interpretative repertoires are also part of any community's common sense and are available to the members of a culture, providing a basis for shared social understanding. They can be thought of as books on the shelves of a public library, permanently available for borrowing by the members of a discursive community (Edley, 2001). Interpretative repertoires are pre-eminent ways of understanding *how* the content of discourse is produced rather than what this content is. When two repertoires lead to contradictions, special *discursive devices* are invoked to resolve them. Thus, when in the same interview scientists say that science both reveals the truth *and* is contingent or subjective, then *the truth-will-out device* (Gilbert & Mulkay, 1984) allows them to talk themselves out of the contradiction.

Existing science education studies have utilized a discursive psychological orientation and discourse analysis to identify interpretative repertoires in different contexts, for instance, investigating science students' discourse of ontology, epistemology and sociology of scientific knowledge (Roth & Lucas, 1997), students' talk about physics concepts such as rotational motion (Roth, Lucas, & McRobbie, 2001), articulating environmental education designers' discourse about why and how they design environmental education (Reis & Roth, 2007), the interactive production of scientific identities (Lee & Roth, 2004), and producing conceptual change interviews (Roth, 2008b). Little is known, however, about the interpretative repertoires teachers use in the teaching of science; and even less is known about how teachers introduce or promote opportunities for participating in internships in scientific laboratories. Investigating interpretative repertoires—i.e., discursive resources—allows us to understand how discourse is used and how it reflects the contexts of communities, language, and common sense assumptions. By identifying interpretative repertoires in this study, I come to better understand the resources teachers may draw on in introducing students to authentic science activities for the purpose of getting them interested in science and science internships.

4.3. Study Design

Concerned with students who pursue science careers, the purpose of this ethnographic and discourse analytic study is to investigate the ways that scientific activities are presented in a high school biology and career-preparation course. In particular, I studied one honors biology and biology career preparation class for a one-month period. During that period, the class was observed every school day, the lessons were videotaped, and field notes were taken. As part of a larger study (not reported here), I conducted an ethnographic study that followed thirteen students from this class while completing their internship in a world-class science laboratory. Prior to and following the internship, I interviewed students about their career goals. In the present study, I mainly focus on the teacher discourse. Teacher discourse, however, is not to be understood as a singular phenomenon. Discourse is produced for an addressee and therefore is marked through and through by the understandings (meanings) of speaker and listener (Bakhtin, 1986). Therefore, because a teacher speaks to and *for the benefit of* N students, any teacher discourse has to be understood as a phenomenon characteristic of at least N+1 individuals (students and teacher). More so, the teacher does not only speak for the benefit of students, but also in view of their responses to her talk, which she must expect to be intelligible, thereby mediating the production of her own talk as intelligible on the part of the students.

4.3.1. Participants

In this study of discourse, I focus not on the individual human participant per se but on the use of language. Generalization therefore is not from a sample of people but from a sample of discourse assumed by speakers (here the teacher) to be shared with their audiences (here mainly students) for whom the discourse is designed and to whom it is directed. In my specific study, I focus on Elizabeth, the teacher of an eleventh-grade biology class and a biology career preparation course. Her discourse serves as an example for the kind of discourses teachers use in introducing science activities; this is a kind produced for and therefore implied to be understood by students. Because Elizabeth spoke to and for the benefit of her students, what she said and how she said it is not singular but implicitly shared with her students; a high degree of congruence of this assumption can be expected given that she has extensive experience teaching both science and career preparation courses. In the specific course researched here, there were 28 grade eleven students, 20 of them were career preparation students as well. That is, 20 out of 28 students in the classroom took both the biology class and the biology career preparation course (i.e., eight out of 28 students did not take the biology career preparation course but in the same biology class). The eleventh-grade biology curriculum was compressed into one semester during which students take the biology class for 1.5 hours per day during an entire semester.

At the time of the study, Elizabeth had been teaching for 26 years and was the head of the high school's science department. There were several career preparation courses in this school, including art, carpentry, human services, and music. The biology career-preparation course in this study was the only one of its kind in the mid-size city that related to fundamental science. The career-preparation course was funded by the school district, allowing the school to finance some student learning resources, including science magazines, microscopes, and bus tickets for visiting science laboratories.

In the biology and career-preparation course, Elizabeth drew on multiple practices including lectures, experiments, and demonstrations. She also used a variety of material resources to buttress her teaching, including videos, microscopes, dissection equipment, textbooks, overheads, chalkboard, and newspapers. For students who took career preparation course in particular, the teacher used a chalkboard to communicate information about off-campus science activities. That is, after announcing each opportunity, Elizabeth wrote the related information on the chalkboard for students to browse and sign up for. If students had an interest in a specific opportunity, they would write their names on the chalkboard or contact the teacher individually for further information (Figure 4.1).

Figure 4.1. Information about authentic science opportunities on chalkboard.

In addition to teaching eleventh-grade biology, Elizabeth arranged and conducted a variety of scientific tasks in which students could participate. Moreover, the career preparation students had to use extra school time (beyond the formal timetable) to participate in various science activities to complete the career preparation course, which requires 100 hours of engagement over a two-year period (eleventh and twelfth grade). Students usually relied on Elizabeth to get information about specific science activities and counted on Elizabeth's arrangements with the places where students might do an internship. However, students retained their full rights to decide where they want to do their internship after listening to the teacher's introduction to the different possible places/institutions/laboratories. Thus, Elizabeth's classroom talk was an *essential* resource in students' decision-making process concerning the specific internship that they chose to engage in.

4.3.2. Data Sources

As part of a larger study on learning about science in school and in real laboratories, I interacted with teachers and students for six months and videotaped more than 126 hours in different settings (e.g. school, science laboratories). The wider context set by these data sources provided us with the understanding of interpreting the 22 classroom lessons analyzed, which were taught by the same high school biology teacher; I also draw on interviews with the teacher and students. To explore the ways the teacher introduced authentic science opportunities, I examined the 22 tapes and identified those sections where Elizabeth introduced science activities to students. During those episodes, the discursive features of interest in the study occurred with particularly high frequency, though they also could be found elsewhere in the videotapes. From the field notes that were taken in the classroom, I found that these episodes usually happened at the beginning of a class, that is, the teacher introduced the science activities before she started to teach. These episodes relate to introductions of authentic science were exhibited in four kinds of activities: visiting a forestry laboratory, participating in a cancer research study, participating in a health expo, and taking part in an astronomy activity. These four science activities were separately introduced on different days and sometimes Elizabeth introduced one activity twice (i.e., forest lab [JAN 9], astronomy [JAN 11], visiting a health expo [JAN 9, JAN 20], and cancer research center [JAN 19, JAN 20]).

Episodes were transcribed using transcription notation adopting basic Jeffersonian system symbols (Atkinson & Heritage, 1984) and repeatedly read the transcriptions while conducting an open coding procedure. By coding and recoding these transcriptions, I found more reasonable and manageable chunks or patterns for analysis. These patterns of variation and consistency in a range of features allowed us to map the pattern of interpretative repertoires that the teacher was drawing on (Potter & Wetherell, 1995). I formulated tentative repertoires and descriptions and subsequently subjected these repertoires to peer review and public discussion with members of my research laboratory who were working on other research projects and did not have a stake in my project. I formed hypotheses of functions and effects in the discourse. I then tested these hypotheses about the interpretative repertoires in the entire dataset. During the repeated process of generating hypotheses and testing them by rereading the transcripts I ultimately derived the set of six interpretative repertoires presented here.

4.3.3. Credibility

In this study, discourse analysis makes it possible to explicate how Elizabeth deploys interpretative repertoires to introduce science activities to students in the classroom. Although I analyze mainly what the teacher says, her discourse cannot be isolated from the nature of her audience. Her talk is recipient-designed, which means, it is structured to be intelligible to students, whom she expects to act upon the talk and make choices; the forms of talk she deploys therefore have to be shared with them. Any features and structures of the discourse therefore are characteristic of the audience as they are characteristics of this teacher's talk and the possibilities for teachers to talk in career preparation courses generally.

To establish the credibility of interpretative research, besides finding coherence from earlier studies, I adopted several techniques from fourth-generation evaluation (Guba &Lincoln, 1989). To satisfy the criterion of *prolonged engagement*, I interacted with teachers and students for six months and went to school to observe the class every day for one month to build up a relationship of trust through participating in the classroom. Meanwhile, I took field notes in the classroom, talked to the teacher and students before and after class, and videotaped each lesson. These techniques deepened my study through *persistent observation*. By discussing research questions and findings with *disinterested peers* in my laboratory, I was able to test working hypotheses outside my research context. The gradually developing process of generating research questions and analyses allowed the study to satisfy the criterion of *progressive subjectivity* (i.e., the emergent nature of my claims). I also returned to the classroom to interview the teacher to conduct a *member check* of my findings.

4.4. Interpretive Repertoires Designed to Interest Students in Real Science

I designed this study to identify structural features in the discourse deployed during a career preparation course. Meanwhile, what the particular teacher (Elizabeth) said was intended for her students, though the latter may not have responded immediately, and therefore represents more general forms of talk presupposed to be suitable for its intended audience. Except in certain situations (e.g., students' surprise about the unlimited quotas in the cancer activity), students tended to listen to the teacher's introduction. This discourse, which can be understood as a "sales pitch" by means of which students come to be enrolled, was of interest to us because it is designed to generate students' understanding and interest in a variety of scientific career possibilities. In my analyses, I am not interested in identifying particular content or knowledge, such as, for example, the fact that a group of scientists uses an electron microscope or in one teacher's specific knowledge about it. Rather, I am interested in the kinds of interpretative repertoires used—those discursive forms that go unchallenged and are shared with the audience—in the descriptions of the various opportunities from which students can choose a site for their internship. Thus, if the mention of electron microscopes is used in the context of describing science as expensive and a laboratory as having access to (virtually unlimited) government funding, then it constitutes a particular discursive resource to describe science as specialized and professional.

In this study, I identify six interpretative repertoires, that is, discursive resources used in the promotion of authentic science activities; these repertoires exhaustively represent the teacher discourse over the 22 lessons observed. Each of these repertoires presents and constructs a particular dimension of science, that is, scientific knowledge-related activities are represented as (a) *special* and *specialized*, (b) *a-stereotypical*, (c) *emotive*, (d) *relevant*, (e), *empirical*, and (f) *rare opportunity*. In the following, each of these interpretative repertoires is described and illustrated. (I 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.)

4.4.1. Science Is Special and Specialized

The *interpretative repertoire of specialization* invokes technical, professional, specialized aspects of a particular field, community or ideology. In the study, Elizabeth frequently introduces particular scientific skills, knowledge, equipment, personnel, or environments to establish the specialized aspect of science activities. Episode 1 is part of Elizabeth's introduction to the opportunities of visiting a forestry laboratory. After the discussion with students about the forest laboratory research interests and the scientific working situation, Elizabeth summarizes several reasons for participating in the science activity.

```
Episode 1
01 there are a lots of interesting jobs though available in:um in:um
02 biological fieldwork. most of them probably government funded,
03 essentially. SO: the forestry lab is a federal government um la:b and so it
04 has the electron microscopes, you also: there are a couple guys out there, a
05 couple of: researchers who keep tarantulas, those are kind of fun to see, that
06 is just kind of a side issue. what I'm think about seeing theses, going on
07 these tours, um you get to see things like I just mentioned, but you get
08 to see what the workplace looks like if you were a scientist, a biologist
09 working for say the government um or the museum as we saw there on
10 the last tour.
```

In Episode 1, Elizabeth uses words like "a government-funded forestry lab" (1:03), professional scientific equipment "electron microscopes" (1:04) and "researchers" (1:05) to support her to produce descriptions that have the potential to be resources enabling students to visualize what they would see if they were to go to the science-related site denoted. I called these chunk of words as part of specialized repertoires, because they indicate the specialized or professional aspects of science. For instance, when Elizabeth establishes the special nature of the laboratory by emphasizing that it is a government-funded laboratory. These words indicate that the laboratory is a special organization (as supported by a powerful organization, the federal government) where students would see electron microscopes—the expensive and high technology aspect of the laboratory. To further encourage students, Elizabeth also uses specific terms for enrolling students to see themselves as specialized personnel "scientists or biologists" (1:08) working for specialized organizations such as "the government or museum" (1:09) or in a specialized field "biological fieldwork" (1:02). These terms all demonstrate the specialization of science as a way of supporting Elizabeth's promotion. Furthermore, in Episode 1, Elizabeth also uses an *a-stereotypical repertoire* (see more detail in the next section) for introducing the science activity to students. Although she mentions the a-stereotypical aspects of the science activity "a couple of researchers who keep tarantulas" (1:05), using something of general interest to spike her discourse, she also emphasizes that this is "just a kind of a side issue" (1:06). "Side issue" suggests that there are more important things to see and that those would be the specialized aspects of the science activity. Here, Elizabeth uses two kinds of repertoires to introduce the forest laboratory; one (the specialized repertoire) invokes the professional aspects and the other one (the a-stereotypical repertoire) invokes unusual aspects of science. However, she utilizes a discursive device *just-a-side-issue* to privilege one repertoire over the other and solves the tension.

4.4.2. Beyond Lab Coats: A-stereotypical Science

The *a-stereotypical repertoire* invokes unusual, exceptional and unaccustomed aspects of a particular objective. In the study, Elizabeth describes possible exceptional characteristics of science activities to articulate fun and surprises students possibly may have while spending time in the laboratory. As she introduces the visit to the forest laboratory as part of Episode 2, Elizabeth especially points out human social situations. The very fact that she articulates this point also makes it stand out as something special, allowing students who have not thought of scientists as normal human beings having social interactions to note this issue.

Episode 2

and also you get to see these people in their, sort of social situations as well, so I'm saying they keep pet tarantulas. so you get to see these people as human beings right. who have their quirky senses of humor and you know that kind of thing, right, so sort of beyond the lab coat and the Einstein hair and stuff, to see scientists as people.

The general public tends to think of scientists as neutral, objective, professional, and intelligent persons who investigate nature and do not frequently interact with other people. Special events such as the conferral of the Nobel Prize to individual scientists only lend themselves to support such a view, as this event only significantly acknowledges individuals' contributions. From Episode 2, the social interaction in the laboratory is addressed. Elizabeth sketches the human side of scientists and concretely describes their everyday personalities by talking about "their quirky sense of humor" (2:03) or about the keeping of pets ("they keep pet tarantulas" [2:02]). That is, having a sense of humor and owning pets are characteristics of ordinary people but are not common in the stereotypical images of scientists, who generally are portrayed to be dispassionate rather than having "feelings for the organisms," as the study of Barbara McClintock life and work suggested (Fox-Keller, 1983). Elizabeth reminds students to see beyond the typical image of scientists "sort of beyond the lab coat and the Einstein hair and stuff" (2:04) and encourages students to rethink what they believe about scientists. In the interview at the beginning of the chapter, Elizabeth states that she knows visiting a forest laboratory does not appeal to students, so she describes people in the laboratory as keeping pet tarantulas to emphasize the unusual aspect of a science lab. That is, this form of discourse is designed to address students' interests when they likely are indifferent to visiting a laboratory.

Here, Elizabeth breaks the commonsense, stereotypical image of scientists by describing personification and reference to individual human beings and their actions. In fact, students tend to pay more attention to what teachers are saying when their teachers break *stylistic norms* such as science's infallibility and its opposition to common sense (Lemke, 1990).

4.4.3. Fun and Enthusiasm in Science

The *emotive repertoire* invokes personal comments and emotions. In the study, Elizabeth uses many emotion-related terms to convey the value of science opportunities. For example, in Episode 3, she introduces an astronomy activity in which students get a chance to write a proposal for going to an observatory; Elizabeth constantly uses emotive words to buttress her introduction and promotion.

```
Episode 3
01  so this will be a FABULOUS opportunity to just get the glimpse into how that
02  process works. so you will be writing a proposal as a group, to get a access
03  to the observatory for the observing time, and then what you will be doing,
04  is um: tracking asteroids. right, so this sounds very interesting.
```

Here, Elizabeth uses expressions "a fabulous opportunity" (3:01) and "this sounds very interesting" (3:04) to promote this particular opportunity. These affective words and personal comments provide opportunities for students to have positive feeling about these science activities. Especially these comments are from the teacher—Elizabeth who is an experienced teacher exhibits proficient understanding of and about science. The emotive repertoire produced in a way is hardly challenged, as the nature of the people's feelings and emotions is personal and so barely questioned by others (Reis & Roth, 2007). Further more, teachers who are enthusiastic and interested, and who speak of the beauty of scientific understanding instill in their students some of those same attitude (National Research Council, 1996). Thus, the emotive repertoire serves as a direct form of illustrating these positive features of science activities and may invoke enthusiasm in and passion toward science in the students.

4.4.4. Science Is Relevant to Us

The *relevant repertoire* invokes the closeness and relevance of science to the student audience. Throughout her teaching, Elizabeth draws on this repertoire that relates science laboratory activities to students' daily life, future life, important issues of their friends, relatives and the surrounding environment. When introducing the opportunity of visiting a cancer research center, for example, Elizabeth accentuates the relevance of cancer to these high school students.

```
Episode 4
01    so the: cancer research center that we have here in Victoria, it's very new,
02    been around for a couple of years, doing cutting edge research in cancer.
03    it is a big topic in bio twelve, so you will get some um: you know,
04    in depth knowledge they are really help you there.
05    Um and also a focus of topic that's a concern for most people.
06    most people know someone who has cancer, this type of cancer.
```

Elizabeth uses discourse that demonstrates the value and usefulness of participating in science activities to address their relevance to students. This discourse connects the participation to students' neighborhood "we have here in Victoria" (4:01), students' future life "a big topic in bio twelve . . . that will really help you there" (4:03–04), and typical students' concerns "that's a concern for most people" (4:05). By using "here" in the first sentence (4:01), the discourse employs the *toponym* (linguistic term for name of place, region) "Victoria" (4:01) to emphasize the nearness of the cancer research center. Thus, the distance between students and the center becomes less alienating and more relevant to students. Furthermore, by deploying "big" in the third sentence (4:03), the discourse draws on relevance by relating knowledge of the activity to students' subsequent twelfth-grade biology course. That is, the value of the activity is articulated to be very relevant to students. Elizabeth exhibits knowing the content of biology course for the twelfth grade ("it is a big topic in bio twelve" [4:03]]), consistent with her status as the twelfth-grade biology teacher. By having the opportunity to see the relevance, her discourse provides the students with more descriptions of the value and benefits of participating in the opportunity.

4.4.5. Sciences Are Empirical Disciplines

The *empirical repertoire* invokes actions, practices and technical experience of the audience (students). In the study, Elizabeth draws on this repertoire while deploying experiential words to help students imagine possible actions and experience they may have in the activity. During the introduction of the cancer research opportunity, Elizabeth points out the possibility of hands-on activity to the students.

```
Episode 5
01    this workshop will include hands on lab opportunity right,
02    so you're gonna do research in the enzyme digest lab,
03    so, this is just technique that is commonly used um: when you study DNA
04    ok so that would be a really neat opportunity
…     …                                                    (continued)
05    so it will be presentation, and workshop, and lab, you know so a four hour
06    opportunity to really learn some more about DNA, about lab techniques,
07    working with DNA, actually doing the technique, and learning more
08    about: um cancer from, you know the place here, one of the top of
09    research facilities probably in the world, that's why we want it here
```

In Episode 5, an empirical repertoire promotes the opportunity. Elizabeth frequently draws on this repertoire by using experiential words to deliver her introduction of science activities ("a hands-on lab opportunity" [5:01], "do research" [5:02], "a technique that is commonly used" [5:03]). She names and thereby highlights actions and practices in the activity which students would experience to convey the value of participation. It can be noticed that in Episode 5, Elizabeth uses only three sentences to introduce the hands-on opportunity and makes the positive comment "a really neat opportunity" (5:04) quickly at the end. The concept of "hands-on" articulates a strong positive sense in itself, allowing Elizabeth to move quickly to a positive conclusion. After Elizabeth reports administration issues of the science activity, she summarizes the value in the opportunity. In the adscript section of Episode 5, Elizabeth draws on the repertoire to emphasize again the actions and practice in the activity "working with DNA" (5:07) and in "actually doing the technique" (5:07). Here, Elizabeth uses high modality to strengthen the advantage, such as by stating that students could "really" (5:06) learn some "more" (5:06) about DNA, by "actually" (5:07) doing the techniques and learning "more" (5:07) about cancer. The high modality indicates and emphasizes the very authentic value of hands on activities in learning science.

4.4.6. Rareness of Science Opportunities

The *rare-opportunity* repertoire invokes rareness, uniqueness, and scarcity of opportunities to experience authentic science first hand. In the study, Elizabeth draws on this repertoire to articulate the opportunities offered to them as uncommon and precious. When introducing a cancer research opportunity to the students, the repertoire allows Elizabeth to point out the process of negotiating the time of the opportunity with the researchers.

```
Episode 6
 E:  01  ok, so just: an opportunity I'd like to extend to everyone in the class
 S:  02  OH:::?
 E:  03  for career prep practically um: um:, to get a good experience here
     04  and four hours, so the cancer research center that we have here in
```

05 Victoria, it’s very new, been around for a couple of years,
06 doing cutting edge research in cancer.
… ………. (continued)
07 so it is not a school day, um and it’s not a Pro-D day either, um
08 but that’s the only way I could fit the four hours lab opportunity like
09 that, I wanted to do it on Friday afternoon like we do other things,
10 but they don’t want to stay that late, starting at one thirty, they
11 didn’t want run to five thirty. so this is the best way I could do,
12 to take the advantage this opportunity. ok?

In this discourse, the rareness of the activity might be contributed to by students’ conditions (e.g., career prep or not), the rare science opportunities from science communities, and the teacher’s efforts in negotiating time. Usually, the “authentic” science activities were offered only to career preparatory students rather than non-career preparation students in the class because of the limitation of resources and quotas for participants implemented by the science communities. But this time, the opportunity of participating a cancer research was open to all students “I’d like to extend to everyone in the class” (6:01) and Elizabeth articulates for the students that she had tried her best to negotiate the time and space (6:07-11) to fit most students (“So this is the best way I could do to take advantage of this opportunity” [6:11-12]). For the non-career preparation students, the science opportunity is more unique, rare, and infrequent. So, one non-career prep student responds to the opportunity by saying “oh” (6:02) with extended and raised pitch exhibiting to everyone surprise and unexpectedness for the rare and precious opportunity. That is, the rare-opportunity repertoire provides resources for catching students’ attention, and in this situation, the student takes this opportunity as unusual event for him as a non-career preparation student. Meanwhile, the science research itself is very “new” and “cutting edge” which are articulations of the recentness of this particular science activity; it therefore is likely to provide an unusual learning opportunity for students (6:05). In the rare-opportunity repertoire, the teacher promotes science activities in a way that encourage students to take advantage of this precious opportunity because of their rareness and uniqueness.

4.5. Interpretative Repertoire Changes In and Through Interaction

In daily life, interpretative repertoires are used spontaneously and interactively instead of fixedly and firmly; the use of repertoires may be changed with changing context. For example, the interaction between students and teacher might mediate the teacher's use of repertoires. Thus, in the present study, after the introduction of a health expo activity, two students participated in the activity and provided the teacher with feedback. Afterwards, Elizabeth talked about the activity again and drew on a different repertoire to convey the value of the activities. In Episode 7.1 and Episode 7.2, I notice a discourse that advances the same science activity from different spatiotemporal situations by using different kinds of repertoires.

Episode 7.1

```
E:    01   um: ya so two students went yesterday to this um: what sounds like
      02   a really good opportunity super size your health, and annual health
      03   expo for students by students that, commonwealth place yesterday,
      04   and it turned out to be::: not very good ((Elizabeth laughs))
S-A:  05   really?
E:    06   so::: again organizing a big conference like that, you know, it's
      07   not easy, but it sounded like it would be pretty good. they had a
      08   kinesiologist, there were biofeedback and all these you know good
      09   sounding topics and so on, but apparently just was not well
      10   organized: to be really the educational
S-B:  11   It was good but for a younger age group
E:    12   okay so all right for a younger age group ok
```

Even though the activity had finished already, the teacher still mentions it in front of the whole class. In Episode 7.1, Elizabeth frequently draws on the emotive repertoire to introduce the science activity of the health expo, for instance, “a really good opportunity” (7.1:02), “it would be pretty good” (7.1:04), and “good sounding topics” (7.1:08-09). Meanwhile, she also draws on the specialized repertoire at the beginning, for instance, “super-size your health” (7.1:02), “annual health expo” (7.1:02), and “they had a kinesiologist” (7.1:08). Then the student comments that the activity was good but more appropriate for a younger age group (7.1:11), drawing on the emotive repertoire (“It was good” [7:11]) to exhibit the positive side of the activity and on the relevant repertoire to deliver the negative message (“for a younger age group” [7:11]). The student says that the activity is not appropriate for high school students but would be relevant for a younger group. When the teacher receives the negative evaluation from the student “Okay so for a younger age group . . . okay . . .” (7.1:12), she still re-articulates salient issues in ways that convey the values of the activity, as shown in episode 7.2.

Episode 7.2

1 if you have already committed your time to it, sometimes you can,
2 you know go in and get what you can out of it right? or just learn
3 other things what you expect to learn right? like learning
4 in this case about, you know what are some other thing that could
5 go wrong when people put a conference on, and that’s a actual
6 activity that some of you, in you work places in the future maybe
7 involve in is actually organizing and putting on a conference too
8 so there is another you know learning experience to take away in the back of
9 your mind for, sometime when you may be involved in doing that.
10 um and not especially your professional life but sometimes
11 they were um other outside activities you do, volunteer work you
12 do, or hobbies or interests you have are often involved in a conferences

`and stuff like that, so you know, sometimes you can manage to salvage something even from what initially seems like a real disappointment.`

In Episode 7.2, Elizabeth draws on the relevant repertoire, which provides opportunities for students to reflect on the learning experience in the science activity and thereby to remind them that although they did not get what they expected from the science activity, they could still take something away from the experience (7.2:8). She provides examples in saying that in the future they may participate in some conferences (7.2:7), other outside activities (7.2:11), volunteer work (7.2:11) or hobbies and interests (7.2:12). Students could learn how to organize them, learn about why things could go wrong (7.2:5). This discourse is a potential resource for students to connect these activities to their future life and it articulates ways for the students to relate to what they have learned from the activity.

Despite introducing the same science activity to students, Elizabeth draws on different repertoires in articulating the values of the science activity in different situations. In Episode 7.1, emotive and specialized repertoires are deployed, but in Episode 7.2, the relevant repertoire buttresses the value of the science activity. From the two episodes, I learn that the use of repertoire is not fixed but spontaneous and situated, not unidirectional but interactive. Teachers talk and act differently because or when they realize new possibilities in changed positions.

4.6. Interpretative Repertoire Frequencies

One of the limitations in analysis of interpretative repertoires is that it is difficult to make clear and consistent judgments about the boundaries of particular repertoires (Potter, 1996a). To overcome this limitation and to advance discourse studies, I draw on a linguistic method to help define the boundary of interpretative repertoires. In this study, I rely on counting *times* and *clauses* in the introduction of each science activity to illustrate the frequency of each repertoire in the discourse. The method of counting times and clauses is described and exemplified in the following paragraphs.

After identifying these six repertoires in the study, I counted the repertoire frequency during those approximately 20-minute periods specifically designed to introduce each of the four sites that could provide students with internship opportunities. The unit of repertoire is based on continuity of repertoires that might be composed of one or several clauses (that were defined through a linguistic theory as introduced in the following section). If another interrupted a repertoire, I counted them as different repertoires. The boundaries of an interpretative repertoire could be another repertoire or no repertoire discourse. Sometimes different repertoires occurred frequently within 20 seconds; in other cases, none of the repertoires described were mobilized in an episode of the same length. For instance, when Elizabeth discussed administration issues or classroom behavior management, none of the interpretative repertoires were featured. A summary of the frequency of repertoires in each introduction of science activities is illustrated in Table 4.1.

To better explore understanding of the efficiency of repertoires, I adopted Michael Halliday's Systemic Functional Linguistic (SFL) theory to assist my analysis. SFL is extensively applied as a research tool in many disciplines, such as reading development, classroom dialogue, social class hierarchy, social culture, social language and social gender research (Unsworth, 2000). Drawing on SFL, I identified and distinguished all kinds of clauses to calculate the clause units in the discourse. A clause is a pattern of wording built around a verb (Unsworth, 2001). Clauses beginning with conjunctions like "when" and "because" are known as dependent or subordinate clauses and clauses without conjunctions are known as independent or ordinate clauses. For example, there are three clauses in the sentence "When the weather is sunny, he likes to go out and play with friends." "When the weather is sunny" is a subordinate clause, while "he likes to go out" and "and play with friends" are ordinate clauses.

Table 4.1. Frequencies of interpretative repertoires used in introducing four science activities and students' participation in each activity.

Science Activity	Forest lab		Health expo		Cancer		Astronomy		Total		
Regulations of Activity	8 quotas, No charge, After school		No limit quotas, No charge, School time		No limit quotas, No charge, After school		No limit quotas, Charge, After school				
Participation(N)	8 (5 waitlist)		2		14 (initial 22)		0				
Episode time	7.30 min		4.22 min		4.45 min		2.43 min		19.20 min		
Clauses (N)	111		59		81		53		304		
Repertoires	clauses	times	clauses	times	clauses	times	clauses	times	clauses	times	C/T
1.Specialized	77	13	14	10	17	11	16	9	124	43	2.89
2.A-stereotypical	6	2	0	0	0	0	0	0	6	2	3
3.Emotive	2	2	4	4	3	3	5	5	14	14	1
4.Relevant	3	3	12	3	6	4	8	2	29	12	2.42
5.Empirical	0	0	0	0	4	2	3	2	7	4	1.75
6.Rare-Opportunity	0	0	2	2	15	7	0	0	17	9	1.89
Total	88	20	32	19	45	27	32	18	197	84	(Average) 2.35

There are other clauses as well. For example, clauses containing verbs that indicate tense are called finite clauses, whereas those that do not indicate tense by their verbs are known as non-finite clauses. For example, in the sentence "To achieve the goal, he worked very hard," "to achieve the goal" is a non-finite clause; "he worked very hard," which indicates past tense by the verb "worked" is a finite clause. Furthermore, some clauses are interrupted by other included clauses. For instance, the sentence "the bird, having yellow feathers, leaped on the ground for a while and then flew to the sky" contains three clauses: "the bird leaped on the ground for a while"; "having yellow feathers"; and "and then flew to the sky." These explicit and consistent rules of identifying clauses help me define the boundaries of interpretative repertoires, as now I have clear and the smallest units—clauses that make it possible to differentiate different units of repertoires. Take, for instance, the sentence “the activity is fantastic, valuable, relevant to your study and interesting.” If I did not have clauses as units, it might be confusing to note how many times that repertoires happened in the sentence (in terms of 6 identified repertoire categories). Should I repetitively count these different emotive words or should I count only one time for these emotive words, as they are all in the sentence? Whereas if I followed SFL and deemed this sentence as a clause, then I can easily identify that repertoires happened two times in the sentence because a clause is my smallest unit. Therefore, based on the rules in SFL, I counted the frequencies of clauses and repertoires as illustrated in Table 4.1.

Speakers often draw on a number of different repertoires, flipping between them as they construct the sense of a particular phenomenon or as they perform different actions (Potter, 1996a). In Table 4.1, I note that the specialized, emotive and relevant repertoires all occurred in the four science activity episodes (Forest lab, Health expo, Cancer Research and Astronomy). Among them, specialized repertoire occurs most often (124 clauses and 43 times). According to the highest frequency, I find that the teacher constantly describes professional and technical aspects of science in the classroom as the most frequent way of introducing science. It is also noteworthy that the emotive repertoire is used in a very economical way in the four episodes; it is included in only 13 clauses for thirteen times with the lowest rate of clauses and times (C/T = 1). In examining the details of each science activity interaction, I note that the teacher used only one clause to express feelings or comments about the science activities. Using emotive repertoire here demonstrates the economical aspect of the teacher’s introduction of the science activities. The relevant repertoire also appeared in the four activity episodes but was less economical, with the high rate of clauses and times (C/T = 2.42). That is, the teacher uses more clauses to support her talk about the relevance of the activities to the students’ lives. As Table 4.1 shows, the a-stereotypical repertoire had the lowest frequency; it only appeared in the introduction of visiting the forest lab. The a-stereotypical aspect of science seems not to be a central point for the teacher to deliver, but just a side value (1:06) for students during the science activities.

4.7. Students' Registrations and Articulations of Registering A Science Internship

To better understand possible relations between the teacher's introduction and students' participation in these science activities, I collected information about students' registrations of these science activities and conducted interviews to understand students' explanations of participating in a science internship. Here I understand relations to be not of the causal kind. Rather, human beings make decisions on specific grounds; they have *reasons* for acting in one rather than in another way. These grounds or reasons *motivate* their actions (Holzkamp, 1993). Interpretive repertoires provide such grounds, as they allow students to say, for example, "I went to the Cancer research center *because* you don't often get such an opportunity" (rareness of science opportunities).

Table 4.1 summarizes information about students' participation in these four science activities. From the first row, we can see that there are different activity regulations such as quotas limit, charge requirement and different time (in school or after school time) for participation. Comparing students' participation in these four activities, we can see students' enthusiastic participation in visiting a forest laboratory. Because in addition to eight student registrations, five students wanted to be on the waiting list for getting the chance to visit the forest laboratory. I cannot and do not attempt to conclude causality concerning students' participation from repertoire use but recognize their role as rationales in student explanations why they chose one over another opportunity. Table 4.1 therefore illustrates the important roles of specialized and a-stereotypical repertoires. Because the specialized repertoire is the most frequent repertoires (13 times and 77 clauses) used by the experienced teacher. Meanwhile, many students registered the activity of visiting a forest laboratory (8 students registered and 5 on the waiting list) that was introduced by the a-stereotypical repertoire—the only appearance among these four activities. As supported in the teacher's interviews (the beginning of the interview episode), the unusual or uncommon aspects of science often attract her students' attentions (i.e., “forest lab doesn’t have a whole lot of appeal to most of them, so I mention, well, there are a couple of guys there keep tarantulas in the office you know”). This finding is in accordance with the assertion that students pay more attention when teachers talk against stylistic norms (Lemke, 1990), such as when Elisabeth draws on the a-stereotypical repertoire.

Second, from the individual interviews with 13 students before they went into a science internship in a university-based biology laboratory (i.e., research in drinking water), I asked questions like “Why do you want to participate in this science internship? How do you feel about your participation in this internship? What do you expect from this science activity?” In a similar way, students were presented with the science internship information mainly from the teacher introduction. Thus, what students said in the interviews reflected their teacher’s introduction in the classroom discourse, as it is the main source for students to know about these particular activities: They reproduced words and genres of the teacher’s discourse for their own intentions and thereby produced and reproduced these genres as cultural-historical phenomena (Bakhtin, 1986). Although students provide their explanations about why they want to participate the internship, I am not interested in their “reasons” of participations but how they articulate their reasons (grounds for actions)—how do they draw on interpretative repertoire (i.e., the shared discursive resources in the classroom) to help answering these questions.

In the interviews, 11 out of the 13 students articulated their motivation of participating in this internship with emotive repertoires. That is, using emotive words and comments to explain “I think it is really cool,” “I’m excited about it,” ”I expect it will be interesting and fun to figure out what is going on.” Eight students articulated their reasons of registration with specialized repertoires to emphasize the specialized aspects of science “you are actually going to be with scientist, so actually seeing what it is,” “I want to see what it is like to work with scientists and everything.” Five students used relevant repertoires to relate the science activity and their personal interest “Personally it will give me a really good experience, because it will actually let me know if I want to go into biology, like major in something like being a doctor.” Five students drew on empirical repertoires in their reasoning to stress the value of hands on and doing science

"I also really want to find out about the water, and the minerals in our water and things like that so I am really excited to be doing that." Finally, four of these 13 students also drew on rare-opportunity repertoires to highlight the advantage of the precious opportunity "It is interesting and I should go to it, because I have the opportunity right, so I think I want to go to take advantage of the situation." Here, I find that no student used a-stereotypical repertoires to articulate their registration. This might be related to the content of the individual interviews where students tried to convince the interviewer to recognize their science related articulations and so not mentioning the a-stereotypical aspect of science.

From students' registrations in these four science activities and the teacher' interviews, I take that specialized and a-stereotypical repertoires may serve as important resources for gaining students' attention about these science activities. From the individual interviews with students, I take that specialized and emotive repertoires are the two most frequent resources used by students to articulate their motivations of participating in these activities. This phenomenon is consistent with the frequent repertoires (specialized and emotive repertoires, see Table 4.1) drawn on by the teacher in the classroom. Thus, the findings shows that the specialized, a-stereotypical, and emotive repertoires of science activities served as salient components in the introduction of science discourse.

4.8. Conclusion

This study was designed to better understand the discourse deployed to interest students in real science activities. Through an investigation of the interpretative repertoires on which these discourses drew in one classroom, I find that the teacher's promotion of authentic science not only is stated explicitly but also is delivered implicitly by different unquestioned repertoires. My study shows precisely how a teacher may deploy a variety of interpretative repertoires—a discourse genre—to bridge authentic science opportunities to students. In this study I identify six interpretative repertoires: science (opportunities) as specialized, a-stereotypical, emotive, relevant, empirical, and rare-opportunity. Each repertoire invokes a different dimension of science. These repertoires are important, because they constitute *generalized* cultural patterns, ways of talking, rather than individual patterns: speakers do not have to defend them, but use them in support of their claims in each situation. They therefore provide resources for grounding decisions in ways that are intelligible and comprehensible to others, especially when individuals are asked to *account for* their decision-making and acting. To be able to function this way, these repertoires have to exist for all participants (Roth, 2005). That is, these repertoires are intelligible and exist in the culture of the classroom that is shared by the teacher and students. Therefore, the teacher's talk about authentic science never entirely is her own; the talk presupposes its intelligibility and therefore also the shared nature of the repertoires. Furthermore, from the interaction between the interpretive repertoire and the students' responses, I found that interpretative repertoire is spontaneous, interactive, and contextual. Although introducing the same activity to students, Elizabeth utilizes different repertoires to support her presentations in different contexts.

The counts of interpretative repertoire frequencies illustrate the different efficiencies of different repertoires. For instance, the emotive repertoire, which used the lowest frequency of clauses (C/T = 1), is a more economical resource, but specialized, a-stereotypical and relevant repertoires took more space and effort to articulate (C/T > 2.35). In addition to the data from the teacher's science introduction, the information from the teacher interviews, students' registrations, and students' explanations for participating in a science internship also indicate that specialized, a-stereotypical, and emotive repertoires are salient components in the discourse about authentic science. The teacher's introduction to authentic science in a career preparation course, the only one of its kind in the city, allowed me to collect rich data on interpretative repertoires and the mundane and commonsense assumptions which exist in daily life. That is, because I am interested in language *use* rather than in particular opinions or views, a large number of linguistic patterns are likely to emerge from a few people, small samples are generally adequate for investigating these phenomena (Edwards & Potter, 1992). Furthermore, thick description increases the transferability of the study to new situations (Guba & Lincoln, 1989).

My study illuminates interpretative repertoires for introducing authentic science to students. The results may be of interest to teachers aiming at increasing the participation rates in science among their students. After the analysis, I returned to the classroom to check my categories with the teacher. She articulated interest in how she actually talked to get her students involved in the experiences in the laboratories of science.

> I found it was interesting, the analysis of my- um of what I was doing with the students because I wasn't thinking of course:, uh um I hadn't a time about, exactly HOW I was getting a message across but I was very, I'm always conscious to get the message across. . . . So it was interesting to see how things that I, things. that I learned to say out of their experience, um how those can be analyzed and labeled you know has particular um. You know categories of: of: conversation, or DISCOURSE yea: so it was interesting.

In this quote, Elizabeth articulates being conscious about *what* she said but not aware of *how* she said it: "it was interesting to see how things I learned to say out of their experience." Elizabeth thereby indicates that teachers need to learn how to introduce these science activities to students and need to practice saying out of students' participating experiences. Consistent with her many years of experience, Elizabeth articulates arranging all kinds of science activities for students to participate in and receives much feedback about their experiences from students. These experiences give her chances to learn, practice, and improve what and how she introduces these science opportunities. Therefore, the experienced teacher's discourse in the study provides many valuable resources for science teachers in general and beginning teachers in particular to introduce authentic science, as Elizabeth her self spent many years to learn.

How may the finding be applied? Studies with beginning science teachers, show that they find it helpful to post large signs (e.g., "justify," "elaborate," and "explain") posted somewhere in the room to support new teachers in using them (Roth & Boyd, 1999). Likewise, the findings in this study provide key repertoires for new teachers to post in the classrooms and further draw on them for introducing science. Thus, teachers may not have to think about all the different aspects of talking they actually want to employ, but in terms of the repertoires. These are limited in number and may constitute something like master switches that allow the teacher to talk about relevant aspects, for example, without having to plan what she says at the sentence level. Some possible images established through these interpretative repertoires also need attentions because of repertoires' shared and cultural nature. For instance, in this study, the most frequent repertoire drawn on by both the teacher and students (probably dominant in the cultural)—specialized repertoires—represent science as a technical, professional activity that is distant with everyday activities and alien to students. To reach the goal of enculturating students into authentic science, we should be aware of providing thorough information to students. Especially science educators found that students have numerous misunderstandings about the nature of science (Bell, Blair, Crawford, & Lederman, 2003) as do teachers. My findings illustrate different repertoires that represent different aspects of science communities, thus more complete images of science may be achieved by drawing on different repertoires and not just the dominant one. Meanwhile, identifying these cultural possibilities of repertoires use in classrooms also serves as a form of assessment for investigating the possible images of science established in the classroom discourse.

CHAPTER 5: TO BE OR NOT TO BE? DISCURSIVE RESOURCES OF (DIS)IDENTIFYING SCIENCE-RELATED CAREERS

Preface

Preparatory to students' arrival in the internship project, I wanted to investigate students' career orientation towards science because one of the objectives of the internship is to understand whether it had any effect on students' decision to pursue science as a career. Most of the previous studies about students' career orientation used conventional methods and psychological categories to detect their attitude. They used questionnaires or tests to identity "factors" that influence students' career choice. However, these methods are not without their critics. Thus, I decided to use the same method as in the previous chapter. In chapter 4, I had identified interpretative repertories to understand the "introducing science" discourse. These interpretative repertoires had provided concrete resources for others to learn and to use; and the teacher used them because they are (recipient-) designed for the students and therefore supposed (implicitly or explicitly) to make sense to them. Thus, to investigate students' career orientation, I decide to identify interpretative resources when they talked about their career choices in semi-structured interviews because they serve as concrete resources for us to understand the way students articulate their "career choices." They teach us how to talk about science careers in adolescents' language if necessary. Therefore, the main question I investigate in this chapter is:

"How do high school students articulate their preferred and dispreferred science-related careers?"

Remarks: The individual interviews with students not only taught me about their science-related career discourses, but also provided a wonderful opportunity to learn about their personality, their views on the internship project, and even whether they were comfortable with the camcorder. My first interviewee was Candy who was the first volunteer for these individual interviews. Her laughter and enthusiastic voice warmed up the interview atmosphere and helped me to know more about her good friends (e.g., Kelly). The close interaction and friendly conversation in interviews became a bridge between students and myself. Students had a chance to learn about me and I had a chance to understand their culture and discourse. Thus, when I needed to choose some students as my focus group (e.g., for chapters 6 & 7), the interactions in these individual interviews gave me a better sense to select students who were more comfortable with the camcorder.

This chapter is based on collaboration with the following authors and has been submitted to the Journal of Research in Science Teaching.

Hsu, P.-L., Marshall, A., Roth, W.-M., Guenette, F. (submitted). To be or not be? Discursive resources of (dis)identifying science related careers. *Journal of Research in Science Teaching.*

Abstract

One of main objectives in science education is to enroll students into science majors and careers. Many researchers have investigated high school students' career choices or studied the difference gender makes in learning science and choosing science as a career. However, few investigations exist that have studied the ways in which high school students articulate their possible careers generally and the way they ground (justify) these possibilities particularly. Because discourses tend to mediate human behavior, this study focuses on the justifications are done drawing on interpretive repertoires, that is, forms of talk that for the purposes of the conversation at hand are taken as uncontested. The purpose of this study is to identify the interpretative repertoires high school students draw on when asked about career choices and to articulate the relation between interpretative repertoires and students' identities in science-related careers. Thirteen high school students were video recorded in interviews lasting 40–60 minutes. To encourage students' engagement in thinking about their possible career choices, I used a mapping task to explore high school students' science-related career aspirations. Drawing on discourse analysis as method, I found that these high school students' career aspirations are not only stated explicitly but also delivered implicitly by means of different repertoires. In the study, I identify four interpretative repertoires: the (a) formative, (b) performative, (c) consequent, and (d) potential repertoire. Each repertoire exhibits different ways in which students envision science-related careers. Thus, through this study, I better understand how students construct their science-related identities, and several suggestions provided for facilitating students' aspirations into science. This study also contributes to careers counseling services, as students' ways of identifying their science-related careers are better understood.

5.1. Introduction

Researchers and public policy makers have expressed concern about the lack of interest and participation in science among students (George & Kaplan, 1998). Many adolescents, particularly female and minority students, choose not to pursue careers in mathematics, science, and technology (Jacobs & Simpkins, 2005). To understand students' attitudes about science, many researchers have focused on factors related to students' career choices in science (Dick & Rallis, 1991; Packard & Nguyen, 2003; Post, Stewart, & Smith, 1991; Wang & Staver, 2001; Woolnough et al., 1997), gender differences and correlations in students' science-related interests, attitudes and experiences (Christidou, 2006; Fadigan & Hammrich, 2004; Farenga & Joyce, 1999; Jones, How & Rua, 2000; O'Brien, Martinez-Pons, & Kopala, 1999; Weinburgh, 1995), and the role of social encouragement for students' science motivation and confidence (Keeves, 1975; Stake, 2006). These studies were designed to identify crucial factors or influences on students' science career aspirations or plans, for instance, the importance of career-related internships (Packard & Nguyen, 2003); informal science education program (Fadigan & Hammrich, 2004); self-efficacy and interest (Post, Stewart, & Smith, 1991), ethnic identity, academic achievements and socioeconomic status (O'Brien, Martinez-Pons, & Kopala, 1999); and educational outcomes, instructional quantity, and home environment (Wang & Staver, 2001). In fact, high school students face an important transition, as they will choose majors or careers after graduation, especially because occupational attainment at some later stage (e.g., age 33) is significantly related to the job aspirations expressed at age 16 (Schoon, 2001). How do high school students at that age articulate their possible, science-related futures, and therefore, aspects of their possible future identities?

The purpose of the present study was to examine the features of high school students' discourse about science-related career choices and therefore about their possible future identities. That is, I am concerned in particular with high school students' perceptions about possible science-related careers as these are expressed in their own discourse. However, in contrast to the majority of educational researches, I am less interested in *what* factors or attitudes affect students' career aspiration and more interested in *how* students deploy language to articulate and relate to their possible science-related careers. Underlying my research is the supposition that human actions are situated and contextualized and people's mind cannot easily be assessed as if it is something stable and fixed. Accordingly, I chose a relatively new perspective—discursive psychology—as my method and theory of choice. Utilizing this conceptual framework, I analyzed students' discourse in an interview situation minute by minute, and identified interpretative repertoires—the shared discursive resources in the culture—to better understand several aspects of high school students' science-related identities as they explored their possible science-related careers.

5.2. Background

This study is concerned with high school students' discourses about their science-related career choices. Because career choices are at the heart of who someone is, how someone describes her- or himself, and the possible futures a person envisions for her- or himself, I review in the following the literature on discursive psychology (my theory and method), a particular aspect of discourse salient to the analysis of spoken and written text, and on recent work concerning science education and identity.

5.2.1. Discursive Psychology

Initiated by Edwards and Potter (1992), "discursive psychology" is a relatively new perspective in the area of language and social psychology with great potential for science education research (Roth, 2008b). It was influenced by and constitutes a further elaboration of Wittgenstein's (1958) later philosophy on language, ethnomethodology (e.g., Garfinkel, 1967), rhetoric (e.g., Billig, 1985), sociology of science (e.g., Gilbert & Mulkay, 1984), conversation analysis (e.g., Atkinson & Heritage, 1984), and discourse analysis (e.g., Potter& Wetherell, 1987). Following Piaget's pioneering studies in cognitive psychology, children's understandings of the world were taken to be a coherent, internal cognitive representation, whose nature can be examined via careful experiments and interviews (Edwards, 1993). Through experimental manipulations and procedures in traditional psychology, language was operationalized and reified as an apparently neutral means for getting at presupposed underlying cognitive states. Researchers took language as a window through which one could look at the thoughts in peoples' minds. In contrast, discursive psychology took discourse as a topic investigating, among others, the techniques interaction participants use to manage their talk. Rather than attempting to produce a psychology of people trying their best, in a disinterested manner, to remember events or adduce causal responsibility, discursive psychologists treat people as agents who have a stake or interest in their talk to perform particular actions. For instance, instead of language being used to recall memory of past events, remembering is understood as the situated production of versions of past event, while attributions are the inferences that these versions make available (Edwards & Potter, 1992). As for attitude, traditional research often ignores and suppresses variability by means of restriction during experiments (e.g., forced choice responses), gross coding, and selective reading (Potter & Wetherell, 1987). In discursive psychology, variability is expected as people perform different actions with their talk. Thus, rather than treating attitudes as inner entities that drive behavior, discursive psychologists study attitudes as a family of evaluations that are performed rather than preformed (Potter, 1998). Discursive psychology focuses on how people in interaction do attitude and belief talk, which constitute resources for making sense that they make available *to* and *for* one another, and on the common repertoires they draw on to constitute a topic such as future careers. Discursive psychology is not interested in proving or disproving the nature or existence of real minds or what people really think, privately and inaccessibly; but rather, it examines the verbal conceptualizations as flexible components of situated talk for situated purposes (Edwards, 1993). For instance, when a student says "I think I can do a good job like animals dissections, so I want to be a biologist in the future," from a discursive perspective, instead of using psychological entity (i.e., self-efficacy) to interpret, discursive psychologists may make claims about how the student draws on a particular *interpretative repertoire* to support her or his claims.

5.2.2. Interpretative Repertoires

The concept of *interpretative repertoire* first appeared in Gilbert and Mulkay's (1984) sociological study of biochemistry laboratories in the UK and USA. These researchers found that scientists employ certain stable interpretative discursive forms that share an underlying assumption and therefore stem from the same repertoires. These recurrent interpretative resources are used with great flexibility to generate radically different accounts of social phenomena. They identified two interpretative repertoires: *empiricist* and *contingent*. The empiricist repertoire usually occurs in formal discourse (e.g., papers of conference) where scientists use impartial and objective words to support their articulation like "the experiment confirmed . . ." or "the results show . . ." The contingent repertoire often appears in informal settings (e.g., interviews) or when things go wrong, where scientists use many interpersonal words such as "Dr. Smith *believes* that . . ." or "the data must result in human errors . . ." Gilbert and Mulkay found that drawing on the empiricist repertoire, scientists represent themselves as objective and as following particular experimental procedures that lead to factual results. Drawing on the contingent repertoire, scientists represent others and themselves as social beings whose work could be affected by their desire, beliefs, and prejudice. Any inconsistencies and differences in discourse are differences between relatively internally consistent, bounded language units such as interpretative repertoires (Wetherell & Potter, 1988, p.172). I therefore can define an interpretative repertoire as a lexicon or register of terms and metaphors drawn upon to characterize and evaluate actions and events (Potter & Wetherell, 1987). Because discourse is designed *for* recipients—presupposing the intelligibility of the talk also on the part of the intended audience—interpretative repertoires fundamentally constitute *shared* discourse features. In fact, researchers analyzing discourse themselves have to be competent users of these repertoires, because they would not be able to identify, describe, and theorize these if they were not (Roth, 2005).

Interpretative repertoires denote forms of talk that discourse participants unquestioningly (a) take for granted for the purpose at hand (e.g., the audience had not challenged the speaker's statements) and (b) draw on to buttress other aspects of talk that are contentious and uncertain (e.g., the speaker had no absolute answers to the topic of conversation). Interpretative repertoires also are part of any community's common sense and are available to the members of a culture, providing a basis for shared social understanding. They can be thought of as books on the shelves of a public library, permanently available for borrowing by the members of a discursive community (Edley, 2001). Speakers draw on these resources presupposing that these are unchallenged by the audience; that is, interpretative repertoires constitute ways of talking that speakers presume to be shared. In this study, identifying interpretative repertoires in students' articulations related to possible science careers can help us to better understand ways of connections and links between students and science communities through the salient use of language.

5.2.3. Identity

Literature over the past decade has shown that identity is increasingly becoming one of the core issues in the study of knowing and learning generally and in science specifically (Roth & Tobin, 2006). How students engage in science is influenced by how students view themselves and whether or not they are the kind of person who engages in science (Brickhouse, Lowery, & Schultz, 2000). Identity—who we are for ourselves and who we are in relation to others—is a complex phenomenon, and seems to have a core that undergoes developments when we articulate ourselves (Roth, 2006a). In an educational context, Gee (2001) proposes four different ways to view identity, that is, nature-identity (a state developed from forces in nature), institution-identity (a position authorized by authorities within institutions), discourse-identity (an individual trait recognized in the discourse/dialogue of/with rational individuals), and affinity-identity (experiences shared in the practice of affinity groups). Influenced by Gee, Brown (2004) further proposes the idea of discursive identity to reflect an understanding that speakers select genres of discourse with the knowledge that others will interpret their discourse as an artifact of their cultural membership. In the present study, I am interested in how students draw on discursive resources to construct their science-related identities; these resources are more general and can be used to constitute even opposite claims (Roth & Alexander, 1997). I see identity as arising from social interactions—a dialectical relationship of individual and collective and different identities arise in persons that are deemed appropriate or necessary for the occasion. Thus, a research interview becomes not just an elicitation of information but also a site of co-production, management and presentation of identities and self; this is a process whereby the interview itself becomes topic (Lee & Roth, 2004). Students' identities in this study were produced and reproduced in and through talk–in–interaction in an interview situation. Identity provides a lens through which individuals reason about the world and their roles in it (Brown & Kelly, 2006), but at the same time, reasoning also provide a resource to produce and reproduce identity. In this study, how students reason the relationship between themselves and possible science-related careers—how students draw on interpretative repertoires (cultural resources) to link science identities—provides a site to understand aspects of students' science-related identities at both individual and collective levels.

5.3. Research Design

This study was designed to investigate the ways that high school students discursively interpret possible careers and how they are related to science identities in a semi-structured interview situation. In this, my study was part of a ten-month research project focused on the development of scientific literacy through participating in an internship at a university biology laboratory. I interviewed students before and after an internship experience in a university science laboratory about their possible futures generally and their possible science careers in particular. To understand the context from and within which students talked about their possible careers, I followed them for through their biology and career preparation courses over 22 lessons and then through their internship producing a total of 126 hours of videotapes.

5.3.1. Participants and Data Collection

Participants in this study were 13 high school students attending a public school in a mid-sized Canadian city where they were enrolled in an eleventh-grade honors biology course that also has a biology career preparation function. The career preparation students participate in various extra-curricular science activities to complete the career preparation course, which requires one hundred hours of internship over two years (grades eleven and twelve). Their experiences provided a rich resource for the purpose of understanding students' reasoning for pursuing science-related careers. To establish a relationship of trust and to better understand the high school students' school life, I observed their biology and career preparation class for a period of twenty-two lessons (one month). The classroom contained many learning resources, including science magazines, microscopes, science posters, and scientific models. I invited students who had an interest in participating in an internship project to take part in an interview in their biology classroom.

To facilitate the students' exploration of science career choices, I adapted a possible selves mapping activity as an interview. Based on the work of Cross & Markus (1991) and Markus & Nurius (1986), *The Possible Selves Mapping Interview* (PSMI) was developed to explore students' future possible selves including cognitive manifestations of goals, aspirations, values, and fears (Shepard & Marshall, 1999). In this study, I invited students to focus only on possible careers. The semi-structured interviews used the PSMI procedure as a guide to ensure coverage of major themes but also allowed enough room for students to articulate freely. First, students brainstormed their possible careers and wrote each down on different color cards to differentiate their likes (green) and dislikes (yellow). Then, students ranked these cards in term of degree of like and dislike, grouped the cards if possible, and explained their reasons for the ranking and grouping. In these 40–60 minutes semi-structured interviews, I interviewed 13 high school students (11 female student and 2 male students) individually. I videotaped these interviews, including (or to show the) interviewer, interviewee and the possible selves mapping activity (see Figure 5.1). I understand this configuration as a mediating element in the production of the talk: the students provided explanations *for* the researcher, who thereby was assumed to be a knowledgeable recipient; and in so doing, she contributes to making this an interview. Data for this study includes 13 interview videotapes, artifacts produced in the interviews, and the researchers' observation and field notes. Videotapes were all transcribed immediately for data analysis—*discourse analysis*.

Figure 5.1. A student (on the right) explains her possible career choices with available resources (i.e., pens, cards, and the map) to the interviewer in a semi-structured interview. (Drawing is portrayed from the actual image on videotape)

5.3.2. Discourse Analysis and Credibility

As sociologists of scientific knowledge, Gilbert and Mulkay (1984) developed *discourse analysis* as an approach to study scientists' discourses in biochemistry. Discourse analysis is the study of how talk and texts are used to perform actions and as well as the resources that people draw on in the course of those practices (Potter, 2003). Discourse work typically asks questions such as: How is X done? (Potter, 2003) or (as in this study) "How do students articulate their science-related identities through talking about their possible careers?" It examines how people deploy language to construct everyday life rather than seeing language as a resource and a medium, providing clues as to what is going on inside people's minds. Interpretative repertoire is an important topic generated from the study of discourse analysis. Identifying interpretative repertoires helps us to understand the shared language resources among participants in a culture or community such as adolescents in my study particularly. In this study, I identified interpretative repertoires in students' articulations about their possible science-related careers in order to understand ways of connection between students and science communities. I transcribed the 13 interviews adopting basic Jeffersonian system notation (Atkinson & Heritage, 1984, see Appendix) and repeatedly read the transcripts while conducting an open coding procedure. By coding and recoding these transcriptions, I found more reasonable and manageable chunks or patterns for analysis. These patterns of variation and consistency in a range of features allowed me to map out the pattern of interpretative repertoires upon which students were drawing (Potter & Wetherell, 1995).

I then formulated tentative hypotheses about possible repertoires and tentative descriptions and subsequently subjected these repertoires to peer review and discussion with members of my research laboratory who were working on other research projects and did not have a stake in this project (Guba &Lincoln, 1989). I formed some hypotheses of functions and effects in the discourse. I then tested these hypotheses about the discursive repertoires used in the entire dataset. During the repeated process of generating hypotheses and testing them by rereading the transcriptions I ultimately derived the set of four interpretative repertoires presented here. In this study, discourse analysis makes it possible to explicate how high students used interpretative repertoires to articulate the relationship of their identities and these science-related careers. More details of validating discourse analysis are introduced for new discourse analysts (Antaki, Billig, Edwards, & Potter, 2003; Burman, 2003; Potter & Wetherell, 1987). In the present study, I implemented several recommended techniques to identify interpretative repertoires: (a) having the research question in mind when looking through transcripts; (b) not using terms indicating mental states (attitude, belief) to interpret the discourse; (c) searching for relatively internally consistent patterns; and (d) paying attentions to the audience's responses such as no further challenges to previous repertoires (as the shared and unchallengeable nature of interpretative repertoires).

5.4. Interpretative Repertoires of Talking About Science-Related Careers

This study was designed to better understand students' discourse about their career choices generally and their interpretative repertoires and science-related identities in particular. Drawing on discourse analysis and discursive psychology, I identified four frequent interpretative repertoires that students used when talking about possible science-related careers in the interview situations. Each of these interpretative repertoires presents a particular resource for identifying students' possible science-related careers (See Table 5.1). These repertoires pertain to the (a) formative, (b) performative, (c) consequential, and (d) potential dimensions of future actions. In the following sections, each of these repertoires is described and illustrated in terms of identifying and dis-identifying. In the following, I describe and provide examples for each of these repertoires and further discuss its relation to students' science-related identities. Implications from each repertoire are discussed and suggested for recruiting high school students into science.

5.4.1. Formative Dimensions of Actions

The formative repertoire invokes formations, special characteristics or requirements for becoming a particular agent. If we look at the example of being a scientist, students normally describe that scientists are smart, professional, special and specialized, and they need to have a lot of schooling before being a scientist. These required characteristics or processes sometimes become students' reasons to articulate about their possible careers in the future. Students often draw on formative repertoire to support their reasoning and identify or dis-identify their possible career choices. In the following sections, I show five excerpts (2 identifying and 4 dis-identifying cases) to demonstrate how these formative repertoires were used in the interview situations.

Table 5.1. The interpretative repertoires and identification resources for talking about possible careers

Interpretative Repertoire	Identification Resource	Identification	Agency	Example
Formative	Formation or requirement of Actions	Identify	Special and Beneficial	• Psychologist—"Psychologist, uhm I think psychology is so interesting… I love just learning about that"
		Dis-identify	Too ordinary/ Too challenging (extreme cases)	• Waitress— "it is pretty mediocre. It is kind of funny to knowing that I can make as much as a 45 years old woman." • Astronaut — "well I would love to go up into space but it is so much preparation to do that"
Performative	Actions	Identify	Practicable	• Immunologist —"I find it interesting like how you can work with, like viruses and find sort of ways to like slow them down and sort of test with that."
		Dis-identify	Impracticable	• Dentist — "It's just like drilling in your teeth, ah, I just oh, I cannot, like the noises, oh it just gets to my ears and it drives me crazy. I just can't do it."
Consequent	Effects of Actions	Identify	Influential	• Doctor—"After helping a patient, it would be pretty cool to see have them like smile you know"
		Dis-identify	Not influential/ Too influential (extreme cases)	• Chemistry/Math teacher — "There is no turnout, like sure you solve the equation but then what? what is the point?" • Surgeon— "I would be like really paranoid that I would screw up or something and kill somebody."
Potential	Action Potentialities	Identify	Expanding	• Biotechnologist— "You can sort of branch out into different topic areas and a lot of it is sort of finding different ways to like make things better"
		Dis-identify	Stationary	• Elementary teacher— "It usually kind of seems to stay the same, like the same curriculum. I think I would be more interested in being able to keep learning"

In the following excerpt, Mandy wrote down "specialized doctor" as her preferred career and "clinical doctor" as a disliked career. When asked for reasons for choosing "specialized doctor," she emphasizes the character of a specialized personnel— "focus in on one thing" and "master"—the trait of being a specialized doctor. (I use eight digits to trace the sources of exemplary excerpt. For instance, "0126-2034," "0126" indicate the interview was on January 26th and "2034" indicates the excerpt starts from the twentieth minute and thirty-forth second of the interview video tape)

```
                                                          (0126-2034)
Interviewer:  so number three is ?
Mandy:        specialized doctor, I guess I (.) just am:: uhm you could focus in
              on one thing, and you could really kind of MASTER that and be able
              to open something, I'm not sure exactly what the would be(.) yet,
              but something more specialized rather than just like a clinical
              doctor ((points to the card))
Interviewer:  so do you discuss this with your friends or family before?
```

Mandy's words show that not any doctor could be her possible career but a specialized one. Specialty becomes the central explanation for reasoning her career choice as if specialty is something attached on and followed by that particular career. In the next excerpt, Elise also draws on formative repertoire to explain the reason for choosing "psychologist" as one of her possible careers.

```
                                                          (0110-3033)
Interviewer:  so how about this one ((points to a card)), psychologist?
Elise:        psychologist, uhm::: I think psychology is SO interesting (. . .
              continue. . . ) I love just learning about that, because in order
              to do this sort of a job (.) or anything, to succeed in any type of
              job, you have to be, like you have to understand psychology
              because(.) like if you are a lawyer or a message therapist, you have
              to learn how to communicate with people and understand like (.) when
              it is right to say what (.) and what to say (.) and you know just
              generally it is just a really good thing to know, it is a good course
              or if you can get a degree in that (.)it is really good
Interviewer:  like a necessary (.) A course you have to do.
Elise:        yeah
```

When Elise explains why she wants to be a psychologist, she quickly mentioned "psychology"—the subject of study before being a psychologist. Elise generalizes the advantage of learning psychology to other occupations "lawyer" and "message therapist" as learning psychology is the key to most successful careers. She also describes how she enjoys the learning process and formation of being a psychologist — "psychology is so interesting," "to learn how to communicate," "it (psychology) is a good course." These formation processes before being a psychologist become Elise's main reason to identify her possible career.

However, sometimes students drew on formative repertoire to dis-identify their career choices. In the following excerpt, Kelly has some concerns about being a surgeon, general practitioner or pediatrician because of the schooling requirement.

(0117-2543)

```
Kelly:         because if I want to become any of these other things ((fingers point
               to surgeon, general practitioner, pediatrician cards)), I have to
               go to school for at least seven years (.) so that is holding me back
               too
Interviewer:   so you mean when you graduate from high school, you can be a personal
               trainer?
Kelly:         Yeah, I can pretty much go into that (.) easy
Interviewer:   okay
```

"Personal trainer" is Kelly's favorite career and she explains it by comparing other preferred careers (surgeon, general practitioner, pediatrician). Although she likes the idea of being a doctor, the years of schooling — the intellectual and time demands to become a doctor is an issue that to holds her back and so she dis-identifies it as her favorite career. With a similar way of reasoning, but slightly different, Claire reasons why she has concern about being a doctor although doctor is one of her preferred careers.

(0118-3016)

```
Interviewer:   which part situation you don't like about it (doctor)?
Claire:        the schooling
Interviewer:   oh:: I see (.) you have to take a lot of courses
Claire:        a lot of courses (.) and I don't know if I can handle that though
               (.) because my cousin tried taking some of the course but he (.)it
               was too much for him (.) so::
Interviewer:   um:: so he give up?
Claire:        yeah he give up
```

Claire explains why the preferred career “doctor” was ranked as number 3 but not number 1. When interviewer asks which part of being a doctor is her concern, she points out “the schooling” and then describes a witness perspective—her cousin gave up being a doctor because of “too much” courses. Here, Clair draws on a formative repertoire to express her concern of being a doctor and also further supported by a reliable voice—her own cousin who is a relative of Clair and would not likely lie to her. This *corroboration (is there another witness to this event?)* from a reliable witness makes people’s utterance stronger and more convincing (Potter, 1996b).

In addition to the issue about schooling of transformation to be a science-related agent, June dis-identifies “astronaut” as her possible career because of the physical training required beforehand.

```
                                                           (0112-1921)
Interviewer:  you like the science subject but you don’t like astronomy?
June:         no
Interviewer:  why?
June:         well (.) I would love to go up into space, but it is so much
              preparation in order to do that, so if there is something in the
              future, someway to go up into space without all those ((waving
              hands))
Interviewer:  physical training?
June:         yeah, tasks, it is too much I think (.) but if you could just shoot
              up there, I would love to go
Interviewer:  then you would do that.
Jun:          yeah
Interviewer:  Okay, so how about this one.((points to another card))
```

The preparation before becoming an astronaut is June’s main concern when she dis-identifies this choice “so much preparation in order to do that.” Without these preparations, June further mentions her willing and positive comments to be an astronaut. In addition to the intellectual or physical demands, the environments in the process of formation could also be a concern for dis-identifying a career. For instance, in the next excerpt, Candy dis-identifies “teacher” as her possible career.

(0109-2311)

```
Interviewer:  so a teacher?
Candy:        um:: so my philosophy on that is that, you go to school to get out
              of school, to go back to school, to go back to SCHOOL, again they
              need to be done, obviously teachers need to (.) because you know (.)
              yeah nobody, I can really respect someone who can go k to twelve,
              go to university and then come back to maybe grade twelve or grade
              eleven, or, you know, that is not for me.
Interviewer:  so how about the group named inside?
```

Candy emphasizes the repetitive cycles in a similar environment when becoming a teacher "go to school (K-12) to get out of school, to go back to school (university)" and "to go back school (K-12)." In Candy' description, going in and out schools is the repetitive process and formation to becoming a teacher. This issue become a concern for Candy to dis-identify "teacher" as her possible career.

In the interviews, students frequently drew on formative repertoires to discuss requirements and specialty as an important consideration for preferring a career in the future. For most students, science-related careers are special and specialized, and they need special training and requirements before becoming a science-related agent. Some students appear willing to accept these challenges and look forward to establishing this type of specialty, however, some students deem these requirements as a concern. Some general formations, such as educational demands and the time needed in the process of becoming a science-related agent, normally reduce students' interests. However, students were more likely to choose science-related careers when they could realize benefits and advantages in the process of becoming a science-related agent—being a beneficiary in the transformation. The beneficial formations of becoming science agents were deemed as a part of what students want to become— a part of their science-related identities. The distance between where students are and where science agents are has become one of the crucial considerations in students' career plans. As science educators, if we can make the formation of becoming a science agent more familiar and meaningful to students, make the black box of transformation transparent, and make connections at different stages of formation, students will become beneficiaries in the process of becoming science agents and more students are likely to enroll in science-related careers.

5.4.2. Performative Dimensions of Actions

The performative repertoire invokes actions and performances of science-related careers. When considering possible careers, students frequently talked about the relevant actions in these careers to support their opinions. For instance, they described actions in their personal shadowing experience, family or friends' relevant experience, or their understanding of science careers gleaned from the media. In the interview, students frequently drew on performative repertoires to identify or dis-identify their possible careers. In the following sections, I exemplify performative repertoires with three identifying and two dis-identifying excerpts.

The interview discourse was designed to understand students' reasons for choosing the careers written on cards. After writing down "marine biologist" on a card as one of her favorite careers, Amy talks to the interviewer about her reason for writing this. She starts to articulate this even before the interviewer has asked any questions about the card.

(0131-1255)

```
Amy:          um:: marine biologist, I don't know, I have always, since I was little
              I just said I want to be a marine biologist
Interviewer:  OH REALLY? why?
Amy:          I don't know WHY, I was just so drawn to it, like I LIKE animals (.)
              and the work experience that you get to do, it's like going out on
              the site (.) and like seeing everything all the wild and how it
              naturally is like, I think it is just so amazing.
Interviewer:  you say all animals or marine animals?
Amy:          just marine animals
Interviewer:  okay
```

Even though Amy says at the beginning "I don't know," she then goes on to articulate reasons for wanting to be a marine biologist every since she was a child. Although Amy expresses her uncertainty, the interviewer still asks "Really?" and "Why?" to request more explanation. In response, Amy says, "I don't know" again and then continues her reasoning. She discloses her positive emotions about the subjects that biologists investigate, “I like animals,” and then describes the actions that a marine biologist would do “going out” and “seeing everything all the wild” in their work. In the end, she describes these working experiences (being a marine biologist) as “so amazing.” Thus, Amy describes that she likes the actions that a marine biologist would do at work.

In a similar way, Kyla describes one of her preferred careers—immunologist. In the following excerpt, Kyla had written down “immunologist” as one of her possible careers and the interviewer asks for an explanation.

(0125-2730)

Interviewer: okay how about this one? (finger points to the “immunologist” card)
Kyla: that one (.) I find it interesting like how you can work with, like viruses, bacteria, and find sort of ways to like slow them down and sort of test with that.

In response to the interviewer’s question, “How about this one?” Kyla describes actions in a working situation that an immunologist would have “work with viruses,” “slow them down” and “test them.” When asked about preferred career cards, both Amy and Kyla depict actions performed by the particular science-related agent—a marine biologist and immunologist—from their understanding of these fields of science.

In the following excerpt, Jennifer depicts many actions that occur at work, like the previous examples, but here it is from her personal experience of working with a marine biologist. Thus, the excerpt illustrates more detailed actions and observations. While talking about one of her preferred careers (marine biologist), Jennifer mentions a previous incident to support her statements.

(0202-2507)

Interviewer: so which part you like (.) most?
Jennifer: um I liked the field experience, like going out, we went dredging and um which is where you pull a net behind a boat, and it drags along the bottom, and you pull it up and you bring it onto deck and you get to see what is on the bottom, all the sea life. so we have,

like, at one point, we had an octopus actually, so it was this big and little and orange and swimming around in our hands, it was so cool, like sea cucumbers and um:: little decorative crabs and stuff, it was pretty fun.

To explain her choice, Jennifer describes a previous marine biology camp experience. After listening to Jennifer's experience in the camp, the interviewer asks "which part" of the camp experience she liked most. Jennifer vividly describes what she saw and did in the camp. In the description, Jennifer depicts many actions that she and the biologist did in the camp. Also, she uses many plural pronouns to buttress her description like "we went," "we had," and "our hands" as if she did exactly the same thing as a biologist. The description of what Jennifer did with the biologist tells the interviewer that she knows what a biologist does and has practiced it in person before. At the end of description, she evaluates the experience as "it was so cool" and "it was pretty fun." After the episode, Jennifer further confirms the camp experience as a crucial point for choosing marine biologist as her favorite career. In the excerpt, we see how a student describes numerous actions to support her explanation of choosing marine biology as a possible career. These *vivid description* and detail of incidents can be used to create an impression that the speakers have made a skilled observation (Edwards & Potter, 1992). The student draws on actions and practice as a way to identify "marine biologist" as her possible career. That is, her science-related identity was identified by science-related and practicable actions.

In addition to using a performative repertoire to identify possible careers, students also use performative repertoire to dis-identify their possible careers. When Elise writes down one of her non-preferred careers on a card— "doctor (I can't handle too much blood)," the interviewer noticed that there is a note (I can't handle too much blood) written on the card, so then asked for Elise's experience with blood.

(0110-1040)

Interviewer: do you have some experience with the blood?

Elise: oh blood, no, I just get so nauseous. I don't know, I just CAN'T handle it. Like you know, people on the shows, on TV and when they are doing plastic surgery, and they're like they show you that stuff on TV.

```
                Now I'm like, OH MY GOSH, no.
Interviewer:    okay yeah, so now you're going to category, so name (.) some way to
                group it
```

Elise mentions that she could not stand seeing blood because of her unpleasant reaction, “nauseous.” She also describes the actions that she saw on television where “doctors are doing plastic surgery.” In conclusion, Elise waves her hand and says “Oh my gosh, no” to express her comments on these actions. Here, Elise dis-identifies “doctor” as her possible career by describing the actions she saw on television. In the following statement, Alice also uses a performative repertoire to dis-identify possible careers (dentist or nurse).

(0124-1614)

```
Interviewer:    Why?
Alice:          well I don't know. It's just like the drilling in your teeth, AH:::
                I just UM:: I cannot ((waving hands)), like the noises, AH::: it just
                gets to my ears and it drives me crazy. I just can't do it. and the
                nurse, I don't know, I'm taking chemistry right now and I don't like
                chemistry (.hhh). and like my teacher is like, chemistry you have
                to know all this stuff. like AH::: it's like, it is a lot of
                measurements and stuff.
Interviewer:    your dad would like you to do the nurse?
```

When articulating her reason for not being a dentist, Alice mentions dentists’ actions “drilling in your teeth” and her unpleasant reactions “the noises . . . it drives me crazy.” Furthermore, she says that she cannot see herself doing that kind of work: “I just can’t do it.” As for being a nurse, Alice connects the occupation to chemistry, the subject that she does not like and the disliked actions “a lot of measurements” that her teacher mentioned before.

In performative repertoires, students talk about scientific actions that they have observed, practiced or heard about. Usually students talk about these actions as practicable to identify possible careers and impracticable to dis-identify possible careers. That is, students’ science-related identities related to science-related agents were characterized by what they do as practitioners. Students usually have positive comments when they realize these actions and practices are practicable for them—being a successful practitioner. Performative repertoires illustrate that students' experiences or practices in science-related workplaces have an important role for their career choices. Thus, if students could have more opportunities to have authentic science experiences (e.g., participating internships like the 13 students in my study), they could understand more about what science agents do in their everyday practice. These practices provide opportunities for students to experience science-related actions more authentically and experience the pros and cons of science practices in person. They can then reflect on the experiences to see if these actions are practicable for them. This, in turn, could lead to further development of a science career identity.

5.4.3. Consequential Dimensions of Actions

The consequent repertoire invokes the effect, impact and influence of actions. To explain the reasons for choosing these careers, students often mentioned the consequence or influence of the careers, for example, helping people or improving the environment, as having an impact on society. To exemplify the consequent repertoire, I demonstrate four identifying, two dis-identifying excerpts and one mixed excerpt. "Psychologist" was one of June's possible careers written on a card. She explains to the interviewer why she wants to be a psychologist.

(0112-2706)

```
Interviewer:  so which part do you like most? to be a psychologist.
June:         um I like the helping part, helping people and making them better,
              yeah.
Interviewer:  Okay great, now you just write this one ((points to another card))
```

After June describes the work of being a psychologist, the interviewer asks, "Which part do you like better?" as a psychologist. June mentions the effects on other people, such as the "helping part," "helping people" and "making them better." Here June describes helping people—the effect of actions as her favorite part.

In the following excerpt, Kelly also mentions helping people as a crucial reason but also describes the nature of the recipient. "Pediatrician" is one of Kelly's possible careers written on a card, thus the interviewer asks her why.

(0117-1556)

```
Interviewer:  why do you want to be a pediatrician?
Kelly:        just because helping children and stuff like that (.) and it just
              I have always been fascinated with children and how, they are so
              innocent too and they can't, and they are helpless as well.
Interviewer:  okay
```

Like June's explanation that helping people is a reason to be a pediatrician, Kelly points out the particular kind of people whom she wants to help, "children," whom she describes as "innocent" and "helpless." Here, the consequent repertoire is constituted by the effect of actions (helping) and more detail about the recipient of the effect.

In the next excerpt, the consequent repertoire Claire uses is not only to mention the effect of action but also the feedback from the recipient. Claire wrote down "doctor" as her possible career, so the interviewer asks for her explanation.

(0118-2815)

```
Interviewer:  and which part do you like most about being a doctor?
Claire:       after helping a patient, it would be pretty cool to see have them,
              like smile you know?
Interviewer:  and recover?
Claire:       yeah
```

Like June and Kelly, helping people is one of Claire's favorite aspects of her preferred career (doctor). She mentions her good feelings about helping these people when she receives concrete feedback from people: "It would be pretty cool to see have them like smile."

These three examples above all contain the term "helping" which illustrates that these students describe helping as a crucial aspect of their preferred science-related careers. The following example of consequent repertoires also shows the function of "helping," but does not mention the term "help" explicitly. "Sports therapist" is Amy's favorite career and the interviewer invites her to talk about it.

(0131-1135)

```
Interviewer:  your first one would be sports therapist?
Amy:          therapist like working with people who have either injured
              themselves or (.) have problems that they don't know how to solve.
              so just working with them to overcome THOSE kinds of:: things.
Interviewer:  mm:: what is the difference? ((points to two cards))
```

Amy reasons that sports therapists will work with people who have injuries or problems and be able to help them overcome these issues. Here, although Amy does not explicitly say, "help" people she says "work with them to overcome (problems)" which posits the therapist as the helper of these injured people.

In addition to using consequent repertoires to identify possible careers, students sometimes use consequent repertoires to dis-identify possible careers. When Joe explains part of his disliked cards group, he puts "pilot" and "surgeon" together as a group and names the group "precision/risk." After articulating other cards, he continually talks about the group and reasons for not choosing them as possible careers.

(0123-1525)

```
Joe:          yeah and I wouldn't want to be a pilot or a surgeon((points to cards))
              because (.) it seems too risky to me. like I'll (.) if I was a surgeon,
              I would be like really paranoid that I would screw up or something
              and kill somebody. Same with the pilot it is the same in a way, not
              for me.
Interviewer:  okay great, so your number one is medical lab technician. could you
              talk about why you want to be a technician?
```

Joe mentions the possible negative consequences "screw up or something and kill somebody" to dis-identifying possible careers. It has been suggested that people frequently draw on *extreme-case formulation* (using modalizing terms: never, completely, every) to justify their arguments (Pomerantz, 1986). Here, Joe not only uses extreme modalizing terms "too (risky)" but also describes a extreme incident "killing somebody" to emphasize possible consequence. This extreme-negative consequence becomes an unchallengeable and convincing reason for dis-identifying possible careers.

Like Joe's extreme-case formulation about consequence, Amy also uses a consequent repertoire to dis-identify one of her possible careers but in a slightly different way.

(0131-2422)

```
Interviewer:  okay great. How about teacher? Which subject do you want to teach?
Amy:          well I definitely wouldn't want to teach math, or chemistry, yeah
              no
Interviewer:  no math or chemistry?
Amy:          no math or chemistry.
Interviewer:  why? why not?
Amy:          I just don't like I don't like working with equations (.) it just
              bothers me. like there is no turnout, like sure you solve the equation
              but then what? what is the point?
Interviewer:  You mean:: you mean no meaning?
Amy           Yeah sort of (.) there is no point
```

"Teacher" is one of Amy's preferred possible careers. In addition to the general question "how about teacher?" the interviewer asks a more specific question about which academic subject she would like to teach. Amy does not answer this question directly, that is, she does not answer which subject she wants to teach but talks in an exclusive way, mentioning which subject she does *not* want to teach (neither math nor chemistry). Then the interviewer confirms what she heard by asking a question, "No math or chemistry?" to request Amy's confirmation. Amy confirms the interviewer's understanding by saying the same words but with an affirming intonation "no math or chemistry." The interviewer asks "why?" and "why not" to request further explanation. Amy first says that "I don't like working with equations" and points out an issue that bothers her—she does not see the point of doing an equation. That is, she might not clearly know what happens after solving an equation or the consequences of doing an equation. Here, Amy use extreme formation "no turnout" and "no point" to emphasizes the importance of knowing the point or the consequence of an occupation. Otherwise, she would not consider choosing that occupation as her possible career.

In addition to using identifying or dis-identifying actions to talk about possible careers, students would use both identification and dis-identification to strengthen their explanation. In the following excerpt, Mary explains why she does not want to be a marine biologist.

(0126-2347)

Interviewer:	so, why not? because you have a lot fun there, but you don't want it (marine biologist) to be a career?
Mandy:	YEAH um:: (.) I guess I am more interested in things that affect humans, rather than kind of the marine animals. it's (.) I kind of like the larger scale, like the actual visual impact rather than just (.) researching and knowing everything about crabs. but I guess to me it is more effective or (.) I'd feel like I was doing more if I was learning about diseases, so I could help people rather than just crabs.
Interviewer:	so you mean helping people is more?
Mandy:	yeah, helping people is more what I would like to do, having an impact and knowing that I am doing something.
Interviewer:	mm:: so how about this one? ((points to another card))

After mentioning a camp experience, Mary comments that she had great fun at the camp but she does not really want to be a marine biologist. The interviewer questions "why not?" to express her curiosity that even though Mary had fun, she does not want to do marine biology. Then Mary responds and tries to explain that what interests her more is "affecting humans rather than kind of the marine animals," "the actual visual impact rather than just researching and knowing everything about crabs" and "so I could help people rather than just crabs." These terms "affect," "help" and "impact" indicate that the student greatly values the implication of her preferred careers. Through this impact, the student might be able to "know that I am doing something." This excerpt exhibits a student's explanation of choosing "doctor" as a possible career because of its wider influence and impact, which indicates her awareness of actions in that career. In potential repertories, students draw on the consequence of actions as one resource to identify their preferred careers.

In consequent repertoires, students mention effects, influences or consequences of actions as ways to relate their career choices. Usually students take having apparent influences as reasons for identifying their possible careers and having no influence for dis-identifying possible careers. However, sometimes students describe influences on others as negative due to the heavy responsibilities (e.g., I don't want to be a surgeon because I cannot take the responsibility of others' lives). In consequent repertoires, students usually made positive comments when mentioning these science-related careers that have more influences—being a contributors that can help or influence others in a positive way. As other studies (Shmurak, 1998) point out, girls, like most students in my study, choose science-related careers often based on their desires of helping people, animals, or environments. These collective relations with others contributed to students' plans for becoming science-related agents, that is, students often described the identities of science agents as having an important relation with society, people and the world. The implication of science practices on society is usually taken as the identification resources of becoming a science-related agent.

5.4.4. Potential Dimensions of Actions

The potential repertoire invokes future potentialities or trends in one's career. Students frequently spoke about the possibilities of expanding life or learning, for instance, being able to learn more, update or do something different. Here, we list four identification excerpts and two mixed excerpts to exemplify the potential repertoire.

After completing the mapping process, Wendy realized that one group of her possible careers were all related to science and she tries to explain the phenomenon to the interviewer.

(0116-3749)

```
Interviewer:  but why not history or English or
Wendy:        I guess the sciences are more exciting, and there's endless
              possibilities to them.
```

Wendy said, "Sciences are more exciting" and "there's endless possibilities" in science fields. Here, Wendy emphasizes and values the potential or the room for growth as the reason for choosing science-related careers.

In the following excerpt, Kyla also uses the potential repertoire to articulate her possible career, biotechnologist.

(0125-2158)

```
Interviewer:  how about number one? Why do you want to be a biotechnologist?
Kyla:         um, because it really interests me and with something like that, from
              what I can understand, you can sort of branch out into different topic
              areas(.) and a lot of it is sort of finding different ways to like
              make things better sort of and find better ways to deal with things
              like oil spills and stuff.
Interviewer:  wow it sounds like you know this career very well
```

Kyla wrote down “biotechnologist” is her favorite career and she mentions that, from her understanding, a biotechnologist can “branch out into different topics” and “find different ways to make things better.” Here, Kelly twice uses the term “different” which emphasizes the diverse nature of the actions of a biotechnologist.

Similarly, Kelly mentions the possibilities in the science-related career of surgeon to explain her choice.

(0117-3150)

```
Interviewer:  how about this one (finger points to the “surgeon” card)? you think
              they have high goals?
Kelly:        yeah you are always taking new courses; you are always having to
              update; you are always learning new things; it is never the same.
              All you (.) like you will probably never see the same injury ever.
              like maybe a broken bone, but it is never going to be broken in the
              exactly the same place. there are always going to be different
              situations like factors around and everything like that.
Interviewer:  ok so how about this one ((points to another card))
```

When Kelly talked about not wanting to be a librarian, and mentioned that she saw librarian as a career with almost no goals. Therefore, when the interviewer asked for her explanation about becoming a surgeon, she asks one more question: “Do you think they have high goals?” comparing to librarians. Kelly answers by describing the dynamic process whereby a surgeon is “always taking new courses,” “having to update,” “learning something new” and “having different situation.” In addition, as a surgeon, “they never see the same injury” and “never in the same part” of the body. These extreme modalizing terms “always” and “never” indicate Kelly’s affirmation and terms like "new," "update," and "different" illustrate Kelly's values with respect to being a surgeon.

In the next excerpt, Jack also uses a potential repertoire to buttress his explanation for being a family doctor. In addition to emphasizing the possibilities, his explanation relates to a time scale.

(0111-3755)

```
Jack:          um:: well as a career, it is good because there is, well, a lot of
               room for advancement and learning all that, but, um mostly just it
               is something, I know I can enjoy it for a very long time. um something
               I can continue to be learning and using new information and all that
               for well, the rest of my life basically.
Interviewer:   do you mean you have to learn new information
Jack:          yeah, you would have to learn new information as the year passes
Interviewer:   yeah, okay, so how about this one ((points to another card))
```

When the interviewer asks Jack if he thinks that "family doctor," as one of his possible careers, is a good career, he affirms the question "yeah." He further explains that because of the many characteristics of being a family doctor he will likely enjoy the career for a "long time." These characteristics include "a lot of room for advancement," "continue to be learning," and "using new information." Jack's statement illustrates the importance of these learning opportunities and the progressive aspects of being a family doctor; it also shows a time consideration of benefiting during the career.

Like performative repertoires and consequent repertoires, sometimes students draw on a potential repertoire to dis-identify their possible careers. In the following excerpt, Jennifer use potential repertoire to describe nurse as her non-preferred career comparing to people who take care of animals.

(0202-3335)

```
Interviewer:   and how about being a nurse?
Jennifer:      nursing, yeah yes and no. I have always thought about it but it
               doesn't, it isn't the same as marine biology (.) I think animals they
               can be very different, and human beings are like the same but with
               tiny bits of difference.
```

```
Interview:     mm::You said your grandparents live very near the ocean?
```

When talking about possible careers, Jennifer mentions that her mother is a nurse. Therefore, the interviewer asks Jennifer if she wants to be a nurse. At the beginning of the interview, Jennifer had already mentioned that she wanted to be a marine biologist so when Jennifer talks about being a nurse, she automatically compares it to her favorite career, marine biologist “it (nursing) isn’t the same as marine biology.” Then she points out marine biologists’ study targets vary—“animals can be very different”—and refers to the service target of nurses as similar—“human beings are like the same but with tiny bits of difference.” Here, Jennifer identifies marine biology as her possible career by valuing “differences” and dis-identifies nurses by devaluing “sameness.”

In the next excerpt, Mary uses a potential repertoire to identify and dis-identify her possible careers but also points out her feelings. Mary prefers to be a doctor rather than a teacher; she emphasized the reason in terms of learning opportunities.

(0126-2812)

```
Interviewer:  so how about teacher?
Mandy:        it is a lot of I don’t know, just preparation, and doing the same
              thing like. if I wanted to be a teacher, I would have to probably
              be more at middle school or something where you teach a range of
              subjects, rather than teaching the same thing year after year. I
              think I would get kind of bored of it when you are not learning. like
              with a doctor something you are always learning something new and
              kind of always having to update. where as with a teacher, it usually
              kind of seems to stay the same, like the same curriculum. So I think
              I would be more interested in being able to keep learning.
Interviewer:  okay, so if you are a teacher which subject you teach?
```

In the excerpt, Mary writes down “teacher” as one of her possible careers but it is the least ranked one. She first mentions that the downside of being a teacher is they usually do the “same” thing and expresses her feeling about the routine work “I think I would get kind of bored of it.” Then she compares it to another career—a doctor. She emphasizes the big advantage of being a doctor as “you are always learning something new and update” while as a teacher you “stay the same." Here, the student situates herself in the future and emphasizes that her possible career should be more dynamic and expanding. In the potential repertoire, students identify their science-related careers through potentialities and possibilities as their resources for identification and dis-identification.

In potential repertoires, students spoke about potentialities and possibilities of actions in bigger timescales to support their opinions. Students described expanding action possibilities as important in identifying their science-related careers, and a stationary state as a resource for dis-identifying other possible careers. Students usually had positive comments when science-related careers are described as having many possibilities, varieties, potentialities or diversities—being a lifelong learner. For students, especially high school students who are going to decide their majors in university or work types, it is very important for them to see the various possibilities of their future actions because these possibilities could not only serve as goals for learning current practice but goals of transcending present day achievements. Communicating present science obstacles and the need for solutions and improvements to students would be important ways of recruiting newcomers in the science fields.

In summary, through these analyses of interpretative repertoires drawn on by students, I found that students' science-related identities were related to being: (a) beneficiaries; (b) practitioners; (c) contributors; and (d) learners. If students could realize the special and beneficial transformation of becoming a science agent; practicable actions in science workplaces, influential and collective relations to the worlds; and expanding actions possibilities of being in a science-related career, students would likely have positive emotional valences when considering science as their possible careers.

5.5. Talking Science and Non-Science Related Careers

To see if there was any difference between articulating science and non-science related careers, I counted the frequency of interpretative repertoires students drew on when reasoning their career choices. In the interviews with 13 students, students were asked to write down possible preferred careers and disliked careers and then rank the degree of like and dislike. Thus, various careers, including science and non-science careers, were written down and articulated by students afterwards. Some students wrote down 10-20 different kinds of careers and some students only had 2 careers. For the purpose of representing the data, I selected the first three liked and disliked careers ranked by each student (only two careers selected from students if they only wrote down two) for counting interpretative repertoires used in articulating their reasons for these choices. Sometimes, students drew on several interpretative repertoires to articulate one career, whereas sometimes only one interpretative repertoire was used to support their reasoning. The results are summarized in Table 5.2 in terms of different repertoires, agency of being that agent, and science/non-science related careers (students informed me whether they are science-related careers or not).

Students spoke at length about science-related careers possibly because they are in a biology honors class, and many of them are science oriented. However, some students had interests in non-science related careers like lawyers and singers. From the frequencies of formative repertoires, we can see that students use more formative repertoires for articulating science-related careers (20%) than non-science (6%). Also, most students talked about science-related careers as something special and beneficial in the transformation of being a science agent and then identity their possible careers (*N*=10). However, some science-related careers were articulated as something too challenging to achieve such as doctors and astronauts. As for non-science related careers, no students mentioned the process of being a non-science agent as special and beneficial but described non-science careers (e.g., waitress) as something too ordinary and not requiring schooling or preparation (*N*=2).

From the frequencies of performative repertoires, we can see that students drew on performative repertoires most to reason their choices for science (32%) and non-science (50%) related careers. Most students described the science-related practice as practicable actions (*N*=18) to identity their careers, whereas describe non-science related practice as something impracticable (*N*=15) for them. From the frequencies of consequent repertoires, I find that students use the effect of actions to support their articulations of science (29%) and non-science (26%) related careers. However, most students portray science-related careers as influential practice and as making important contributions to society (*N*=17), whereas non-science related careers as not influential practice (*N*=6). As for potential repertoires, most students described science-related careers as something having many action potential and possibilities (*N*=11) and non-science related careers as something having repetitive practice and without potential for learning (*N*=6). In summary, both science and non-science careers are articulated mostly with performative repertoires and consequent and potential repertoires are frequently used as well. However, students drew on more formative repertoires to articulate science than non-science careers. This might be due to the very special nature of requirement and formation in developing agency with respect to science.

Table 5.2. Frequencies of interpretative repertoires when articulating the first three fond and dislike careers.

Interpretative Repertoire	Agency of being that agent		First three preferred and dislike Careers (13 students)			
			Science	Non-Science	Science	Non-Science
Formative	Identify	Special and beneficial	13 (20%)	2 (6%)	10	0
	Dis-identify	Ordinary/Too challenging			0/3	2/0
Performative	Identify	Practicable	21 (32%)	17(50%)	18	2
	Dis-identify	Impracticable			3	15
Consequent	Identify	Influential	19 (29%)	9 (26%)	17	1
	Dis-identify	Not influential/Too influential			0/2	6/2
Potential	Identify	Expanding	12 (19%)	6 (18%)	11	0
	Dis-identify	Stationary			1	6

5.6. Talking about Scientists Before and After A Science Internship

These individual interviews about students' possible careers are took place before a 10–16-hour science internship in a university based biology laboratory. Students were invited to have individual interviews before and after the internship (because of external circumstance, only 11 out of the 13 students were interviewed after the internship). In the first interviews, students completed and articulated their possible selves career maps and their expectations about the upcoming internship. In the second interview, students were invited to revisit their maps and make changes if they wished. The second interview showed that students seldom made changes in their maps—only 2 students changed their career rankings. However, I found that students did change their ways of articulating about scientists after the internship.

Comparing students' talks about scientists before and after the internship is one of objectives of this study. As seen in the previous sections, students defined various careers as science-related careers. For the purpose of comparison, I invited students to articulate one particular kind of scientist—"biologists"—whom students expected to see in the internship activity. Before the internship, I asked questions such as "what do you think about the scientists in the following internship?," "do you have any expectation about them?" and analyzed these dialogues in terms of the four different kinds of repertoires. Also, in the interviews after the internship, I asked questions such as "what do you think of these scientists?," "how do you think of being a scientist in the biology laboratory?" and analyzed these answers for repertoire comparison. Before the internship, most students had been to visit other laboratories but had not actually participated in scientific practice with science personnel like scientists or technicians. In the present science internship, students were in contact with technicians and young scientists under the supervision of chief scientists. Depending on the different nature of each science project, students participated in, but were not restrained to, discussing science papers, practicing laboratory work, data analysis, and science seminars and fieldwork. Table 5.3 constitutes a summary of the repertoire frequencies.

In Table 5.3, we can see there are two substantial changes in the use of repertoires before and after the internship. First, from the frequency of formative repertoires, we can see that before the internship 8 out of 13 students used formative repertoires to describe a career as special and specialized e.g., "I think a scientist is someone who can look and see what is behind those walls… kind of they have learnt a lot, they have done a lot of school and have a lot of knowledge.” Moreover, 2 out of 13 students described scientists as normal human beings “it is not like scientists are, you know like stereotypical scientist who are like super smart and brainy people like all the time, they are not like that they are like actual people, you know, so.” However, after the internship, only one student used formative repertoires to describe scientists.

Table 5.3. The frequencies of repertoire used before and after a science internship.

Interpretative Repertoire	Agency	Before (13 students)		After (11students)	
Formative	Specialized	8 (6)*	10	1	1
	Ordinary	2		0	
Performative	Practicable	6 (5)	6	1	9
	Impracticable	0		8	
Consequent	Influential	0	0	0	1
	Not influential	0		1	
Potential	Expanding	(2)	2	0	2
	Stationary	0		2	

* Numbers in parentheses indicate students who completed the internship.

The second major change involved performative repertoires; 6 out of 13 students described scientists doing something very practicable and interesting before the internship “I also really want to find out about the water, and the minerals in our water and things like that so I am really excited to be doing that.” However, after the internship, 8 out of 11 students spoke of the actions of scientists in the laboratory as impracticable for them “I don’t know if I would have the patience, because like you don’t get results right away and you have to wait for money to come in, so that you can continue on and then they take a lot of time.” As for the potential repertoires, 2 out of 11 students described the stationary action possibilities of being a scientist “if you’re doing things over and over again, that aspect could get boring or monotonous at some point in time.” With respect to frequency of use of these four interpretative repertoire before and after the internship: (a) students seldom drew on formative repertoires to articulate being a biologist, this result shows that after the internship, students may have reduced their expectations of special requirements for being a biologist; (b) from the frequency of performative repertoires, we see that students described a lot impracticable actions related to being a biologist after the internship. This shows that the students may not value the routine and tedious practice of everyday life in the laboratory; (c) students seldom use consequent repertoires to articulate the scientists in the internship. It possibly relates to students' lack of understanding or acknowledgement of the consequence of microbiology in the internship; (d) 2 students emphasized the expanding possibilities of being a biologist before whereas 2 students emphasized the stationary possibilities after the internship. It shows that the students may not have recognized the potentialities for future work in the internship.

5.7. Discussion

One of the aims of science education is to recruit students into the practice of science. However, lack of student enrolment and interest has become an issue in science education. Understanding the construct of students' science-related identities is useful because it accounts for the importance of both individual agency as well as societal structures that constrain individual possibilities (Brickhouse, Lowery, & Schultz, 2000). To understand career-related aspects of students' science identities, I invited high school students who were in a science honors class to talk about their possible careers. From students' explanations about their possible careers, I found that students in the interview discourse frequently drew on different unquestioned repertoires to support their articulation of possible careers. In this study, I identified four interpretative repertoires: (a) formative, (b) performative, (c) consequent, and (d) potential. Each repertoire invokes different ways of connecting students to possible science careers. The four repertoires draw respectively on different dimension of actions—formations of actions, actions, effects of actions and action possibilities to articulate the relationship between students and possible careers. Through these interpretative repertoires, I better understand how students articulate both their individual agency and the collective structure constrained in science fields; what makes students connect to science and further choose it as a career; what constitute students' science-related identities. From the findings, I see students describe science careers in terms of "what is required for them to be able to be a science agent," "what they do," "what they do in relation to others," "and what they can do differently as a science agent." These ways of identification have important implications for educators and researchers, as they are discursive resources shared among and from students. Through students' identification of their preferred science careers, I further claim that students' science discourse identities are: (a) beneficiaries in the becoming process; (b) competent practitioners; (c) contributors to the world; and (d) lifelong learners.

Several recommendations for recruiting students into science are suggested: (a) help students overcome concerns regarding intellectual and time demands in becoming a science agent, and communicate the benefits and advantages in different stages of transformation; (b) expand students' personal experiences of science practices and offer science career-related internships or intensive science programs to students inside or outside schools; (c) illustrate the importance and implications of science practice, and discuss science's consequences or effects related to collective levels; and (d) increase motivation and achievements for students, and discuss potentialities and possibilities beyond current science practices. These recommendations from the findings are intended so that students can "develop an understanding of what science is, what science is not, what science can and cannot do, and how science contributes to culture" (National Research Council, 1996, p. 21).

We see a considerable difference between the frequency of interpretative repertoires in identifying science and non-science careers. That is, students tended to articulate science-related careers as something that requires more special and specialized characters or requirements than non-science careers. Thus, when students considered science-related careers, they would draw on more formative repertoires to articulate these. However, students used other repertoires (performative, consequent, and potential) more equally whether articulating science or non-science careers. From the frequency of interpretative repertoires, particularly questions about students' articulation of biologists before and after the science internship, we can see that students used fewer formative repertoires after the science internship, which might reflect that most students realized their capability of doing science in the internship and so did not emphasize that a biologist is a genius and special after the internship. As for the performative repertoire, after the internship, most students articulated these science practices as something rather impracticable. This result suggests a very important message regarding the issue of using science internships as a way to recruit more newcomers.

In the internship, the objectives discussed and negotiated among the scientists, researchers, and the schoolteacher were meant to provide students with opportunities to practice everyday work in the laboratory and invoke the connection between science and the life world. Thus, students were, for the most part, to practice science work in the laboratory and discuss the implications for society of each science project. However, the everyday work in the laboratory was mainly focusing on microbiology to identify bacteria or chemicals in the water. Much work was time consuming and repetitive to avoid contamination and get accurate results. These are realities in most laboratories, however most students claimed that they could not stand the waiting time and repetitive work.

As science educators, we face a dilemma for designing a science internship for students. Should we show the real life of scientists and technicians to students? Or should we design an internship in terms of what will attract students? For instance, should we speed up these science practices and skip the repetitive steps, so students can see the results right away? This issue should be considered and discussed individually in terms of the objectives governing the internships. However, the interpretative repertoires identified in my study allow me to reflect on students' participation in the internship and generate further suggestions for future science internships. That is, the four dimensions of actions in science practice should be equally discussed and communicated in science internships because they are the main repertoires students drew on to identify their science-related careers.

Applying the open-ended task—Possible Selves Mapping Interview (PSMI)—as a way to facilitate students' thinking of career choices sets up a positive interview example for collecting data in science education. It not only helps us obtain a more complete picture of students' articulations of career choices but also allows an increase of students' self-determinations, as compared to structured or traditional semi-structured interviews. The findings of this study also have implications for educators, researchers and teachers to generate career-counseling services especially focusing on science for high school students, as we now better understand how students may identify or dis-identify their possible science-related careers.

CHAPTER 6: NATURAL PEDAGOGICAL CONVERSATIONS IN A HIGH SCHOOL STUDENTS' INTERNSHIP

Preface

When high school students finished the internship, the technicians and scientists praised them for their learning. For instance, one technician said, "Especially in the last discussion, I was surprised at how well they were able to put it into context. I was surprised when they started talking about debt relief and all this other kind of stuff. I was like, okay, that's awesome someone has a good idea of the bigger picture." However, as mentioned in the research-design section, technicians have no educational background or pedagogical training, so how do students "learn" science in such an informal setting! This made me wonder what mechanisms or structure allowed these non-teachers to "teach." The question of how they "teach" students and how students "learn" from them became a starting point to finding out what is going on during the internship; it resulted in this chapter. If I could understand the process of learning in an informal setting, the findings could serve as fundamental pedagogy for everyone, with or without pedagogical training. The findings would not only help educators of informal science learning but also schoolteachers and educators. Therefore, the chapter's research question asks:

"How do teaching and learning happen naturally during a science internship?"

This chapter is based on collaboration with the following authors and has been accepted in the Journal of Research in Science Teaching.

Hsu, P.-L., Roth, W.-M. & Mazumder, A. (in press). Natural pedagogical conversations in a high school students' internship. *Journal of Research in Science Teaching*. DOI: 10.1002/tea.20275.

Abstract

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

6.1. Introduction

The American Association for the Advancement of Science (AAAS) and the National Research Council (NRC) have argued that K–12 science education needs to move beyond didactic instruction to a more constructivist, inquiry-based pedagogy in which students engage in "authentic," long-term science investigations (Soloway et al., 1997). The term *authentic* here is meant to denote forms of engagement that have a considerable degree of family resemblance with what scientists and technicians in science-related fields really do in their daily work. Some science educators interested in providing their students with "authentic" experiences therefore create opportunities for middle and high school students to work at the elbow of scientists and technicians in science laboratories (Barab & Hay, 2001) or at the elbow of environmentalists (Roth & Lee, 2004). Authentic science activities are important in promoting inquiry because they provide natural problem-solving contexts that exhibit a sufficiently high degree of complexity to make them interesting (Lee & Songer, 2003). Internships in science research settings and internship-like learning environments have received increasing attention as a means of helping students construct and appropriate understandings, practices, tools, and language used in scientific activity (Varelas, House, & Wenzel, 2005).

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

6.2. Background

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

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

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

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

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

6.3. Study Design

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

6.3.1. Ethnography of School Science and Career Preparation

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

The teacher involved in this study had 26 years of teaching experiences and was the head of the science department. In this course, she guided students to learn biology through lectures, experiments, demonstrations, etc. She also used multiple resources to buttress her teaching, including videos, microscopes, dissection equipment, textbooks, overheads, chalkboard, and newspapers, etc. In addition to teaching eleventh-grade biology, the teacher arranged and conducted a variety of scientific activities in which students can participate. To ease her task, the school released her from one course of teaching. There were many career preparation courses in this school, including in the arts, carpentry, human services, and music. The biology career preparation course in this study was the only academic career preparation course that related to fundamental science (e.g., biology, physics, chemistry, and math) in the entire district (8 high schools in this school district; some of the high schools in the suburbs had science and environment programs). The career preparation course was funded by the school district, allowing the school to finance some student learning resources, such as science magazines, microscopes and bus tickets for visiting science laboratories.

6.3.2. Ethnography of the Scientific Laboratory

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

The laboratory members included the chief scientist and head of the research program, a laboratory manager, three scientists, five postdoctoral fellows, one administrative assistant, 28 technicians (e.g., field managers, research assistants, graduate students et al.), and a large and more frequently changing number of undergraduate co-op students. Technicians were the main contacts for the high school students throughout the internship. Most technicians were in their

20s or 30s and have biology-related majors. Technicians usually worked in the laboratory for eight hours a day and had lunchtime and coffee break time and sometimes collected samples in the field. There were many different projects going on at the same time and technicians often went back and forth in the laboratory to use different equipment and instrument for their work, or even went to other laboratories for different instrument if necessary. The atmosphere in the scientific laboratory was energetic and collaborative. For instance, music is playing in the background during laboratory work, members chated over lunch or coffee, and lab members had celebrations on special days such as dressing in Halloween and holding Christmas party in the laboratory.

6.3.3. Participants and Participation

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

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

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

6.3.4. Data Sources and Analysis

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

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

6.3.5. Reliability and Validity

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

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

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

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

6.4.1. Participation Trajectories

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

I found that similar participation patterns occurred regularly despite the difference between tasks. The three main phases include *demonstration*, *practice*, and *connection*. In the *demonstration phase*, Nora usually introduced the purpose of the task and demonstrated the techniques at the same time. She either stood or sat in front of the equipment and the students gathered around her to watch the demonstration and clarify Nora’s actions prior to engaging in the tasks themselves (Figure 6.1). In the *practice phase*, Nora invited students to do the rest of the work while she stood beside the practicing individual to monitor his or her practice. The students continually checked their actions with Nora. The other students would watch their peer’s actions, clarify their understanding of these actions, observe other aspects of the environment, and ask relevant questions. With easier tasks, if space was available, the three students would sometimes practice together. In the *connection phase*, Nora usually explained the connection between the previous task and the next step by showing concrete results from the previous task. Because of the invisible nature of microbiological objects, students could not easily observe what they had done. Nora always prepared some concrete samples or pictures to show them the results of similar actions before starting the next task. For example, after filtering water with a pump, the paper filters need to be incubated overnight to allow bacteria to grow on the plates so that they can be observed with the unaided eye. In this case, after practicing the filter techniques, Nora would show samples that already had been incubated overnight. She explained the purpose of the previous task and made a connection to the next task (e.g., "Nora: so tomorrow these guys will look like these [agar plates with growing bacteria patterns on them]. Cindy: Oh, and then just like so much *E. coli* in there!").

Figure 6.1. In the internship, both groups of students observe their technician's demonstrations in the laboratory.

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

During the five days of internship, there were a total of eighteen tasks with practice phases. By counting all the D-P-C sequences in five days, on average, 36.2%, 53.0%, and 10.8% of the time was spent in the demonstration, practice, and connection phases, respectively. Figure 6.2 exemplifies the temporal structure on one of the five days and shows that the practice phases are the longest among the three phases. Day 1 contained 5 tasks that took different time periods to be accomplished. For instance, in Task 2, the technician took 3:25 minutes to demonstrate how to collect bacteria from water sample by using pump and paper filters and three students took 4:35, 4:52 and 9:25 minutes, respectively, to practice the technique. Then the technician took 2:43 minutes explain how this techniques connect to this next task—picking bacteria from paper filter and nurturing them on agar. Further, in the trajectory of doing science, many actions were implemented in each phase. For instance, in the demonstration phase of Task 2, many actions occurred.

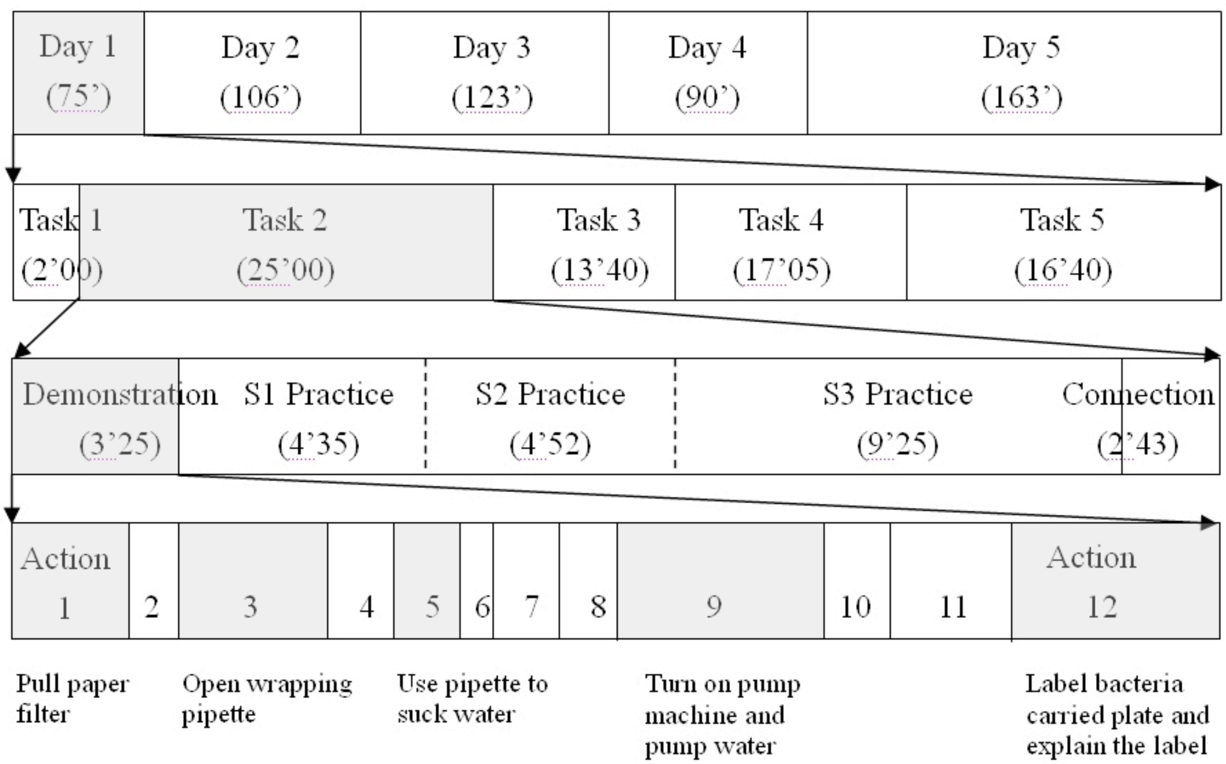

Figure 6.2. The trajectory of internship in doing science.

Twelve actions were identified as main actions in terms of what these technicians explicitly orientated and said. From (a) pulling out the paper filter from a package, (b) putting the paper filter on the pump bottle, (c) opening wrapped pipette, (d) putting pipette on pipette handle, (e) using pipette to suck water, (f) squirting sample water into pump bottle through filter paper, (g) using pipette to suck water again, (h) squirting sample water into pump bottle through filter paper again, (i) turning on the pump machine for pumping air out of pump bottle, (j) picking paper filter from pump bottle, (k) putting paper filter on medium plate, and (l) labelling the bacteria-carried medium plate. The technician orchestrated the participation trajectory during the internship by connecting the sequence of techniques step by step from collecting bacteria to identifying their DNA host with support of showing gradual results.

6.4.2. Transactional Structures

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

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

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

Episode 1 (022110345)

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

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

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

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

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

Episode 2 (022111230)

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

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

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

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

Episode 3 (040311100)

1	Cindy:	cool (1.53) this is how many times it's spinning↑((the	I
2		right hand points to the screen of micro centrifuge))	
3	Nora:	that's how fast it's spinning. ((the left hand points to	R
4		the screen of centrifuge)) (1.21) um:: (0.38) what is that	
5		measurement then (.hhh) (1.52) RPM (1.03) rounds per	
6		minute(1.33) or revolutions per minute I guess::	
8	Cindy:	so every minute only goes around ten times↑	C
9	Nora:	UM:: ten thousands times.	R
11	Cindy:	OH:::↑OH [times a thousand.	C1
12	Nora:	[times a – YA:::↑	R1
13	Cindy:	I was like that is <QUITE slow:::> like I thought it was	C2
14		like sh::((right index finger whirl in the air))	
15	Nora:	oh ya it's going fast.	R2

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

My analyses show that the I-R-C-R based conversation transactions serve a special function: participants, especially students, actively initiate a conversation by asking questions without having explicit facilitation from others. In this way, some tacit knowledge that normally goes without saying comes to be made salient, noticed, and explicitly discussed. Thus, active participants evolved better and more fruitful understandings. As we can see, I-R-C-R transactional structures have similar and overlapping portions with I-C-R transactional structures. They both have I-C-R structures but I-R-C-R structures have one more "R" after "I." In this study, the technician usually initiated I-C-R structures while students preferentially began I-R-C-R structures (see more detail in Table 5.3). That is, in this study students began a lot of clarifying events during their internship in the science laboratory.

6.4.3. Organization of Natural Pedagogical Conversations

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

6.4.3.1. Preference

In the following sections, I am interested in how the technician and students respond each other according to the *preference organization* introduced in conversation analysis. Preference is an organizational form that realizes the mechanism of sequence- or turn- organizational features of conversation rather than expressing the motivation of participants (Sacks, Schegloff, & Jefferson, 1974). Actions that are performed in a straightforward way and without delay generally coincide with "preferred" responses, whereas those that are delayed, qualified, and accounted are associated with "dispreferred" actions (Heritage, 1984). In terms of preference, besides preferred and dispreferred organizations, I found an interesting dispreferred preference organization—*ambiguous dispreferred preference*—which is different from the preferred or dispreferred terms and indicates a simultaneously preferred and dispreferred organization. To avoid confusion, I named the extremely opposite response to the preferred one *obvious dispreferred response*. In the study, these ambiguous dispreferred preferences were identified in three different contexts: (a) offer/invitation, (b) assessment, and (c) self-inadequacy/deprecation. The responses of three different contexts of preference organization are listed in Table 6.1. In the following paragraphs, I exemplify these ambiguous preferences from both groups' conversations.

Table 6.1. Preferred, dispreferred and ambiguous preference organization in apprenticeship.

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

6.4.3.1.1. Offer/Invitation.

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

Episode 4 (022110718)

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

```
05  Cindy   =oh okay=
06  Nora    =if (0.85) I don't know
```

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

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

6.4.3.1.2. Assessment.

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

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

```
Episode 5                                                    (022110630)
 01  Cindy:  Okay (.) so (.) just take one twenty five↑
 02          ((right hand points to the pipette))
 03  Nora:   Um,Ya (.) but you want to put the filter on first
 04           ((points to the filter))
```

Demonstrating how to filter the water included putting the paper filter on the pump filter, covering it, using the pipette to "suck" 25 millilitres of water, and squirting it into the pump filter. Cindy is the first student to practice this task, and before her action, she checks with Nora "Okay, so, just take one twenty-five?" (5:01) while her right hand moves towards the pipette. Here, Cindy apparently forgets that the first step is to put the paper filter on the pump filter and she tries to start using the pipette to suck up the water. Despite the wrong sequence, Nora does not directly say "No" but "Ya" (5:03) and suggests doing another action first: "Put the filter on first"

(5:03). Here, Nora responds ambiguously to Cindy's assessment. She agrees with Cindy's assessment but also slightly disagrees and suggests the alternative sequence. The ambiguous preference in the assessment context supplies a bigger timescale for responding to students' understanding rather than just judging the present action. Therefore, students not only may come to understand what they should have done but also may come to anticipate what their next steps ought to be.

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

6.4.3.1.3. Self-Inadequacy/Deprecation.

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

Episode 6 (022110800)

```
01   Cindy:  what a mess here ((laughter))
02   Nora:   that's okay (.) so am I. ((continue next actions without
03           correcting the mess))
```

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

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

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

6.4.3.2. Formulating

Formulating is a pervasive feature of talk to focus participants' attention on what is going on (Roth & Middleton, 2006). For instance, in the sentence "May I ask you a question?," before I ask a question, I formulate my own action in the next seconds, that is, to ask a question. In terms of this conversational feature, I found three different kinds of temporal characteristics in the internship: (a) prospective, (b) simultaneous, and (c) retrospective formulating. My ethnographic work shows that these three characteristics have different functions. In addition to *self-formulating*, I also find *other-formulating*, a category to describe a situation in which one participant formulates what another is doing or has done. Further, both self-formulating and other-formulating have prospective, simultaneous, and retrospective features in the internship. The respective functions of each feature are listed in Table 6.2, and characteristic episode featuring are exemplified and described in the following subsections.

Table 6.2. Self-formulating and other-formulating conversation features in the apprenticeship between students and technicians.

Conversation feature	Self Formulating		Other Formulating	
	Technician	Students	Technician	Students
Prospective	Guide	Assess	Guide	Assess/*Guide
Simultaneous	Guide	Inform	Guide	Assess/*Share
Retrospective	Confirm	Share	Evaluate	Assess/*Assess

* Students formulate peer' actions (between students).

6.4.3.2.1. Self-Formulating.

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

```
Episode 7                                                  (022110426)
01   Nora:   and then we're gonna scrape this guy off (2.64) ((right hand uses
02           tweezers to pick out the paper filter)) one of you guys wanna
03           to open one of those↑ ((left hand points to plates on the desk))
04           I'm sure I have done that before (0.63)
05   Cindy:  okay (2.28) ((opens one of the lids))
06   Nora:   and we'll just (0.66) put the filter paper (0.5) ((puts filter
07           paper on the open plate)) right on (1.11) and make sure it's
08           (1.07) fully down there's no little air bubbles underneath
```

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

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

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

6.4.3.2.2. Other-Formulating.

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

Episode 8 (022110730)

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

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

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

Episode 9 (033113730)

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

After observing Cindy practicing in the fume hood, which is made of glass, Nora says to Kelly: "See, notice how her hands are all the way inside the flow"(9:01). This *retrospectively formulates* what Cindy has done; she then *evaluates* and comments on Cindy's action "That's good" (9:04). Further, Nora formulated Cindy's condition—Cindy got used to working in front of the glass (9:04). In the other-formulating actions, technician and students guide and formulate the way for others about how things could be done by others. That is, participants are more likely to accomplish the practice successfully when they recognize that the other-formulation articulates what they currently do; and they have a resource for retrospectively establishing the quality of their own actions in terms of what the other-formulating action has established.

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

These self-formulating and other-formulating actions in the internship by technicians and students served different functions (Table 6.2). These technicians formulated their actions prospectively and simultaneously, which guided students to see what the former wanted them to see and formulated their own actions retrospectively, which provided and confirmed descriptions for what has been done. Technicians also formulated students' actions prospectively and simultaneously to guide their practices and retrospectively formulated what students has done to evaluate their actions. As for students, they formulated themselves prospectively to assess the accuracy of their oncoming actions. They formulated themselves simultaneously to inform others about their actions and formulated themselves retrospectively to share their experience with others. In addition, students formulated the technician's actions to assess their understanding of what they were seeing. Moreover, students formulated peer's actions prospectively to guide, simultaneously to share experiences and retrospectively to assess peer's accuracy of actions. Through these different formulating actions, I observed the participants' dynamic roles in and during the internship. These technicians sometimes were guides, at other times they were evaluators; and students were assessors, informers, guide, or experience sharers. That is, students were not just students who learn from the technician but could be a guide or teachers for their peer or experience sharer for either the technician or peer.

6.5. Prevalence of Observed Patterns

In the internship, students had numerous opportunities to practice "doing" science, their dynamic transactions provided a great resources for the purpose of finding tendency and patterns. To overview these transactional structures, natural conversation organizations, and features in the five days long internship, I pick the beginning, middle, and closing stage in the internship to represent different stages in the internship. Each stage extends for about 40-45 minutes and all three stages include the participation of the technician (Nora) and three students (Cindy, Kelly, and Joe). During the three stages, I indicate who initiates the conversation by using "T" to represent technician and "S" to represent student. Following the turn-taking principle in conversation analysis, all these frequencies are counted by the unit of turn taking no matter how many sentences the participants said. That is, one turn may have ten sentences or only one word or just a gesture or body movement. For I-C-R and I-R-C-R transactional structures, I usually identified the C (clarify, confirm or concern) first and then extendedly found the surrounding turns. As for preference organization, the forms of response are the cues for coding in terms of turn taking too. With regard to formulating, I coded these different types of formulating by watching videos and transcript together to ensure their orientation and timing of formulating and the boundary is the different forms of formulating. For instance, in demonstration phases, Nora used a lot of self-formulating, and the defining feature of self-formulating would be whether it is prospective, simultaneous, or retrospective.

Table 6.3. Frequencies of transaction structures, natural conversation organizations and features.

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

Table 6.3 shows the frequencies of transaction structures, natural conversation organizations, and features in different stages of the five-day internship that totaled about ten hours. Meanwhile,

transaction structures are represented in terms of I-C-R and I-R-C-R structures, natural conversation organizations are represented in terms of different contexts (offer/invitation, assessment and self inadequacy) and natural conversation features-formulating were represented by different orientations (self-formulating & other-formulating) and different timing (prospective, simultaneous and retrospective). These frequency results of transactional structures, natural conversation organizations and features are described in the following paragraphs in terms of different stages (beginning, middle & closing) of the internship and demonstrated with bar graphs.

6.5.1. Transactional Structures

The investigation of transaction structures allows me to see the conversation structures in the internship, and further to see the changing dynamic transaction between technicians and students over time. Two issues in particular are salient in transaction structures. First, *I-C-R structures are more frequent in T-initiated transactions; I-R-C-R structures are more frequent in S-initiated transactions.* During I-C-R structures (N = 41) in the three stages, T-initiated transactions occurred 36 times (88%), meanwhile in I-R-C-R structures (N = 29), S-initiated transactions occurred 27 times (93%). This result shows that T-initiated transactions are dominant in I-C-R structures, but S-initiated transactions are dominant in I-R-C-R structures. That is, students adopted a lot of clarifying actions in the internship. Second, *diverse transaction structures tendency.* By looking at the frequency from the beginning to the closing stage, I found that the transaction structures have a diverse tendency (see Figure 6.3). That is, in the beginning stage only the technician initiated I-C-R but in the end of the internship, I-C-R could also be initiated either by the technician or by the students. Namely, at the end of the internship, the technician used more clarifying actions to respond to students' initiation. Likewise, in the end not only students initiated I-R-C-R, but the technician also initiated some issues, and had further clarifying actions, in order to get responses from students.

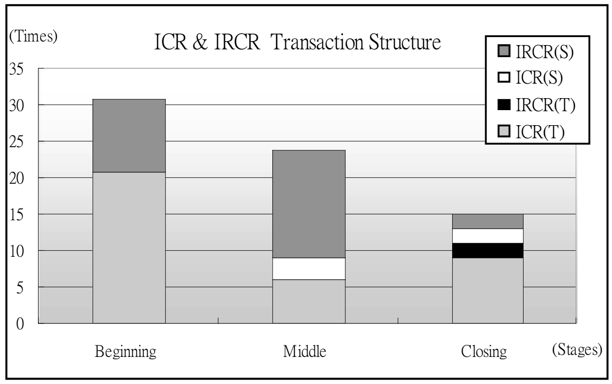

Figure 6.3. Frequency of ICR and IRCR in different stages of the apprenticeship. ICR (T) and IRCR (T) indicate that the technician initiated these transaction structures; ICR (S) and IRCR (S) indicate that students initiated these transaction structures.

6.5.2. Natural Conversation Organizations

Studying the conversation organizations allows me to better understand how participants interact or respond each other. For instance, from the response of students to technicians' previous introduction or response of technicians to students' previous questions, I can realize how well the teaching and learning unfold in the internship Five phenomena in particular are salient in the conversation organizations. First, *preferred responses occurred more frequently than obvious dispreferred and ambiguous dispreferred.* In total frequency, I can see preferred responses are the most frequent preference (*N* = 113 [63%]) and same phenomenon occurred in each stage as well (See Figure 6.4). That is, the technician and students both generally acted intelligibly for the other so that a preferred response could happen all the time.

Second, *assessment contexts happened more frequently.* In the three frequent contexts (i.e., offer/invitation, assessment, and self inadequacy/deprecation), assessments are the most frequent context in the internship (*N* = 138 [77%]). The assessment discourse allowed the technician and students to assess the other's actions and make them intelligible to each other. In assessment contexts, 62% (85 out of 138) of responses are preferred. That is, students generally had an understanding of what was going on, because, to get a preferred response, students needed to understand the demonstration or knowledge explained by the technician. For instance, the assessment question from students: "Should I sterilize the tweezers now?" To get a preferred response from the technician "Yes," students needed to be aware that they should sterilize the tweezers beforehand.

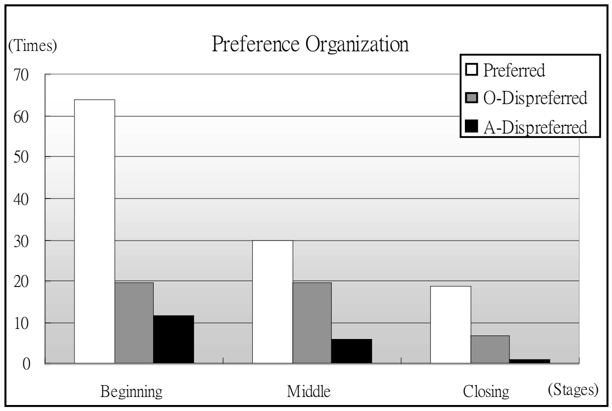

Figure 6.4. Frequency of different preference organizations in different stages of the apprenticeship.

Third, there was a *decrease in assessment tendency.* I can see the times of assessment decrease from the beginning (*N* = 71 [52%]) to the end (*N* = 21 [15%]) of the internship (see Figure 6.5). This result shows that with time went by, the technician and students were more familiar with each other and the tacit knowledge of scientific work so that they did not need to assess others' actions so often.

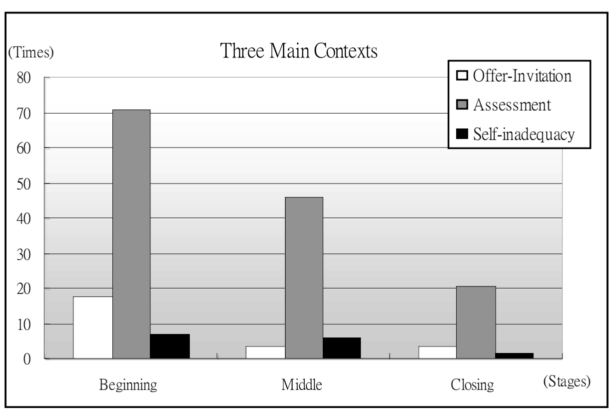

Figure 6.5. Frequency of different contexts in different stages of the apprenticeship.

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

Fifth, *T-initiated self-inadequacy is responded to with ambiguous dispreferred organizations.* When the technician revealed her inadequacy in the internship, students always (*N* = 3 [100%]) responded to her in an ambiguous way—"silence."

6.5.3. Natural Conversation Features

Investigating conversation features-formulating, I could see how participants articulated their own or others' actions to direct others for their target behaviors. Two issues in particular were salient in the conversational feature formulating (See Figure 6.6). First, *there were frequent self-formulating actions.* I found that self-formulating actions were used a lot by both the technician and students in the internship (*N* = 201 [58%]). Technicians and students frequently used this way to make sure that their actions are intelligible to others. Second, I observed *prospective formulating is more than simultaneous and retrospective*. According to the timing, prospective formulating is the most frequent formulating action (*N* = 213 [61%]) in the internship. With this organization, a technician prepared students to see what she wanted to be observed and students could assess the correct actions in their practice.

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

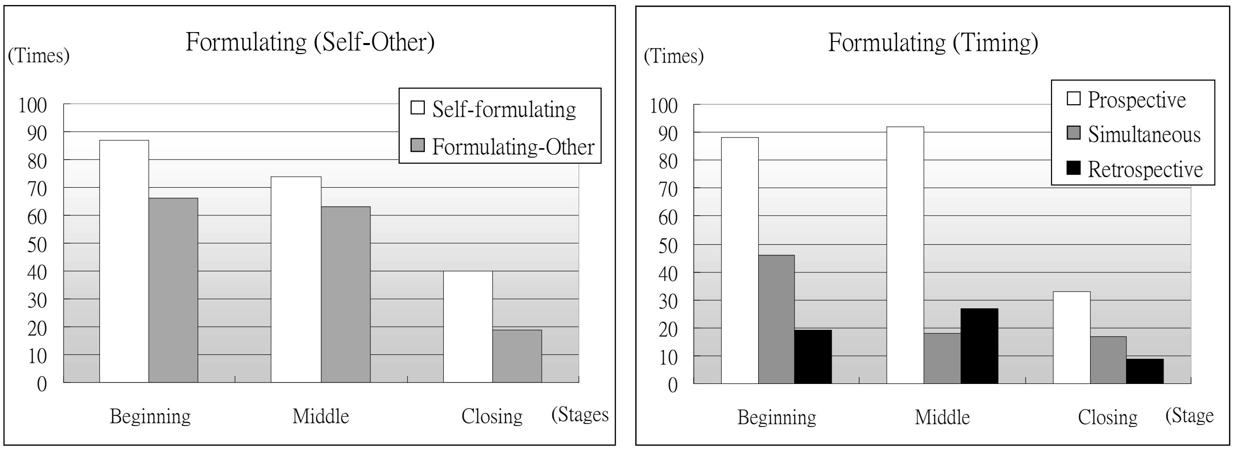

Figure 6.6. Frequency of different formulating actions in different stages of the apprenticeship.

6.6. Discussion and Implication

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

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

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

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

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

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

CHAPTER 7: LAB TECHNICIANS AND HIGH SCHOOL STUDENT INTERNS—WHO IS SCAFFOLDING WHOM?: ON FORMS OF EMERGENT EXPERTISE

Preface

In most previous studies on students' partnership with scientists, the researcher described the project as apprenticeship activities (Collins, Brown, & Newman, 1989). Through the process *of modeling, scaffolding and fading*, students (newcomers) gradually learn the work of science from scientists (old timers). In addition to the concept of apprenticeship, educators proposed the concept of *legitimate peripheral participation* (Lave & Wenger, 1991) to describe students' learning trajectory from peripheral to core participation in communities. When I read these theoretical concepts in the literature, I could not wait to use the concepts to explain my internship data. However, two concerns emerged about "fitting" my data into the theoretical concepts. First, I found the concepts did not fully explain my data, and contradictions existed between my data and the concepts. For instance, the scaffolding phase seemed not always a case where technicians scaffolded students, but students could scaffold technicians. Second, I found these theoretical concepts only explained the big picture. When I tried to understand students' micro levels of interaction with technicians, the concepts did not help me. Therefore, I felt it was necessary to propose different theoretical concepts to explain and describe the internship data and findings. Thus, the big question for this chapter is:

"How does science expertise unfold in a science internship and what are suitable theoretical concepts to describe it?"

This chapter is based on collaboration with the following authors and has been accepted to the journal of Science Education.

Hsu, P.-L., & Roth, W.-M. (in press). Lab technicians and high school student interns—Who is

scaffolding whom?: On forms of emergent expertise. *Science Education*. DOI: 10.1002/sce.20289

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 chapter is to report the results of an ethnographic study of high school students' internships in a scientific laboratory. Data were collected through observation, field notes, and videotaping. Drawing on discursive psychology and conversation analysis, I find that laboratory technicians and students draw on different forms of discursive strategies to articulate knowledgeability while transacting with each other. I 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. My 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.

7.1. Introduction

Both the American Association for the Advancement of Science (AAAS, 1993) and the National Research Council (NRC, 1996) argued that K–12 science education needs to move beyond didactic instruction to more authentic science practice where students come to engage like 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, etc.) 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-defied 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, I invited high school students from a Canadian public school to work with scientists/technicians in a neighboring university biology laboratory. One of the purposes of my project generally was to connect the resources in the community (e.g., between high schools and universities), as I 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 my analyses, I put forth the notion of *emergent expertise* to help us understand internship (apprenticeship-like) learning in science settings.

7.2. 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, I 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, Bruner, & Ross 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, I illustrate aspects of mutuality in lab 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, I 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, I am 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, I 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, I do not presuppose individuals' roles as experts or novices but focus on participants' transactions and see what has been produced in their transactions. I 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.

7.3. 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.

7.3.1. 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 chapter, my specific foci are the transactions between high school students and technicians who directly interact with students. In my 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). I therefore denote the experiences as "apprenticeship-like" or "internship" activities. Before inviting high school students to the university science laboratories, I 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 mid-sized Canadian city where they had enrolled in an eleventh-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 two 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 the collaborating science laboratory included 2 male and 11 female students. Meanwhile, I conducted a six-month ethnographic study of the laboratory to become familiar with the scientific projects before the high school students' arrival. I 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.

7.3.2. 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 these 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 5 technicians (3 females and 2 males; 22-30 years old; 4 Caucasian and 1 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 laboratory 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: 12-14hours) in each group and the internship activities were observed and videotaped over the course of two months. The high school students started the internship by reading some relevant scientific papers selected by these 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 7.1). 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 the 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 7.1. High school students interact with the scientific technician in the internship.

7.3.3. Theory of Method

In this study, I 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, I analyze the internship transaction in terms of these three principles rather than presupposing participants' mental states. For instance, when students mention some non-scientific statements, I do not interpret that students "have" particular conceptions, but focus on the available resources, situations, and transactions in that discourse. Likewise, I am 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, I particularly use the internship's naturally video recorded data sources, detailed transcripts, participants' real time responses to support my 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.

7.3.4. Data Sources and Data Analysis

In the process of this internship project, I collected a total of 122 videotapes and hundreds of pages of field notes. For this study, I am 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 two months of observation, field notes, and 15 videotapes (each about 50–90 minutes) of internship activities. I transcribed all the videotapes and adopted basic Jeffersonian system symbols (Atkinson & Heritage, 1984, see Appendix) to demonstrate the episodes for the study. Through repeated watching of the videotapes and reading the transcripts and field notes, I found patterns of variation and consistency in a range of features that allowed me to map out the ways technicians and students draw on to make each other available to accomplish the internship activities. To validate my data analysis, I provide detailed transcripts allowing readers to assess as much data as researchers had to check or challenge my claims. For instance, I 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 my study, as my data consists mainly of naturally occurring talk in its authentic social setting. Thus its ecological validity is strong compared to other research methods (Seedhouse, 2005). I also pay extra attention to participants’ orientations and responses (the emic point of view) to support my claims. To further establish the credibility of my data analysis, I adopted several techniques from fourth-generation evaluation (Guba & Lincoln, 1989). To satisfy the criterion of *prolonged engagement*, I interacted with technicians and students for at least six months, went to school to observe the class every day for one month, and observed scientific work in laboratories to build up a trusting relationship. I took field notes 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 my 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), I 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 me to reduce privilege and satisfied the criterion of *progressive subjectivity*.

7.4. 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 these technicians, the students' main points of reference, have no educational training. Thus, my 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. I 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 me to propose the idea of *emergent expertise* to characterize the apprenticeship-like transactions between experts and novices. In this study, I 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 non-verbal) and tools—as an approach to describe the apprenticeship-like learning process in authentic science laboratories. That is, I 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 7.1.

In the following sections, I 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 me 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.

Table 7.1. 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	(a) Demonstrating techniques with body movements and orally explaining its purpose	(a) Formulating technicians' tacit techniques beyond technicians' instruction through their observation	7 (3%)
Making linking relevant understanding available	(b) Checking or commenting on students' understanding of technicians' instruction	(b) Sharing relevant understanding from school science or everyday life	22 (9%)
Making assessment and clarification available	(c) Opening space for students' assessments and providing immediate feedback to respond to students' assessments	(c) Assessing or clarifying their understanding or adequacy of actions	155 (62%)
Making independent practice available	(d) Supplying opportunities and achievable tasks for students to work independently	(d) Engaging themselves in practice	28 (11%)
Making practice-improvement available	(e) Sharing or considering possible solutions improve practices	(e) Practicing or offering possible solutions for improvement	15 (6%)
Making connection between concepts or practice available	(f) Supplying the whole picture of tasks and gradational results in tasks with visible tools and objects	(f) Connecting the present technique to its purposes or next/precious steps	22 (9%)

Although I also identified similar discursive strategies used by other technicians and students, for the purpose of illustrating my claims clearly, I 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 me 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, etc.) to identify sources of fecal contamination (i.e., *E. coli*) in surface water. In the group, three high school students (Cindy, Kelly, and Joe) follow 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, I 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. I watched videos and transcripts simultaneously and took turn taking as my 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, I would not consider it as a complete unit. From the frequency results in Table 7.1, I 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 7.1, and I 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.)

7.4.1. 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. My 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; I 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.

7.4.2. 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?" My 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, I show how students help the technician to "re-teach" 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)
Kelly:   are you dragging it from the circle [when you]
Nora:                                                    [YES=
Kelly:   =okay=
Nora:    =you picking up bacteria and you're drag it all along.
         ((moving hands in the air to imitate actual doing))
         (1.35)
Cindy:   That's so cool:: (1.08) heh:: the guys ever seen in the
         pictures it was like I'm so
Kelly:   =ya=
Cindy:   = intricate I was like how do they DO that like↑
         ((hands are moving to do the cultivating on plates))
         (0.94)
Kelly:   I thought it just the colonies like movie heh (hhh)
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). Further, 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, I 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, I 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 if different ways of interpretation or instruction were formulated for them.

7.4.3. 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, I 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, I 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, I 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)
Cindy:  OH:::↑OH [times a thousand.
Nora:            [times a - YA:::↑
Cindy:  I was like that is <QUITE slow:::> like I thought it was
        like sh::((right index finger whirl in the air))
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, I can see that Cindy may misunderstand the original explanation from Nora (i.e., ten 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, I 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.

7.4.4. 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, my 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 points out the need for connection immediately and so these technicians could have opportunities to notice when and how to enhance these connections. In the following episode, I show how students initiate these opportunities for these 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, I 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, I 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)

Cindy: what’s that doing
Nora: pardon↑
Cindy: Like (.) what are you like
Nora: this is purification
Cindy: O::kay
Nora: um:: ((drawing lines on the agar))
Cindy: OH: so you’re only taking out the E. coli or whatever and then
((Nora continues drawing lines on the agar))
Nora: EXACTLY ((drawing lines on the agar))
Cindy: I see
Nora: ((sterilizes the scraper, continues and then finishes the plating actions)) ya (.) because this stuff ((holds the new agar plate)) here is a really good nutrient base ((puts down the new agar plate)) whereas this stuff ((holds the old agar plates)) isn’t great, but you can just tell what is and what isn’t E. coli↑
Cindy: mm:
Nora: um:: so (.) has to look like E. coli on here ((points to the old agar plate)) and then it has to look like E. coli on here ((points to the new agar plate)) and then we’re REDOING this step so we’re taking the colony off here ((points to the old agar plate)) putting it onto another one of these plates ((points to other new agar plates))
Cindy: Oh, really↑
Nora: um: just to (.) make sure all the way along (.) we have E. 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., scarp only one colony of *E. coli*). However, from Cindy’s question about its purpose, I 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 ole agar plates) to buttress herself and students to achieve the common understanding. Here, I 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 allows students to better understand the present step but also connects to a bigger picture (differences between steps) that helps 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.

7.4.5. 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)—my analysis of the internship transaction shows that the boundary of experts and novices is not clear and so should not be predetermined. I 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, I 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)
35           there you go now pull (1.38)
31   Cindy:  ((grips the paper filter and pulls it out of the package))
32           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 seconds (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" (5:30). Finally, Cindy grips the paper filter and pulls it out successfully with Nora's formulating and so follows with a celebration sound "yeah" (5:31-35).

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 me 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.

7.5. 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, I 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 me 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).

My analyses demonstrate different forms of knowledgeability (see Table 7.1) 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, I 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, I 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.

I 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, these technicians in my 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* these 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. Afterwards, "authentic student voices" may then be able to consulted to create local and personalized curriculum to improve education (Thomson & Gunter, 2006).

In this study, I 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, I argue that expertise is not a property that belongs to individuals 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 autonomy 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, I 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.

Concerning the notion of emergent expertise, I now argue that expertise is not constituted in individuals but emergent from participants' 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 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 understand *how* to achieve an equitable, student-centered, and empowered education.

CHAPTER 8: FROM A SENSE OF STEREOTYPICALLY FOREIGN TO BELONGING IN A SCIENCE COMMUNITY: WAYS OF EXPERIENTIAL DESCRIPTIONS ABOUT A HIGH SCHOOL STUDENTS' SCIENCE INTERNSHIP

Preface

During the internship, I conducted brief interviews (about 10 minutes) with students about their experience after the internship participation for that day. Although I had accompanied them and video recorded throughout the internship, without their experience, I would not have been able to understand their point of view about the internship. For instance, one girl talked about how proud she was to be able to participate in the science internship, and so her family and friends were happy for her and excited about the activity. "I'm so excited and happy about this! I was called 'the nerd' today 'cause I told them what I was doing, and they're like, 'Oh, geek! No man! It's so cool!'" Before students' sharing experiences, I assumed they might deem the internship one of the routine activities in their career-preparation course. Therefore, although I was so excited about the internship project, I did not expect that these "experienced" students would be so excited about it as well. For me, the brief interviews helped me to see the internship through students' eyes and understand the meaning of the science internship for them. In addition, these interviews helped me to see what I did not expect to see in the first place. I listened to people's experience of the internship, which widened my horizon so that I could see different dimensions of the internship. Thus, to know more about people's experience in the internship, I decided to conduct a formal interview with all key participants (including the students, their teacher, technicians, and scientists) to gain a systematic understanding. Inviting students to do science in scientists' laboratories is an innovative method of research in science education. Investigating participants' experiences of a science internship could help educators and researchers to understand wider dimensions of the internship. Furthermore, these experiential descriptions could provide students with different ways of experiencing a science internship and so they could learn from these experiences. Thus, the big question for this chapter is:

"How do participants experience a science internship?"

This chapter is based on collaboration with the following authors and has been submitted to the journal of Research in Science Education.

Hsu, P.-L., & Roth, W.-M. (submitted). From a sense of stereotypically foreign to belonging in a science community: Ways of experiential descriptions about a high school students' science internship. *Research in Science Education*.

Abstract

Science educators often suggest that students should learn science in ways and settings that bear family resemblance with “the real thing.” Internships in science laboratories constitute one such way in which students may learn science and learn about science. However, very little is known about *how* participants (especially students) experience a science internship in an “authentic” science setting (i.e., a science laboratory). The study was designed to understand the nature of participants’ experiences of “authentic science.” Participants included 11 high school students, 1 high school teacher, 5 laboratory technicians, and 2 scientists. High school students practiced science alongside technicians (young scientists) in real ongoing projects of a biology laboratory. Data sources include 19 semistructured, video-recorded interviews held after the 2-month science internship. Drawing on phenomenographic method, I identified five categories of experiential descriptions : (a) authenticity of university science; (b) channeling and connecting different communities (school, research); (c) advanced knowledge required in and lengthy procedures mobilized by university science; (d) self-exploration and reflection; and (e) comprehensive science learning. Each category’s meaning for participants and implications for science education are illustrated and discussed. This study demonstrates positive evidence of the science internship on helping students learn different dimensions of science and their relationship with science. Suggestions on facilitating the partnership between secondary and postsecondary education are provided.

8.1. Introduction

The American Association for the Advancement of Science (AAAS, 1993) and the National Research Council (NRC, 1996) both argue that K–12 science education needs to move beyond didactic instruction to a more authentic science practice where students engage themselves like scientists. The term “authentic” here is meant to denote forms of engagement that have a considerable degree of family resemblance with what scientists and technicians in science-related fields really do and experience. Authentic science activities are important in promoting inquiry because they provide natural problem-solving contexts with a sufficiently high degree of complexity to make them interesting (Lee & Songer, 2003). Numerous studies investigated student-scientist partnerships, where students and scientists participate together in activities like a project or camp (e.g., Lawless & Rock, 1998). For instance, students may collect real data (e.g., air temperature, clouds, precipitation, etc.) and scientists analyze these data to address real-world questions. The partnership can stimulate students to think creatively, learn science inquiry, communicate with scientists the quality issues of data measurement and interpretation, and so on.

Internships in science research settings and internship-like learning environments have received increasing attention as a means of setting up science activities that provide students with opportunities to experience science as it is practiced (e.g., Varelas, House, & Wenzel, 2005). Previous studies generally focused on students’ conceptual knowledge (e.g., Charney et al., 2007), students’ understanding of the nature of science and scientific inquiry (e.g., Bell, Blair, Crawford, & Lederman, 2003), attitude toward and interest in science (e.g., Gibson & Chase, 2002), and evaluative criteria for characterizing the internship experiences (Barab & Hay, 2001). Little is known, however, about *how* both students and other key participants (e.g., their high school teacher, scientists, or technicians) *experience* such internships and which aspects they consider as salient and meaningful when they have a chance to reflect.

The purpose of this study is to contribute to constructing a better understanding of high school students' and other key participants' *experiences* of a science internship in a university biology laboratory. In particular, the study was designed to provide participants with opportunities (i.e., interviews) to *reflect on* their internship learning experience. To construct an understanding of the experiences of the participants in the project, I draw on phenomenography, a method particularly designed for articulating the ways in which people experience their world.

8.2. Phenomenography

Because the main mission of phenomenography is to explore participants' *experiences* about particular phenomena (Marton, 1981), phenomenography serves as an appropriate theory and method in the study. As an illustration of people's varying ways of experiencing a phenomenon, consider the following example of an experiment of remembering a series of numbers (Marton & Booth, 1997). In the experiment, participants were asked to remember the number series "581215192226." It was found that participants experienced these numbers differently and so displayed different retention (Katona, 1940). Some participants experienced them as individual numbers, reading the series as 5-8-1-2-1-5-1-9-2-2-2-6. Others grouped them into units such as 5-8-12-15-19-22-26 and discerned a rule behind these numbers—an arithmetic progression with alternating additions of 3 and 4. Why do people experience the same numbers differently?

According to Gestalt theory, the different experiences are based on the relationship between perceptual *figure*, that which stands out and which we perceive, and *ground*, i.e., that against which the figure comes to be what it is (Roth, 2006b). As different individuals have different foci, the same material configuration may be perceived differently and therefore the relationship between figure and ground for differs. To identify these varying ways of experiencing in learning situations, the method of phenomenography has been developed in the 1970s. Phenomenography constitutes a *second-order* and *non-dualistic* approach aimed at describing, analyzing, and understanding people's experiences (Marton, 1981). The perspective is second-order in the sense that phenomenography focuses on describing people's experience of various aspects of the world (statements about perceived reality) rather than describing various aspects of the world (first-order perspective: statements about reality, e.g., ethnography). Likewise, my study aims to investigate participants' salient experiences about the internship rather than the internship itself. By using a second-order perspective, researchers investigate not only the world but also people's perceptions of it so as to provide a wider understanding of people's experiences and to supply a pedagogical possibility (learning about oneself).

The perspective is non-dualistic in the sense that subjects and objects are not separated, and so the results of phenomenographic studies are neither constituted solely by mental entities nor solely by the social milieu but, in contrast, consist of internal relationships between the subject and the world—*intentionality*. The basic unit of analysis in phenomenography is "a way of experiencing something," which indicates an internal relationship between the experiencing person and that which is experienced. For instance, a man and a woman become a husband and a wife respectively because of their marriage—an internal relationship between them. Without one of them, the internal relationship would not exist; without the relationship, one would not be seen as a husband or a wife. It is not easy and customary in Western culture to begin studying a relationship prior to thinking about its constituents, but this is precisely what is required here. Therefore, when analyzing participants' experience I am asked to keep in mind that these experiences are constituted both by subjects (participants) and objects (their internships) rather than considered separately from either within participants (e.g., participants' interests or attitudes) or from outside (e.g., the internship's environments or contexts).

From a phenomenographic perspective, learning proceeds from an undifferentiated and poorly integrated understanding of the whole to an increased differentiation and integration of the whole and its parts (Marton & Booth, 1997, p. ix). Take the previous series of numbers as an example, learning could be the process of shifting from experiencing it as individual numbers to discerning it as an arithmetic progression. Different people have different experience and some may be better or worse when viewed by particular criteria (e.g., educational norms). For the internship study in particular, I do not intend to judge which experience is better than the other, but focus on identifying participants' variations of internship experiences that allows educators to understand how participants experience a science internship program differently and further provides participants a potential platform to learn from each other's experience.

Meanwhile, a structure of awareness has been used to articulate that experience has a structural aspect and a referential (or meaning) aspect (Marton & Booth, 1997). The structural aspect includes the internal horizon (discernment of the parts and their relationships within the whole) and the external horizon (discernment of the whole from the context). And through the relationship between the whole and the context, we sense the meaning of the phenomenon—the referential aspect. Returning to Katona's number sequence as an example, an internal horizon that describes the part/whole relationship could be "certain ways of numbers grouping." As for an external horizon, if we present this number sequence in an economic context, as $5 812 151 922.26, people's ways of experiencing the sequence might be changed (e.g., they may perceive it as an amount near 6 billion dollars rather than as an arithmetic progression). Structure and referential aspect of a phenomenon therefore presuppose each other in the act of experiencing. Following the structure of awareness, the study aims to identify participants' ways of experience of the same phenomenon (the internship) and their structural aspect (internal/external horizons of their experience) and referential aspect (meaning for participants in the high school students' internship context) of the phenomenon. Furthermore, two different kinds of variations have shown to be important components in recent studies in phenomenography (Pang, 2003): the different ways of experiencing a phenomenon (the first face of variation) and the critical aspects for each different ways of experiencing a phenomenon (the second face of variation). Likewise, I pay attentions to these variations that help me to better participants' experience about the internship—different ways of experiencing the internship and their different critical aspects.

Higher education researchers (e.g., Tan, 2008) and health and nursing researchers (e.g., Jormfeldt, Svedberg, Fridlund, & Arvidsson, 2007) have increasingly used phenomenography to study human experiences. In science education, phenomenography assisted researchers in documenting (a) students' understanding of scientific concepts such as "solubility" (Ebenezer &

Erickson, 1996), “energy” (Ebenezer & Fraser, 2001), and “photosynthesis” (Carlsson, 2002);(b) students’ perceptions of educational issues such as learning through writing (Ellis, 2004), teaching physics (Marshall & Linder, 2005), learning and learning science (e.g., Tsai & Kuo, 2008); and (c) teachers’ perceptions of text material in teaching science (Peacock & Gates, 2000). Little research has been done, however, about *how* high school students (and other key participants) *experience* internships in a scientific laboratory.

8.3. Study Design

The purpose of this study is to understand how participants experience a high school science internship that is part of a research program concerned with developing scientific literacy. The context of the study is a 2-month collaboration involving a university biology laboratory and a high school class.

8.3.1. Participants and Internship Participation

Before the high school students arrived in the biology laboratory to commence their internship, I conducted a 1-month interpretive study in their high school classroom to observe their science lessons. The students attended a public high school in a mid-sized Canadian city. They were enrolled in an eleventh-grade honors biology course (with a total of 28 students in the class) that also included a career preparation component, a compulsory course for graduating. The eleventh-grade biology curriculum was compressed into one semester during which students take the biology class for 1.5 hours per day during an entire semester. Usually, career preparation students used extra school time to participate in various science activities to complete the career preparation course, which requires 100 hours of work over the junior and senior years. These opportunities of various science-related activities were introduced by their teacher (an experienced biology and career preparation teacher), and students had the autonomy to decide which activities to participate in. Participation in the internship program served as one means of accumulating hours for the career preparation course. Observing and interacting with the teacher and students for about 3 hours (before, during and after classes) every school day in one month allows me to enhance “a community of interpretation” (Apel, 1972) that validates an understanding between researcher and research participants about what they are talking about and doing. For instance, when students talked about the difference of communicative styles or environments between their biology classes and the internship laboratory, these observations allow me to better understand participants’ (students and the teacher) articulations in interviews.

I conducted a 6-month ethnographic study in the university science laboratory to become familiar with the scientific projects and associated scientific practices. I participated in scientists’ and technicians’ weekly and monthly meetings and observed their work in the laboratory. The biology laboratory focused on water-relevant projects such as monitoring water quality, identifying bacteria in water, or tracking contaminants in seafood. The laboratory members included the chief scientist and head of the research program, a laboratory manager, 3 scientists, 5 postdoctoral fellows, 1 administrative assistant, 28 technicians (field managers, research assistants, and graduate students), and a large and frequently changing number of undergraduate co-op students. The chief scientist and the laboratory manager (also a scientist) participated and supervised all of the 2-month internship activities. Four scientific projects were identified as most life-relevant for high school students to participate with leading technicians.

Before the arrival of the students, scientists communicated with their teacher about the types of internship and the time schedule and discussed ways of guiding high school students with each technician in each project. When these technicians needed instruction or help, they approached the scientists for advice. These technicians are undergraduate or graduate students majoring in biology; they have no pedagogical training. These technicians designed an internship plan beforehand and discussed the feasibility of the plan with the scientists.

Thirteen high school students (2 males and 11 females) participated in the program in groups of three or four. I organized the first meeting for these high school students, scientists, and technicians to discuss the projects, negotiate time schedules, and discuss the scientific work in preparation for the internship in the laboratory. Each of the four groups of students was associated with a technician (subsequently one group had two technicians).

In the internship, students spent about 10-16 hours in the biology laboratory over a 2-month period. Normally students started the internship by reading relevant scientific papers selected by these technicians. They participated in discussions and scientific seminars, collected field samples, and practiced particular techniques in their respective science projects. At the end of the internship, each group of high school students presented what they had learned and experienced to an audience of 50 individuals (laboratory members, their high school teacher, high school students, and educational researchers). The students' presentations were praised by the audience generally, particularly the scientists and technicians who expressed amazement at the students' proficiency about these scientific projects.

In exploring what constituted the internship experience, I used observation, video recordings, and interviews to capture the possible variations of these experiences in a rich and comprehensive way. Data sources included observations, field notes, journals, videotaped interviews, and videotaped scientific practices in both the laboratory and the field over ten months (Sep 2005-Feb 2006: observations of the laboratory; Jan-Feb 2006: observations of the high school class; Feb-Apr 2006: observations of the internship; May-Jun 2006: post interviews; a total of 122 videotapes).

In the present study, the researchers shared the understanding of this science internship with participants as I accompanied them throughout the study and collected various data. In this phenomenographic study, I am particularly interested in the 11 students' post-internship interviews (2 students could not be interviewed for unexpected reasons) to understand their ways of experiencing the science internship. That is, post interviews are the main data source for collecting participants' reflective experience and other ethnographic data sources help me understand these experiences not just after the internship but also during the internship. To obtain data that capture the greatest possible variation of the science internship experience, the interviews with the high school teacher, 2 scientists (both are non-native speakers of English), and 5 technicians were also analyzed to gain understanding of the different groups of participants' experiences of the internship. Reporting different groups of participants' voice allows researchers to understand different stakeholders' experience, provides stakeholders opportunities to understand others' constructions about the internship (Guba & Lincoln, 1989).

8.3.2. Interview Context

In phenomenographic research, the preferred method of data generating is the semistructured, individual, oral interview using open-ended questions, in which "researchers need to step back consciously from their own experience of the phenomenon and illuminate participants' ways of experiencing" (Marton & Booth, 1997, p. 121). Immediately after the internship, all participants were interviewed by two researchers (who took turns asking questions) in an interview. Data resources include 19 interviews with key participants (high school students, their high school teacher, technicians, scientists) who participated throughout the science internship. To provide a comfortable environment for interviewees, the interviews with the students and their teacher were conducted in their high school classroom, whereas the interviews with technicians and scientists were conducted in their offices. These interviews were carried out in the form of open dialogues to facilitate exploration of the participants' experiences that had not been previously thematized and so became aspects of the subjects' awareness that changed from being unreflected to being reflected (Marton, 1994). In addition to prepared open-ended questions (e.g., What is your experience in this internship? How do you think about this internship?), the interviewers asked questions in terms of the previous answer of the interviewee (e.g., Can you give an example of what you said? Would you elaborate more about it?).

To provide a space for high school students to articulate their experience in the science internship, I organized a card-sorting activity to encourage reflection. At the beginning of the card-sorting activity, students were invited to reflect on their experience and to write down key words on individual cards (students were encouraged to write as many key words as possible). Usually, students spent from 10 to 20 minutes writing about their experiences and then were encouraged to group the cards into clusters. Afterwards, students taped the groups of cards onto a large sheet of paper and named each group. After finishing the card-sorting activity, students were invited to articulate their meanings and reasons for the groupings (see Figure 8.1). Students used between 8 and 14 cards to denote their experiences.

Figure 8.1. The student (right) wrote 9 cards with key words of her science internship experience and explained her experience while pointing to the resulting map.

The resulting maps provided a visual resource for students in the interviews to articulate their experiences in a more comprehensive way. Also, both the interviewer and interviewee could access the cards as deictic resources to compare or synthesize different articulations of their experience. This card-sorting activity has the further potential to help phenomenographers decrease inevitable social interaction between the interviewer and interviewee and allow the interviewer to conduct a relatively open-ended, interviewee-led interview (i.e., the card-sorting activity asks interviewees to write down key words first and then interviewees are interviewed in terms of these key words). The post-internship interviews with the students showed that the internship experience had a highly positive impact. In the open-ended card-sorting activity, there were 46%, 40%, and 14% of positive (e.g., eye opening experience), neutral (e.g., technology), and negative (e.g., tedious) statements of experience, respectively. The subsequent interviews revealed that 69% of the neutral statements (pertaining to equipment, people, environment) were associated with positive experiences (e.g., “The technology in the lab was really amazing. I didn’t know that anything like that could even exist”). These findings show that students conceived the internship as a meaningful and valuable experience in their high school life.

8.3.3. Data Analysis and Credibility

To bring forward the analyst's prejudices or prior assumptions about this science internship, the first author had a bracketing interview before conducting the data analysis. In the bracketing interview, a colleague interviewed me to respond to the same prompts that would be given to the participants (Kvale, 1983). In this case, I used the card-sorting activity to reflect on my experience about the science internship. That is, the bracketing interview allows the researcher to have an awareness of her own experience and so can discern the similarities and differences between her and participants' experience. For instance, one of differences is that she experienced that high school students had limit autonomy in doing science in the internship. However, only few participants mentioned this aspect and so it is not deemed as a salient experience for participants. In traditional content analysis, data categories are determined in advance. However, in phenomenographic analysis, the categories emerge from the data and are tested against the data, adjusted, retested, and readjusted repeatedly until the whole system of meanings is stabilized (Marton, 1986).

Transcription can be a transformative process that may distance researchers from the interview situations and participants (Dortins, 2002). I therefore transcribed the interviews verbatim and subsequently analyzed the interviews in terms of both video and verbatim transcripts. The video interviews were observed and the corresponding transcripts were read back and forth to capture the authentic situations of the interviews. In this way, the analysis captures not only the interviewees' utterances but also their facial expressions, gestures, laughter, pauses, intonations, etc. This process of reading and re-reading the entire transcript (with video data in the study in particular) also allows researchers to avoid the decontextualization (Bowden, 1996) that occurred in early phenomenographic studies. That is, early analysts arranged and rearranged extracted selected quotes into piles, and so gradually abstracted these quotes that might be interpreted into different meanings .

The phenomenographic approach implemented several steps to discern participants' different ways of experiencing a phenomenon (Dahlgren & Fallsberg, 1991): *familiarization* (reading transcripts; watching videos); *condensation* (identifying significant answers by informants; using students' written key words as resources to interpret their talk); *classification* (grouping similar features within or between participants); *preliminary comparison* (establishing borders of initial categories); *naming* (giving essential names to each category); *contrastive comparison* (describing unique characteristics in each category and resemblances and relationships between categories). Furthermore, *frequency* (how often a meaningful statement is articulated), *position* (very often the most significant elements are found in the beginning stage of answers), and *pregnancy* (when participants emphasize certain aspects more than others, such as through the key words on cards, through gestures or intonations in the video data) were considered to assess the significant elements in participants' descriptions (Sjöström & Dahlgren, 2002).

To establish the validity of the data analysis, I use three criteria introduced to justify the basic quality of phenomenographic studies (Marton & Booth, 1997): (a) each category of description should be distinct from each other and stand in clear relation to the phenomenon; (b) these categories of description should stand in a logical relationship with one another; (c) the system should be parsimonious to capture critical variations in the data. Furthermore, I accorded with the epistemological assumption of intentionality—human knowledge is intentionally constituted through individuals' experience of their reality (Sandberg, 1996) to validate the analysis. That is, instead of using replicability (whether other researchers can identify the same categories) or interjudge reliability (whether other researchers can recognize the original categories), I draw on the analytical framework of Cope's (2002) eight criteria to establish the credibility of this study.

To satisfy these eight criteria, in this study (a) I used a bracketing interview beforehand to understand *the analyst's prior experience* about this internship; (b) I conducted ethnographic studies in both the high school classroom and the university laboratory to better understand *the* *characteristics of the participants*; (c) *the design of the interview questions was justified* in the interview context section; (d) a card-sorting activity provided an open-ended way to *collect unbiased data*; (e) an awareness of using relatively *open minded approach* was used to analyze the data source; (f) *data analysis methods* were explicitly described; (g) the key words on cards served as a useful resource (i.e., transparent raw data for readers' access) to *check interpretations*; (h) *categories of description were fully described and adequately illustrated with quotes*. I included quotes from different groups of participants (i.e., high school students, their high school teacher, technicians, and scientists) that particularly strengthen the credibility of the analysis as I make raw data available for readers to challenge the analysis.

8.4. Experiential Descriptions about A Science Internship

This study was designed to understand key participants' experiences, as made available in interviews, following the science internships of high school students in a university biology laboratory. I am interested in the salient meanings (referential aspect) and structure of these experiences. Drawing on phenomenography to analyze 19 interviews, five categories emerged at individual (reoccurrences within individuals) and collective levels (reoccurrences between individuals): (a) authenticity of university science, (b) channeling and connecting different communities, (c) advanced knowledge and lengthy procedures in university science, (d) self-exploration and reflection, and (e) comprehensive science learning. A summary of these categories (the first face of variation) and their respective referential and structural aspects is available in Table 8.1. In particular, the structural aspects are represented with internal (including focus and the second face of variation) and external horizons. In the following sections, I introduce each category with illustrative interview quotes from the different groups of participants—high school students, their high school teacher, technicians, and scientists.[1]

[1] I refer to participants as follows: interviewers (I1, I2); high school students (S1–S11); their high school teacher (T); technicians (Te1-Te5); scientists (Sc1, Sc2). Capitalized text indicates increased speech volume; italic text indicates the speaker is emphasizing or stressing the speech; quotation marks indicate key words written on cards.

Table 8.1. Referential and structural aspects of experiential descriptions about the science internship.

Category of Description (the first face of variation)		Referential Aspect	Structural Aspect: Internal Horizon: Focus	Variation (the second face of variation)	External Horizon
A	Authenticity of university science	Rare opportunities of involving in authentic science	Non-Stereotype/New understanding about university science	Characteristics of technicians/scientists, atmosphere, equipment, work/project, university laboratory	Stereotypical science from textbooks and public media
B	Channeling and connecting different communities	Closing difference and increasing concordance	Similarities and communication between different communities	Arrangements, conversations, interactions, and negotiations	Expectation of difference between different communities
C	Advanced knowledge and lengthy procedures in university science	Dedication and passion involved in university science	Processes for achieving science accuracy	Involvement of effort/time and technical words	Assumptions of investment for completing science experiments
D	Selves' exploration and reflection	Opportunities to reflect self interests in science	New understanding about selves	Interest in science/future possibilities/awareness of personal development	Past understanding about selves
E	Comprehensive science learning	Comprehensive understanding about science	Hands on activities and purposes behind science practice	Mechanism/process/implication/bigger picture of science	Partial and abstract learning about science (e.g., textbook science)

8.4.1. Authenticity of University Science

The first category relates to the authenticity of university science. Participants valued the rare opportunities (referential aspect) for high school students to see real scientists and to discover how different real research is from what they had learned about in school or in the popular media. By comparing their own general or stereotypical understanding of science (external horizon), participants focused on the new understanding in different variations of characteristics of university science such as characteristics of scientists, (internal horizon). In the following sections, I demonstrate how students appreciated the chance to experience science as it is really done and how their teacher, technicians, and scientists perceived the authenticity component of science in the internship.

High School Community In sharing their experience of the science internship, students often described their internship experience as meaningful because of its "authentic" nature. Compared to a stereotypical image of science, they discovered many different characteristics of science. Such as *scientists don't need to be geniuses* ("this isn't so incredibly advanced as one might think, it doesn't require Einstein" [S4, 05121909]) or *scientists are normal people:*

S7: like te2, she's pretty "normal," pretty cool, like talking on her cell phone at work, she's "interesting" . . . before i didn't really think about it but, in my head i always had this general stereotype about, like extremely intelligent, like walking libraries of information, that's what i thought before. (05081820)

This understanding of scientists' daily life reconstructed the student's previous image of scientists from stereotypical type "walking libraries of information" to non-stereotypical one "normal and interesting" people. In addition to the characteristics of scientists, students also noticed other authentic aspects of science, such as *the relaxed laboratory atmosphere* (e.g., "another thing surprised me was how *laid back* the lab atmosphere was" [S3, 04251618]), *the equipment* (e.g., "I observed a lot of cool machines, lots of expensive equipment" [S5, 04271001]), and the *science projects* (e.g., "actually working with the samples and doing the lab work" [S1, 05153102]). The university surroundings in which the laboratory is located also had important value for high school students. Many high school students had never been to a university, so the internship allowed them to experience being among university students (e.g., "it totally changed my thought about a university student"[S9, 05091310]).

The students' high school teacher as well reflected this appreciation of university science authenticity. She is an experienced biology teacher and had arranged numerous activities for her career preparation course. Compared to other activities offered to her career course students in the past, the teacher acknowledged that this science internship provided more benefits for students:

T: the opportunity to see, what it's like to work in a lab, to be a researcher, i think that's good, we try to give them experience with doing lab work here and see that it requires patience and that it takes time and that you have to measure accurately, but really in the little lab that we do it's difficult to get that across . . . this has the added bonus of being on campus, seeing the university and seeing professors and so this was a BIGGER, a BIGGER opportunity. (06071502)

She suggested that the internship provided her students with a sense of real science such as tremendous efforts for experiments that is difficult to communicate in school and the sense of being a university student. The authentic aspects of both real science and university life in the internship provided an important opportunity for high school students.

Science Community For these technicians who worked closely with the high school students in the internship, they also discerned students' understanding and learning about authentic science. For example, they acknowledged high school students' understanding about scientists' everyday life such as *timeframe and work in the lab* (e.g., "I think they understand what it is like working in the lab now, the flexibility of the hours, and the kind of constraints for different machines and the *expenses*" [Te2, 05091300]), and *field work* especially including inevitable breakdowns in science practice (e.g., "we went down to the beach and unsuccessfully looked for clams but *unsuccessful* is also a part of field work" [Te3, 05050000]). In particular, one technician emphasized that as a fourth-year university student she did not realize the real life of being a scientist until she took the research assistant job in this laboratory:

Te4: they got to know what the research is really like, what the job is like, i think at the end of the day they got tired, a little bit bored, that is very understandable, they are suppose to, like for me, before i took this job i don't `know this either, i really glad they have one day to see what our daily life in research is like, you see that it is not SO fancy. (05090321)`

Te4 recognized the rare opportunity for high school students to experience authentic science, as even a university science major could not easily access it prior to the co-op program. For the scientists, offering students authentic science experiences is an important objective that is successfully achieved and recognized by them. Asked to talk about the experience with the project, one scientist commented:

Sc1: `i think it was very exciting to see high school students come, work with my students and see what we do and WHAT scientists do, like most of the students in school to science are scared, coming into a environment like that, they think like, WOW, you know very strict environment, that are too smart for us to talk to, i think those are fears, put them backwards, so having this opportunity, as some of the students said, OH, NO, they are not scary people, scientists are not scary people, so i though that was great. (06010000)`

Sc1 expressed his understanding of how students' images of science and scientists changed as a exciting result of the internship, for example, going from "scientists work in a strict environment and are too smart to talk to" to "scientists are not scary people." These and other experiential descriptions provide evidence for the fact that both high school and science community appreciated the authentic nature of the internship and deemed it as an educational and meaningful component of high school students' introduction to science.

8.4.2. Channeling and Connecting Different Communities

Channeling and connecting different communities—a high school community and a science community—constitutes the second category. The difference between the two communities is not only noticed physically (e.g., some high school students have never been in a university) but also intellectually (e.g., some high school students are afraid to talk to scientists). Most participants appreciated that connecting the two communities was a valuable and meaningful experience in the internship, not only for closing difference but also for increasing concordance between communities (referential aspect). By contrasting to the general assumptions of two communities (external horizon), participants emphasized on different forms of similarities and communications that connect the two communities (internal horizon). In this section, I demonstrate the different experiential descriptions about the connections and communicative issues in the internship from the perspectives of the high school students, the teacher, these technicians, and the scientists.

High School Community The students recognized the difference between the high school and science community; but in their experience, the difference was narrowed in and by the internship. When students described their experiences at the beginning of the internship, they said they felt foreign or unfamiliar with the new environment:

S6: i feel uncertain and scared but i never thought i d feel like foreign because, like stereotypically foreign, like i am canadian and you're just going into the uvic lab, you're not going to feel foreign, but you feel different and almost excluded from everybody else because you're not wearing the same clothes, you don't know what they know, so you're just drawn into a situation that is not everyday life, so it's very foreign. (04281520)

However, with time and more interaction with technicians/scientists, they felt more comfortable and experienced a sense of belonging in the university science community (e.g., "I remember the first time I went in I was kind of nervous, but the last time I was completely comfortable there" [S8, 05020513]).

To articulate the change, students often acknowledged the planning and preparation arranged by these technicians for the internship. Different technicians led different groups of students with specialized plans in terms of their respective science projects. For instance, students were assigned a newsletter to read, conducted a small research to present, practiced logical and systematic lab work to enable them to perform scientific techniques within a shorter period of time. The students appreciated these plans designed by these technicians and supervised by the scientists as an educational agenda to facilitate their understanding of university science.

In addition to the large-scale plans, students also valued the dialogue and accommodating interactions with technicians during the internship that allowed the students to become part of the science community. During their interaction, students even felt a considerable degree of ownership:

S11: i guess that's because Norris included us so much in it, and he wasn't just like, well this is my project and this is how i do everything, he wasn't, he really helped making us a really big part of it, So it wasn't just like, well you guys can watch me do this, you know, and this is how you could be doing it if you were as educated as i was, right, i mean he treated us as though he was EQUAL to us, and so we got as much out of it. he really made it like, as if we were a big part of it, and TRUSTED us that we could do that kind of a job and help out as much as we did, so i thought it was really cool that he did that and i guess that's why i felt like i was so involved. (050521615)

The students recognized that they were provided as many opportunities as these technicians to practice scientific work and even had equal status to these technicians. Although the students sometimes had difficulty understanding some complex concepts or terms, these technicians usually spent time and effort for discussion and exchange of ideas. The open conversation and interaction facilitated the students' sense of belonging and ownership in the science community.

The high school teacher particularly appreciated the openness of the science community toward these high school students.

T: i just think it's very generous of them, to give their time, for students, i wouldn't want to presume to ask people to give their time like that, i am very grateful that they did, to do that, i think it was a terrific opportunity for the kids . . . what was nice about this is that we had SO MANY students, thirteen, as many as we wanted to go, could go, and that was great, so often these things are restricted to just a few students, so i think it's been one of the BEST opportunities that i've been able to offer to the students for sure. (06073233)

Because the teacher had arranged numerous activities, she recognized how limited these similar opportunities were for high school students. Thus, she was especially thankful for the internship opportunity that was open to every student in the class who had an interest. That is, the internship was open not only to particular students (e.g., gifted or career-preparation students) but to all students and this was acknowledged by the teacher as one of the "best" opportunities she could arrange for students. Thus, the openness of the internship is one of the key elements for bridging high school and science communities.

Science Community From the perspective of the science community, different forms of descriptions about interaction and communication in the internship were generated. Because conducting scientific experiments was expensive, some technicians used real samples, whereas others decided to use extra samples for students to work on. After the internship, Te1 described that next time he would prefer to use "extra samples" to increase "hands-on" activities for students rather than using real samples that need a high standard of accuracy of technique (05050800). That is, the authenticity of the sample is deemed to be an important element in mediating how the technician interacted with the high school students. In addition to samples, schedule matching, students' prior understanding, and equipment availability are also important elements for others:

Te2: definitely trying to manage 4 of us that have very busy schedules, that was probably the biggest hurdle, and also getting, trying to figure out the level they are at, um it's a little more difficult . . . i would say it was probably mostly the time issue, trying to find the time when we are all available, and when nobody else needed of the equipment. (05092500)

Te2 suggested that her greatest difficulty was arranging available time for students, due to her own and the students' busy schedules. That is, matching schedules between two different communities was challenging.

As for the interaction with high school students, different technicians with different groups of students had varying forms of experiential descriptions. Te3 found the high school students to be very active, so she did not need to motivate them (e.g., "the girls were easy to work with, I didn't have to try to get them motivated, like just were quite independent and did everything on their own" [Te3, 05052100]). For Te1, however, the students seemed to be more passive and so he needed to prompt them to ask questions (e.g., "I had to prompt them to ask questions, they weren't asking too many questions without a bit of pushing" [Te1, 05051128]). For Te5, the "infectious enthusiasm" between high school students and technicians made the internship worthwhile (05090220). They all indicate the salient experience of channeling and interacting with students but in different forms.

As for scientists, they also noticed difficulties with communication and negotiation issues in the internship as well.

Sc1: individual graduate students are very different, how they express themselves, some students are extremely technical when they express themselves, other students try to come down to the level of the people they are talking to, THAT'S something takes years to learn, how to come down to the audience level to express yourself, so you don't go over their heads and confuse them, so not all of my students are actually succeed truly, to express themselves. (06010519)

Sc2: well i don't think we had any unexpected challenges and surprises, we had some expected ones, and I think we managed pretty good, some of them are timeframe and also the scope of work, and the scope of projects and the complexity of the level of science, those projects may carry it on, to be able to present that to high school students, that was to be challenging, but i think it was managed very well and i think everyone had benefit from the work. (05090628)

From the scientists' perspective, graduate (or undergraduate) students' skills in presenting complex science knowledge (e.g., Sc1) and negotiation of timeframe and work (e.g., Sc2) were all key components of bridging high school students to the science community in the internship. Pertaining to this category, I noticed that the high school community usually described the workable aspects of communication in the internship, whereas the science community often addressed the challenging aspects of arrangement and communication. One of possible explanations is that the science community felt responsible for the internship curriculum design and reflected space for improvement after comparisons of other groups' practice. Thus, it is proposed by one of these technicians to add more meetings for exchanging ideas of organizing a internship.

8.4.3. Advanced Knowledge and Lengthy Procedures in University Science

The third category relates to advanced knowledge and lengthy procedures in university science. Many participants stressed the process of complexity and tediousness that is involved in university science to achieve accurate and successful experiments (internal horizon) through a comparison of their assumptions about investments for completing science experiments (external horizon). Considering how time consuming scientific research is, the scientists' passion and dedication to their work were particularly appreciated (referential aspect).

High School Community High school students frequently highlighted the advanced knowledge and lengthy procedures of the internship. Even though they knew before joining the internship that lengthy procedures are characteristic of science, students still emphasized that the time-consuming nature and complexity of science surpassed their expectations ("I guess I knew that it would take time, like obviously, but at the same time I didn't think it would take so much time" [S2, 05152150]). Therefore, it makes them appreciate the dedication and passion of scientists.

S11: everything has to be very precise . . . and i realized how much dedication it takes to do an experiment and, how MANY HOURS you have to put in a week. i was talking to some of the people in there, and they were like, i've been here for thirteen hours on end, and i was like, WOW, and i mean, it wasn't a bad thing, i thought it was so cool that people could be that passionate about experiment and want to get through it and find out the conclusion and that they put in thirteen hours a day to an experiment and even if it's just sitting in the lab, which most people would think couldn't be very interesting, i thought it was great. (05050545)

S11 recognized that university science is complex and time consuming, but she considered the challenge as something worthwhile to work on and achieve.

For the high school teacher, she was also aware of the gap between high school students' understanding of biology and the sophisticated knowledge involved in university science.

T: i think in these projects they can see the length of time it takes, for a researcher, and how many times they have to re-do things . . . you know to get a little more depth in some specific topic, that is good, because again with biology eleven, we're covering such a HUGE scope in the course, that we touch on everything very superficially, so it was nice for them to be able to go into more DEPTH on a topic . . . i mean the level is so much more sophisticated, it's up, you know, those researchers are post, umm, the graduate students, so uh they're already five years pass what these students are . . . so, in some ways, that's good, to make them realize, how much more they have to learn. (06071528)

Because the teacher had majored in biology in university and also had 26 years of teaching experience, the gap between secondary and postsecondary science was even more evident to her.

Science Community These technicians were aware of the complexity of knowledge for high school students, as university science is a difficult task even for themselves.

Te2: i asked them the first time they came to the lab, have you read the papers, and right away the both girls said, well we read one of them, which is the handout i gave them, and they seemed to have a little bit of trouble getting through that, and i think it was a whole, a lot of big words kind of intimidating, i know to this day it still takes me three or four goes at it to get through a paper, and actually understand what it is talking about, so you know coming in never reading any scientific paper, i think it is very intimidating, and they might have read it once and been like, I DON'T understand that and I DON'T want to look at it again. (05091910)

Te5: so i don't expect them to know exactly, oh okay that is what we are looking for, like i didn't learn that until second year. (05091409)

Te3: i still have a lot to learn about statistics, so i'm not the best person to explain how we are going to analyze our data. (05051100)

For Te2, to comprehend a scientific paper would take her three or four readings; for Te5, he did not understand some scientific concepts until his second year of university; and for Te3, the statistics involved in her project are something that she still needs to study more. That is, for technicians, university science is still a complex field that needs extra effort and time to learn. The scientists' descriptions of their experiences do not illustrate this aspect, however. That is, the complexity and time-consuming nature of university science involved in the internship was not salient for scientists, but only salient for high school students, their teacher, and technicians.

8.4.4. Self Exploration and Reflection

Category D relates to self-exploration and reflection (mainly of high school students and technicians). The internship provided multiple layers of opportunities for both high school students and technicians to explore possible selves. Participants noticed that they reflected new understanding about themselves in the internship, including interest in science, possible future careers, and awareness of personal development (internal horizon) that was unreflected or unexplored in the past (external horizon). Thus, the internship was valued as a meaningful experience for self-exploration and reflection (referential aspect).

High School Community High school students took this internship as an opportunity to posit and explore various selves as they transition to maturity and were confronted with major turning points into adulthood. The students experienced the everyday lives of scientists first hand and used this knowledge as a way to explore their own possible selves and futures.

S11: It made me realize how much closer i am to being in science, like, how students had been there only a couple of years back, and how, it just seemed so far away before, as if it was like, now i'm a high school student, but EVENTUALLY i'll be a marine biologist, and now it's like within a couple of years i'll be on my way to being a marine biologist, and so i thought that was, it really showed me, cause i mean the students were much older and had already been through what i had been through so, i thought that was really cool. (050511438)

Before joining the internship, S11 planned to be a marine biologist. To her, the internship not only provided experiences that confirmed what she wanted to do, but also gave her confidence that she had the abilities required for her dream career. On the other hand, the internship also allowed students to rule out possible selves. That is, after the internship, S6 realized that being a scientist is not a suitable career for her, as she needs to see the effects of her work "right away" (04282930)—to see a return on her investment quickly, rather than spent lengthy time on repetitive techniques. In addition to connecting future career possibilities with selves, students also described other new understandings about themselves (e.g., "that was really SURPRISING that I was like, wow I didn't know I knew so much of that" [S5, 04272727]).

The high school teacher valued the benefits and opportunities for high school students to connect with postsecondary education in their high school years, especially because she was a career preparation instructor at the same time.

T: i think that was huge for them, that's a BIG, and they're just in grade eleven, so i think for them to get that understanding that this is not very far away, that they are going to fit in, i think that was really good, i think that takes away a lot of the fear of the unknown, for them when they're thinking about secondary, or umm, post secondary, you know, JUST that feeling of familiarity on that part, just that little part of the campus, i think that will be very beneficial for them. (06071301)

That is, from the teacher's perspective, participation in the internship allowed students to realize how close they are to postsecondary education.

Science Community For technicians, they recognized that the internship offered a great opportunity for high school students to reflect themselves as well (e.g., "I think they would learn the most about whether they like science or not from doing that" [Te3, 05050240]). Te4 also noticed that her own trajectory of finding self-interest in science is very similar to the high school students' explorations in the internship.

Te4: i was as confused as they are for a long time too, so i know what it feels like, so i totally understand what they say at the science part, i don't know if i should go into it, and find out later that they have the same things, so i try to really show them the work, and give them an idea, because myself is a university student, and i got to know what science is REALLY like after this job, it's pretty different and not my expectations, so i hope that by this time, students they have sort of more ideas. (05091937)

Based on the similar experience of reflecting self-interest in science, Te4 described how her work might demonstrate real science to these high school students and gave them more ideas about science. These technicians found it interesting that the internship also offered opportunities to develop new understanding about themselves. After interacting with high school students in the internship, Te2 realized how much she had learned about biology "after secondary education" and how she could smoothly communicate her work to a younger audience (05090300). As for Te3, through interaction with the high school students, the experience enhanced her interest in becoming a high school teacher (05051620).

The internship provided opportunities not only for the high school students but also for these technicians to reflect their possible future selves as noted by the scientists:

Sc2: the interesting part is, helped some students to actually even change their mind, like i don't know her name, but she said, well i wasn't sure if i was going into science, but i know that it is not right for me, which is still a positive outcome, because we don't want to make the wrong impression, so later on they would regret the decision about what they made, so the whole ideas was to help them make right decisions, and i was kind of glad to hear that some people actually changed their mind and they won't go into science. (05090425)

Sc2 expressed his appreciation of the impacts on high school students, whether pursuing science or not, because students are able to make an informed decision after the internship. Other benefits were that the internship might help technicians to refocus on their projects by presenting them to high school students, and the process might help them to realize how their work can influence people in an educational way through interdisciplinary collaboration (e.g., "it shows you what kind of impact your work can do on other people" [Sc2, 05090901]). In conclusion, most participants acknowledged that the internship offered high school students a unique means of self-reflection and personal development regarding the pursuit of science and further technicians (scientists) also recognized the self-reflection opportunities provided for technicians themselves in the internship.

8.4.5. Comprehensive Science Learning

The final category relates to comprehensive science learning and understanding. Most participants recognize that the high school students learned the scientific projects comprehensively in the internship. In contrast to abstract and partial learning about science (external horizon), the internship was appreciated for providing comprehensive understanding about science (referential aspect) in terms of its hands-on activities and explanation of purposes behind science practice (internal horizon).

High School Community The internship had provided students with opportunities to understand and to see a bigger picture of science practice such as the reason and purpose behind science practice "before, I guess I never really thought of, I didn't really spend the time to think of why they were doing it, or like, how important it actually was" [S8, 05022146]). Meanwhile, students frequently acknowledged hands-on activities as the favorite ("fun") part of school science. They enjoyed the physical and visible activities and expressed that they are learning by doing. This is the case even more so in the positive nature of the internship experience:

S6: there's a lot of pictures in the biology book, then i got to actually do like the agar plating, we did that and the filtering we did that, and you're not just looking at it in a book you get to do it hands on so that's a really cool way of learning . . . i think that's the best way to learn, because when you're doing it, it's a process that your hands have to do and your brain has to comprehend for you to be able to do it, so it just becomes part of what you do, but when you're reading, you're just reading words, you're not doing anything, so like i'm a really hands on learner. (04280500)

As a result, S6 preferred hands-on activities as they provided a more comprehensive learning experience. As an example, the agar pattern that appeared in the textbook was a mysterious pattern for her. After actually practicing the agar plating, S6 finally realized that the pattern is a result of physical plating by scientists rather than grown by bacteria themselves. Similar to her peers' experiences, S10 could not really understand vacuum filtering in school until she saw how it worked in the internship (04242022).

As for remembering, S8 acknowledged that the internship allowed her to "absorb knowledge quickly" and motivated her to remember it (05025522). That is, she recognized remembering more and absorbed information more quickly during the internship compared to learning science in school. She also described appreciating the opportunity to complete a whole experiment in the internship. The science experiment in the internship was much more complete for S8, as she felt that she only did "parts" of experiments in school. From collecting fish samples in the internship, S8 could learn "every step" of doing scientific research in a more comprehensive way (05025102). On average, when asked about their understanding of these science practices, students reported that they understood (most of) them (i.e., 85%).

The ways of learning and students' comprehension about science in the internship was not a salient experience for the teacher, however. It may be the case that the teacher did not know much about the actual work that students did in the internship as she said in the next excerpt.

T: as i still don't really know too much about what exactly they did, and even in the presentations didn't give a really good picture of what their actual activities were, HOW MUCH they were just observing or how much they were really participating in the research? i know some of them did some field trip work, the only way i would really know well what went on was if i had gone with them, you know and i didn't take the time to do that, i could of, maybe if it was to happen again i would take the, make the time to go and participate maybe once with each group. (06070813)

The teacher said that she could not tell about students' learning in the internship just from the group presentation at the end, as she needed to know more about what they did and participating with students during the internship may be a way to have a better sense.

Science Community Most technicians were impressed with the students' comprehensive understanding about the scientific projects. Technicians acknowledged the students' understanding of the overall science projects through conversations with them (e.g., "I think that they had a pretty good understanding of the concepts, and what was happening for sure" [Te3, 05051800]) and especially through the students' group presentations at the end of the internship (e.g., "they did a great job I was really impressed, they were really organized they did a *good job*, you can see they put some effort in they knew what they were talking about, so it was good, I was proud of them" [Te3, 05051830]). As a learning experience for these technicians themselves, Te4 also described her own learning about her ongoing project during the internship.

Te4: by the time i have to show them, i ask graduate students and i ask my supervisors too, why we do this and some questions and i think i learned a lot during the process too . . . i really enjoyed the presentations, and i learned A LOT from the presentations too, because i really didn't know like, other people i have been working with, so i learn from high school students, it's very simple so it very easy to understand and very clear. (05091430)

Te4 was a new research assistant in her science project when the internship was conducted in the laboratory. She expressed that she actually learned a lot about scientific knowledge from the internship. In order to "teach" these high school students, she continually asked her supervisors to help her clarify her own understanding about the science projects. Meanwhile, the high school students' group presentations in the end also taught Te4 a lot about other science projects conducted in the same laboratory.

The scientists acknowledged the fact that most of the high school students actually had an excellent understanding about university science. They confirmed the students' scientific understanding and great performance in the group presentations. In particular, Sc2 also described the high school students' presentations as being at a graduate student level.

Sc2: the first nation project 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, they all expressed their interest to enroll in science . . . i think the way it was done and presented it looked like it was done by one of our grad students, the content, even the way they presented that you know, and the talk, and the structure and the objectives and how it was outlined you know. (05091126)

Sc2 had been involved in the first nation project and listened to graduate students' presentations before. His opinions about high school students' presentations are especially valid. In general, the learning experience in the internship was valued by most of the participants and deemed as having potential to facilitate more learning opportunities.

8.4.6. Frequencies of Experiential Descriptions Among Participants

The frequency of the five categories of descriptions among participants is illustrated in Table 8.2. In general, there is a hierarchy of experiential descriptions about the science internship between the five categories. That is, category A is the most frequent experiential description (described by every participant), then category B (described by 17 participants), category C (described by 16 participants), category D (described by 14 participants), and category E (described by 13 participants). Generally if participants mentioned category E, they would also include other categories when sharing their experience. This hierarchical relationship indicates that the authenticity aspect of the internship is a salient experience for everyone who participated in the internship, and the comprehensive science learning is the most in-depth one among all experiences.

Table 8.2. Frequency of experiential categories among different groups of participants

Category		A	B	C	D	E
High school community (12)	Students (11)	11	9	11	8	6
	Teacher (1)	1	1	1	1	0
Science community (7)	Technicians (5)	5	5	4	3	5
	Scientists (2)	2	2	0	2	2
Total (19)		19	17	16	14	13

For the high school community in particular, categories A and C are the most salient experiences (described by 12 participants). As for the science community, categories A, B, and E were the most salient experiences (described by 7 participants). An interesting phenomenon is that category C is the most frequent experiential description for the high school community, but the least frequent for the science community. One possible explanation is that complex knowledge and lengthy procedures are a cultural and shared commonsense for the science community. Therefore, it is not a particularly special experience for the community of scientists in the internship. But for the community of high school students and their teacher, it is an unfamiliar and specialized phenomenon, thus especially salient for them.

It is interesting to note that category E had the least salience for the high school community but for the science community it was among the most frequent experiences. One possible reason is that for the science community, the bigger picture, such as the purposes or implications of science, is much more important than the details of scientific techniques. Thus, once technicians and scientists sensed that students understood the bigger picture of science, they would acknowledge students' overall learning. However, for students and their teacher, understanding the details of science may be as important as learning the general picture of scientific research projects. Here, one gap researchers noticed was that the high school students were much more eager and capable to learn about university science than was the general expectation from the science community. It is necessary to provide more space and autonomy for students to participate in similar activities if more resources are allowed and supported.

8.5. Conclusion and Discussion

Drawing on phenomenography as method, the study was designed to better understand participants' experiences of a science internship. Five categories of descriptions about the internship emerged from 19 participants: (a) authenticity of university science; (b) channeling and connecting different communities; (c) advanced knowledge and lengthy procedures in university science; (d) self-exploration and reflection; and (e) comprehensive science learning.

The science education reform movements have pointed out that experiencing science as it is really practiced might assist students in better understanding this part of human life and allow students to begin trajectories of participation in the respective fields. Pertaining to the authenticity of university science, all participants appreciated having the rare and unique opportunities for high school students to see "real" scientists, equipment, projects, laboratory, and its atmosphere, the "real" life of a university. Too often students develop stereotypical images of science and scientists. In the study, the experiences in the internship helped students to recognize differences between the stereotypical images of science they perceived from textbooks or public media and "authentic science." The frequency data in Table 8.2 suggest that authenticity was the most salient aspect of the internship. This phenomenon shows that seeing and being with authentic science is a "big deal" because so little opportunity exists for high school students to contact authentic science in the present secondary education. High school students usually work hard with their textbooks and learn science in an abstract way but rarely have a chance to "see" or "touch" the things they study every day, as if students and scientists live in two separate worlds. To be able to work with scientists and technicians in their scientific laboratory opened students' eyes and provided a valuable avenue for them to experience science authentically. Their positive experiences encouraged us (teachers, researchers) to provide more opportunities to students for working closely with scientists.

Scientists have been identified as crucial personnel to help reform science education by engaging in effective equal partnerships with K–12 schools (Colwell & Kelly, 1999). However, the question of how to establish an effective partnership between the science community and K–12 school is still unclear. The study provides the knowledge required in building such partnerships. Although the difference between the high school and the science communities was clearly noticed, high school students said they felt a sense of gap-closing and of belonging to the science community by the end of the internship (category B). High school students appreciated the forms of communication and interactions that achieved this change, such as the educational plans designed by these technicians and the open and accommodating interaction and conversation with these technicians. As for these technicians and scientists, they may enjoy working with high school students; however, many arrangement and communication issues had to be addressed. The results show that the high school community appreciated the openness and communication efforts of the science community, nevertheless, the science community wished to pursue better interactions and arrangements for high school students in the future. This indicates that the science community valued the internship as much as the high school community did and that it recognized potentialities to improve it if more resources are provided. Useful suggestions from the science community for similar internships to facilitate better communication include: (a) providing more samples for students to practice and discussing plans among technicians and scientists more; (b) having scientists or technicians go into the high school classroom and interact with high school students before the internship; (c) considering high school students' background and prior knowledge when designing a plan; (d) inviting more students and creating more opportunities for high school students to participate in similar activities; (e) ensuring available resources for internships, such as adequate equipment and samples; and (f) choosing technicians who can naturally articulate scientific knowledge for a younger audience.

As internship experiences in other discipline, there are pros and cons that students may experience. For science internship in particular, what are the possible challenges that students may encounter? The advanced knowledge and time-consuming techniques in university science constituted a potential dimension recognized by the participants (category C). Although high school students appeared to be aware of the necessary lengthy procedures needed in science to ensure accuracy for a successful experiment, they were surprised how much time experiments took and repetitive procedures in science. Therefore, the dedication and passion of scientists/technicians were much appreciated by students. As Table 8.2 illustrates, category C is one of the most frequent and salient experiences for the high school community, but the least frequent for the science community. One possible explanation is that category C is the culture in the science community and so was not perceived as a special feature of the internship. However, these realistic characteristics in university science may become an issue or even a barrier to drawing high school students into science, as many students said that they don't have enough patience for the lengthy procedures in science. Many technicians sensed that the lengthy procedures may be an issue for presenting science practice to students, so they prepared semi-products and speeded things up to shorten the waiting time during the internship. However, it was a major concern for most students. One possible solution to mitigate the issue and that might also facilitate a sense of belonging in the science community is to increase students' ownership in the internship, as many studies had illustrated that students' motivation is greater when students choose the context, problem and method of investigation (e.g., Tuan, Chin, Tsai, & Cheng, 2005). That is, to allow students to design their own scientific projects with the support of technicians and scientists, therefore students would have a relevant goal and results to look forward to and expect during the tedious experiments.

Internship has been identified as an important career exploration activity for students to clarify their interests, values, and skills in relation to particular occupational fields and work tasks (e.g., Lent et al., 2002). The findings reflect the importance of the internship experiences for students as self-exploration and reflection (category D) was another salient experiential description for most participants in the science internship. Through interaction with technicians/scientists in the internship, students had the opportunity to reflect on themselves regarding their science interest and possibilities for the future and gained new understanding about themselves. Some students said they wanted to be scientists in the future, whereas others discovered that science might not be a suitable career for them. The teacher, technicians, and scientists acknowledged that the internship provided excellent opportunities for students to make an informed decision about pursuing science. That is, whether the internship made students want to pursue science or not, both realizations are valuable to students. Another interesting result of the internship was that some technicians also gained new understanding about themselves, such as realizing how much their knowledge had increased since high school and wanting to become a biology teacher because of the positive teaching experience in the internship. The internship therefore provided opportunities for self-exploration for both secondary and postsecondary students (technicians). It appeared to be very important for high school students to have the chance for self-reflection in real contexts as they are in the transition of making important decisions for their life.

The fifth category relates to comprehensive science learning, that is, it relates to learning science in a context that is meaningful because motivated by some overall societal concern (Roth & Lee, 2007). For most students, the learning in the internship was very different from learning science in school, which, as previous research has shown, constitutes a multiplier effect in the sense that students learn more science when not directly taught (Roth & Calabrese Barton, 2004). Many differences were highlighted, such conducting complete experiments, doing hands-on activities, and understanding the purpose and implications behind scientific projects. Many students emphasized that the internship provided them with new insights into science. This kind of learning by doing facilitated a deeper understanding about science that is quite different from what they gained from reading textbooks. Furthermore, it was noticed that the internship not only provided hands-on activities for students to learn by doing, but also provided a scientific context, which offered an objective (e.g., improving drinking water quality or examining contaminations in seafood) for students to connect various hands-on activities. This fact has important implications for science education. Students would likely connect their partial understanding gained from various activities (e.g., sampling, accurate experiment, analysis and implication) to a comprehensive and meaningful understanding and may further empower their awareness of using science as tools to improve their communities or neighborhoods.

This study shows the numerous benefits of establishing partnerships between high school and science communities (e.g., self reflections in pursuing science for both high school students and technicians) and identifies particular possibilities of improving such internship programs (e.g., ways of improving communications and curriculum design). The internship can also provide opportunities for all participants to learn from others' experience and for further self-understanding, which is a result that derives from *reflective learning* that parallels to Donald Schön's *reflection-in-action* (Linder & Marshall, 2003). For instance, students who did not discern the internship as comprehensive science learning experience could learn from other students who had. These findings also serve as a foundation to encourage science educators and researchers to explore more effective science internships. For instance, to facilitate internships into experiential learning that links education, work, and personal development through the process of concrete experience, observations and reflections, formation of abstract concepts and generalizations, and testing implications of concepts in new situations. Particularly, internship could also serve as a springboard to facilitate the 21st century's high school reform—*high school career and technical education* (Lynch, 2000). Joining the two provides students with career exploration and planning opportunities, enhances their academic achievement and motivation to learn, allows them to gain generic work competencies and skill useful for employment, and establishes pathways for continuing education and lifelong learning.

CHAPTER 9: STUDENTS' UNDERSTANDINGS OF SCIENCE PRACTICE IN A SCIENCE INTERNSHIP: REFLECTIONS FROM AN ACTIVITY-THEORETIC PERSPECTIVE

Preface

When reviewing the literature on internship or apprenticeship research, I found a contradictory phenomenon in science-education literature. On one hand, many important documents about science education such as *Benchmarks for Science Literacy* (American Association for the Advancement of Science, 1993) and *National Science Education Standards* (National Research Council, 1996) had suggested that educators guide students to experience and participate in science more authentically. The assumption made in many studies is that authentic science activities enhance students' understanding of nature of science (Schwartz & Crawford, 2004). On the other hand, it was apparent that students' views about the nature of science remained unchanged after an eight-week apprenticeship program (Bell, Blair, Crawford, & Lederman, 2003). The uncertainty about the influence of authentic-science activities on students' view of the nature of science led me to question the unsolved debate in science education.

In my study, "doing what comes naturally" (Lincoln & Guba, 1985) was my main principle in guiding the internship. Through discussions between scientists, teachers and researchers, the students' presentations were designed as part of the internship to examine their learning results. When I looked for data sources to examine the debate, the students' presentations serve as a great data source for me to examine their understanding of science practice. Thus, the chapter aims to answer the following question:

"How do students understand science practice after participating in a science internship?"

This chapter is based on collaboration with the following authors and is in preparation for submission to the International Journal of Science Education.

Hsu, P.-L., van Eijck, M. W., & Roth, W.-M. (in preparation). Students' understandings of science practice in a science internship: Reflections from an activity-theoretic perspective. *International Journal of Science Education*.

Abstract

Working at scientists' elbow is one suggestion that educators make to improve science education, because such "authentic experiences" provide students with various types and levels of science knowledge. However, there is an ongoing debate in the literature about the assumption whether authentic science activities can enhance students' understandings of (the nature of) science practice. The purpose of the study is to further address the debate in terms of the ethnographic data collected in a high school students' science internship, including students' internship participations during their internship and students' public presentations in the end of their internship. Drawing on activity theory to analyze these presentations, I found that students presented the science practice as accomplished by individual personnel without collaboration in the laboratory. However, the data of science activities participations show that students had conversations about these complex collaborations within and outside the laboratory. This phenomenon leads me to claim that students experienced authentic science in their internships, but their representation of authentic science is incomplete, like illustrations in textbooks or the media that often attribute achievements to individuals. That is, participating in authentic science internship and reporting science practice are two different activities. The debate of the influence on students' understanding of nature of science is not simply related to situating students in authentic science contexts, but also related to students' values and ideology of reporting their understandings about science. To help students see these "invisible" moments is therefore crucial. I make suggestions for how the invisible in and of authentic science may be made visible.

9.1. Introduction

The American Association for the Advancement of Science (AAAS, 1993) and the National Research Council (NRC, 1996) suggest that K–12 science education needs to engage students in practicing science more authentically rather than provide didactic instruction. The term *authentic* is usually meant to denote forms of engagement that have a family resemblance to the real jobs of scientists and technicians in science-related fields. There are suggestions that authentic science activity is important in promoting inquiry because it provides a natural problem-solving context with sufficient complexity to make it interesting (Lee & Songer, 2003). In particular, engaging students in science practices through apprenticeship allows students to appreciate science as a human endeavor with values and norms (Richmond, 1998). Thus, internships in research settings have received increasing attention as a means of setting up science activities that provide students with an opportunity to experience science as it is practiced (e.g., Varelas, House, & Wenzel, 2005). Existing internship studies conducted with middle- and high school students stress students' understanding of the nature of science and scientific inquiry (e.g., Bell, Blair, Crawford, & Lederman, 2003; Richmond & Kurth, 1999); their attitude toward and interest in science (e.g., Abraham, 2002; Gibson & Chase, 2002); conceptual knowledge (e.g., Bleicher, 1994; Charney et al., 2007); motivation and confidence (e.g., Stake & Mares, 2005); the effect of mentoring styles on students' learning (Bleicher, 1996); and evaluative criteria for characterizing the internship experiences (Barab & Hay, 2001).

There are many studies suggesting that students would develop a better understanding of science practice when they experience science more authentically (e.g., Bencze & Hodson, 1999). Internship or apprenticeship programs that facilitate students' interaction with scientists are promoted as ways that foster authentic experiences and thereby enhance students' understanding about science practice (e.g., Barab & Hay, 2001; Ritchie, & Rigano, 1996). Therefore, the assumption made in many studies is that authentic science activities do in fact enhance students' understanding of nature of science (Schwartz & Crawford, 2004). However, different claims derive from a recent experimental study (pre-test and post-test measurement) that suggests that high school students' understanding of the nature of science remained unchanged after participating in a science apprenticeship program (Bell, Blair, Crawford, & Lederman, 2003). That is, the suggestion that participating in an authentic-science context enhances students' understanding of nature of science remains a moot point.

To further address the issues in this debate, the purpose of my study was to investigate high school students' understandings of (the nature of) science practice during and after their internship in a university biology laboratory focusing on water quality. I use ethnographic data from internship activities and students' presentations to an audience of practicing and becoming scientists at the end of the internship. I use an activity-theoretic perspective to analyze the understanding of (the nature of) science that students exhibit.

9.2. Theoretical Framework

To understand students' understandings of (the nature of) science practice after they complete the internship, I drew on the cultural-historical activity theory to analyze their representations of science enterprise in their presentations. Activity theory is a multidisciplinary theory that describes human activities—farming, manufacturing, or schooling—as historically, culturally and socially situated phenomena (Leont'ev, 1978). In this theory, human activity has a hierarchical structure consisting of four levels: a network of activities; a collective local, motive-driven activity; individual goal-driven and consciously acts; and routinized, condition-driven unconscious operations. From an activity-theoretic perspective, the activity is the minimum meaningful unit for human behavior—from a method perspective an activity therefore is the smallest unit of analysis that preserves meaning, any smaller unit of analysis loses constitutive aspects of it (Vygotsky, 1986). Therefore, I can only understand sense in the context of an activity as a whole (Cole & Engeström, 1993). The structural relations in an activity are frequently depicted in a mediational triangle featuring seven constitutive moments[2]: subject, object, tools, rules, community, division of labor and outcome (Figure 9.1). None of these seven constitutive moments can be studied in isolation and its generic representation (i.e., the triangle) only present at one point in time. Therefore, the cultural and historical aspects of human activities should be addressed with the generic representation.

The relations between pairs of moments—e.g., subject and objects—are not direct but are mediated by other moments—e.g., tools, communities, rules, and the division of labor (Engeström, 1987). The *subject* refers to the individual or sub-group whose agency is chosen as the point of view in the analysis. The *object* refers to the material or problem at which the activity is directed and which is molded and transformed into outcomes with the help of physical and symbolic, external and internal mediating instruments, including both tools and signs. Subject and object mutually constitute each other linked through the transitive action by means of which the former acts on/transforms the latter. Therefore, the object itself is constantly changing structural part of the activity system (Saari & Miettinen, 2001). The *community* comprises multiple individuals or sub-groups who share the same general object and who construct themselves as distinct from other communities. The *division of labor* refers to both the horizontal division of tasks between the members of the community and the vertical division of power and status (as the relation between teacher and student, manager and worker). Finally, the *rules* refer to the explicit and implicit regulations, norms, and conventions that constrain actions and interactions within the activity system. These moments are graphically organized as a triangle featuring different possible relations of mediation; the concrete example is a drinking-water science project where a group of high school student did an internship (Figure 9.1).

In particular, the dialectical thinking in activity theory are important in explaining human

---

[2] Consistent with the materialist dialectical approach underlying activity theory, which takes activity as its smallest unit, I denote structures smaller than the unit as "moment." Moments cannot be understood on their own because they constitute and are constituted by other moments.

activities, such as the relationships of individual-collective, body-mind, subject-object, agency-structure, and material-ideal; that is, the opposites are theorized as nonidentical expressions of the same category, which thereby comes to embody an inner contradiction (Roth & Lee, 2007). For instance, subjectivity and intersubjectivity are dialectically related and therefore presuppose one another. At the very moment that humans utter sentences, they presuppose that others already understand. The well-established activity-theoretic framework, therefore, provides a generic and useful tool to analyze human activities such as a science enterprise. For the study, the tool allows me to analyze students' representations of the results of their science internship.

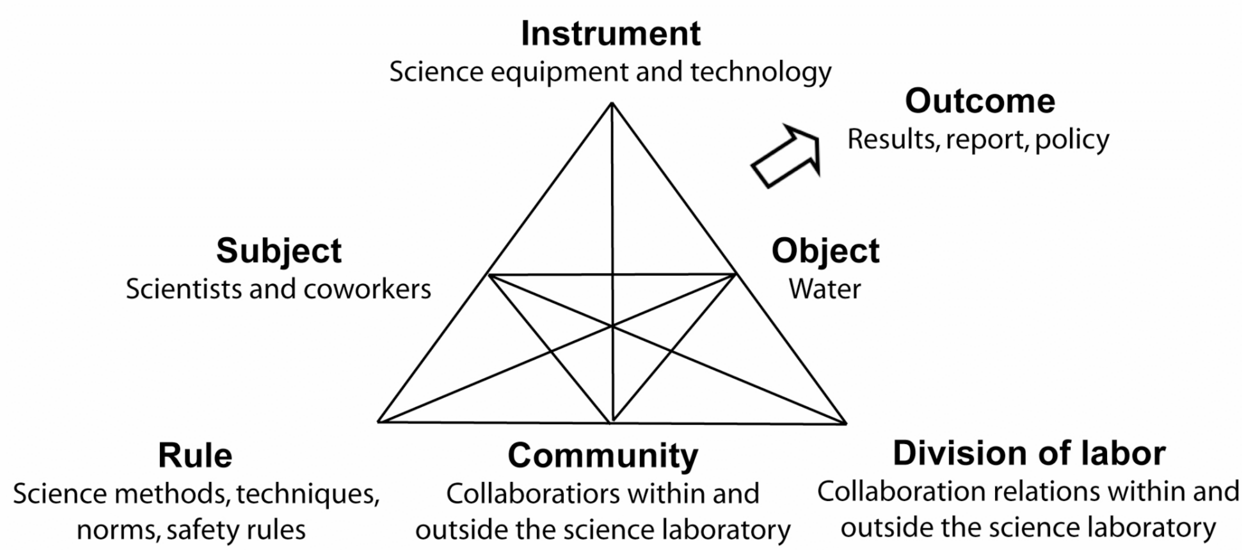

Figure 9.1. The moments of activity system and its respective moments of a drinking water science project.

9.3. Study Design

This study was designed to investigate students' understanding of (the nature of) science during and following an internship in a professional (university-based) biology laboratory focusing on water quality. This high school students' internship study is part of a larger research program concerned with the development of scientific literacy in authentic settings.

9.3.1. Participants

Before inviting high school students to the science laboratory, I first conducted two ethnography studies: in the first, I observed students' science lessons for one month and, second, I conducted a six-month study of the university science laboratory. The students were enrolled in an eleventh-grade honors biology class, which also serves as a biology career-preparation course in a public school of a mid-sized Canadian city. The students used after-school time to participate in various science activities to complete the course, which requires 100 hours over two years (grades 11 and 12). Students relied on the biology teacher for information about science activities and counted on her organization to participate in these activities. The internship in the biology laboratory was one of the options for the career-preparation course. The 13 high school students interested in participating in the internship came to the laboratory in groups of three or four.

The biology laboratory cooperated with many partners (e.g., the city, funding agencies, and researchers at other universities) to investigate the environmental parameters of drinking-water supplies. The laboratory members included the chief scientist and head of the research program, a laboratory manager, three scientists, five postdoctoral fellows, one administrative assistant, 28 technicians (e.g., field managers, research assistants, graduate students, etc.), and a large and changing number of undergraduate co-op students. At the beginning of each week, the lab manager hosted a discussion on administrative issues, troubleshooting, equipment arrangement, and the working reports of last week and scheduled reports for the following week. The administrative assistant and technicians participated in these meetings. There were many instances of collaboration between the different projects in the laboratory and the organization of special events was discussed during the weekly meetings. The meeting minutes were sent to all members to update them about the news in the laboratory. Scientific events such as graduate students' presentations were discussed monthly, involving all members of the laboratory and some external collaborators. Technicians worked in the laboratory for eight hours a day, had lunch, coffee breaks and sometimes conducted fieldwork. There were many projects going on at the same time and these technicians in each project often cooperated with graduate students, while being supervised by the responsible scientist. Technicians went back and forth in the laboratory to use different equipment and instruments for their work, or even went to other laboratories for other instruments if necessary.

9.3.2. Internship Context

Two scientists participated in and supervised all internship activities during its 2-month duration. Before the arrival of the high school students, scientists explained the forms of internship they were ready to provide. They established the schedule with the high school biology teacher and the educational researchers, and suggested ways of guiding the students in each project. The five technicians were either undergraduate or graduate students and were the main practitioners in the four projects. Each technician designed an internship plan beforehand and discussed the feasibility of the plan with the research scientists. The purpose of the internship, for the scientists and technicians, was to demonstrate regular work in the laboratory, show the application of scientific knowledge to daily life, and provide high school students with an opportunity to engage in scientific practice. When these technicians needed instructions or help concerning how to assist the students, they asked the scientists for advice. Technicians were the main personal contacts for the students.

I organized the first meeting for the students, scientists, and technicians to discuss the scientific projects, negotiate schedules and discuss the scientific work in preparation for the internship in the university laboratory. During the first meeting, four technicians presented their science projects to 13 (2 male, 11 female) students and their high school biology teacher. Each of the four groups of students was associated with a technician (one group had two technicians who took turns in guiding students). Students usually started the internship by reading relevant scientific papers selected by these technicians. They participated in discussions and scientific seminars, and practiced particular techniques in laboratories or collected samples from the field. After the internship, each group of students presented what they had learned during the internship to an audience of about 50, including laboratory members (scientists, technicians, and university students), their biology teacher, other high school students, and staff from the Center for Scientific Literacy.

9.3.3. Data Sources and Rules for Coding

Data were collected in the form of observations, field notes, and video recordings throughout the internship including the students' final presentations of their laboratory work. In this study, I exemplify the argument with data sources from 20 videotapes (each about 50–60 minutes) recorded during the internship—technicians' presentations, students' presentations, and their internship activities. To better understand students' understandings of (the nature of) science practice from their presentations. Two tools help me to code these presentations and further assist me to illustrate patterns of the representations of science practice.

First, I use the basic seven (i.e., subject, object, instrument, rule, community, division of labor, outcome) and its historical moments in activity system to code students' representations of science practice. To demonstrate details of my coding, I respectively exemplify data from presentations as followings. *Subject* refers to the technician or students in their group using names ("Nora" analyzed…) or pronouns ("we" filtered the sample…). *Object* refers to the object and its relevant descriptions of the project such as raw samples ("water" or "seafood"), processed samples ("bacteria" and "chemicals" existing in water or "DNA" extracted from bacteria) or technology invention ("household water technology"). *Instrument* refers to assisted tools such as equipment ("filters"), adding chemicals for the process ("rinsing solvent") or water for testing (we use "water" collected from a pond to test the household water technology). *Rule* refers to scientific methods ("genotypical analysis"), laboratory safety regulations ("make sure we did not touch bacteria") or techniques (we then "sterilize" the tweezers). *Community* refers to the collaborators (or collaborative regions) inside ("Colin" uses similar methods) or outside the laboratory (sample from three "First Nation communities"). *Division of labor* refers to the collaborative relationship inside (Samson "helped" me to develop…) or outside the laboratory (we have a "partnership" with the BC government). *Outcome* refers to results, reports, policy or implications reported from their projects (we found that "A.S.A" [identified chemical] in the water). In addition to the seven constitutive moments, I also pay attentions to the *historical* aspect of descriptions about science practice.

Second, I drew on Systemic Functional Linguistic (SFL) theory (Unsworth, 2000) to analyze certain speech pattern. In this study I identified and distinguished all clauses—a pattern of words built around a verb (Unsworth, 2001)—to calculate the clause units in the discourse of presentations. Clauses beginning with conjunctions like "when" and "because" are known as dependent or subordinate clauses. Clauses without conjunctions are known as independent or ordinate clauses. For example, there are three clauses in the sentence "When the weather is sunny, he likes to go out and play with friends." "When the weather is sunny" is a subordinate clause, while "he likes to go out" and "and play with friends" are ordinate clauses. In addition, clauses containing verbs that could indicate tense are called finite clauses, while those that do not indicate tense by their verbs are known as non-finite clauses. As an example, in the sentence "To achieve the goal, he worked very hard," "to achieve the goal" is a non-finite clause; "he worked very hard," which indicates past tense by the verb "worked" is a finite clause. Furthermore, some clauses are interrupted by other clauses. For instance, the sentence "The bird, having yellow feathers, leaped on the ground for a while and then flew to the sky" contains three clauses: "the bird leaped on the ground for a while," "having yellow feathers," and "and then flew to the sky." To code the activity moments of these presentations, explicit clauses served as my smallest units. For instance, the clause "we put the filter onto a blue media" was coded as having one subject "we," one rule "put … onto," and one instrument "the filter and a blue media." Although the clause contains two kinds of instrument, it was coded only once for the instrument moment, because the clause is my smallest unit. So one clause can only be coded for each moment once. If the seven moments were all mentioned in one clause, it was claimed that each moment was

100% addressed (in one clause).

9.4. Understandings of Science Practice

This study was designed to investigate high school students' understandings of (the nature of) science practice during and after their internship in a university biology laboratory focusing on water quality. In the following sections, I first examine students' representations of scientific practice in their public presentations and compare these to these technicians' presentations of the same projects. I then conduct an analysis comparing what students have *actually done* and experienced, as available from my field notes and videotapes, and what they *said* to have done and experienced during the presentations. Finally I use my findings to address the debate of whether participations in authentic science can enhance students' understandings of (the nature of) science practice from the activity theory perspective.

9.4.1. Presenting Authentic Science after Participating in An Internship?

The purpose of my study was to investigate high school students' understandings of the nature of science practice during and after their internship in a university biology laboratory. Investigating science students' presentations offers important information for science educators, as it not only indicates their conceptual understandings of particular science topics but also their discursive strategies of presenting the subject matter itself (Bleicher, 1994). To deepen my understanding of students' presentations, I compare these to these technicians' presentations of the same projects. These technicians' presentations provide me with a basis from which to understand the projects from the perspective of more experienced participants. In the following sections, I first provide descriptions of two presentation episodes. I subsequently draw on activity theory to analyze these presentations, which yields a bigger picture of the similarities and differences between technicians' and students' presentations.

9.4.1.1. Two Demonstrative Episodes of Presentations on Scientific Projects

In this section, I exhibit students' experiences of an internship as it was articulated during their final presentations of a laboratory project and contrast these with the description of more experienced technicians who had guided the students through the internship. In Group B, three high school students (Cindy, Kelly and Joe) followed the technician (Nora) to participate in a scientific project that uses scientific techniques (e.g., water sampling, bacteria incubating, antibiotic plating, etc.) to track fecal contamination in surface waters. The episode shows the beginning of the two presentations in which they introduced themselves and the objective of their project.

Group B Technician's Presentation

Nora: Okay, so as I said before, I'm Nora. I'm working on bacteria source tracking of E. coli in surface water. Um, I'm working with a post-doc named Bab, and uh a senior researcher named Jack, all under Aran so you'll get to know these people, don't worry about it. So bacterial source tracking is basically using genotypical and phenotypical uh characteristics of the, in this case, bacteria to basically determine where it came from and hopefully how it got there.

Group B Students' Presentation

Cindy: All right so, I'm Cindy, this is Joe, and we pretty much did our project on bacteria source tracking. And we worked with Nora and she was really chill, we had a really fun time... (continue) ... Nora is our group leader, obviously from X university, you guys probably know that. Okay so yeah we did bacteria source tracking, it was pretty exciting. Um yeah so the introduction, okay yeah so this is just talking about we were working with E. coli and uh trying to find out where the, the contamination from E. coli is coming from like what from, from what animals.

In this episode, both the technician and students introduced themselves by relating to their "bacteria source tracking project" and both of them reported same objectives in the project "[to] find out where bacteria come from." However, the technician also illustrated aspects of the community and the division of labor in the science practice ("I'm working with a post-doc named Bob, and uh a senior researcher named Jack, all under Aran"). In the high school students' presentation, there is no description of community or division of labor for science practice in the students' presentation.

In addition to the differences illustrated in Group B, the following episode demonstrated other dimensions of difference between them. In Group C, three students (Mandy, Claire, and June) followed technicians Nancy and Rachel (another technician who took turns with Nancy to lead students in the internship) through a scientific project that identifies possible contaminants in the seafood of First Nations communities. After self-introductions, the episode shows how both the technician and students present the motive of this scientific project.

Group C Technician's Presentation	**Group C Students' Presentation**
Nancy: So um salmon farming has been taking place in BC since the late 70s, and some papers have emerged recently saying there's contaminants in the feed. The contaminants are metals and they are organic things like PCBs and pesticides. And there's other studies showing that those contaminants are underneath the net pens, um, so what people are wondering is are they getting into the animals that live around the net pens. And then the bigger question is, what about people that eat food that's harvested in those areas, are there contaminants in those foods that have any reason to worry? So this project is a partnership with three different First Nations groups. They're the north coast of B.C., north coast of Vancouver Island, and the west coast of Vancouver Island. So in partnership with these groups.	Mandy: The project that we were working on was potential bioaccumulation of aquaculture associated contaminants. And the goal of the project was to investigate traditional First Nations marine foods and to determine if the foods contained any levels of contamination that may be a health concern. There were three study areas: those were Ahousat on the west coast of Vancouver Island, and the red dot is marking where Ahousat is, uh Bredon archipelago on the north coast of Vancouver Island, and that's marked on that area as well and Klemtu on the north coast of BC. Which is, arrows pointing to that area.

In these episodes, both presenters note that the objective of their project was to investigate potential contaminants in the seafood of First Nations communities. However, the technician's also articulated the historical dimension of the project. She described previous activities ("salmon farming has been taking place in BC since the late 70s") and previous investigations ("some papers have emerged recently saying there's contaminants in the feed," "there's other studies showing that those contaminants are underneath the net pens") to connect to the objective and concerns that the scientific project addresses. In contrast, the students' presentation did not illustrate the historical dimension. Furthermore, the technician pointed out the collaborative community ("three community") and division of labor ("partnership"), whereas the students presented the locations of communities and their names only. This phenomenon exhibits how these technicians' presentations illustrated historical aspects that went beyond the present project.

That is, three important dimensions of activity theory, history, community, and division of labor were central to these technicians' presentations but not in those of the students whom they supervised. The comparison between these technicians' and students' presentations helps me to understand what students (do not) perceive in the scientific projects. The two episodes clearly exhibit that the fact which aspects of their work technicians reported but the students did not.

9.4.1.2. Similarities and Differences between Technicians' and Students' Presentations

To deepen my understanding, I conducted a quantitative analysis assisted by a linguistic theory. The purpose of the quantitative analysis is to see how much effort presenters put into each activity moment for presenting a human activity— science practice. Drawing on activity theory, I represented in and for my analysis the four groups' presentations (four technicians and four groups of students: Groups A, B, C, and E) in terms of seven basic moments (subject, object, instrument, rule, community, division of labor, and outcome) and its historical aspect constituted as an activity. To define "effort," I drew on a linguistic theory called Systemic Functional Linguistic (SFL) theory to identify the frequency of use of clauses referring to these activity moments (Table 9.1). On average, technicians used 82 clauses in their presentations; the students used 176 clauses.

9.4.1.2.1. Similarities.

Both students and technicians in their presentations emphasized the rule moment in the science practice such as scientific methods and techniques. Students addressed the moment of rule in 40.0% of their whole presentations (clauses) and technicians put 41.5% efforts as well. Also, the moment of outcome is not salient in both students' and technicians' presentations. Students only spent 1.3 % efforts and technicians spent 1.5% efforts to present the results of their science projects.

9.4.1.2.2. Differences.

On average, technicians spent about four minutes and students spent about nine minutes in their presentations. However, technicians had presented each activity moment to present their presentations, where as students did not present the moments of inside community, division of labor and historical aspects of science practice. That is, although technicians spent less time on presentations, they covered more moments of the scientific activity than the students did.

Table 9.1. Frequencies of clauses used in technicians and high school students' presentations discourse on each activity moment of the same scientific projects.

Group	Group A		Group B		Group C		Group D		Total	
Technician /Student	T	S	T	S	T	S	T	S	T	S
Time	4:28	9:28	5:52	11:50	1:51	9:38	4:12	7:08	16:23 (M: 4:05)	38:04 (M: 9:31)
Clauses	99	185	112	228	37	157	80	135	328 (M:82)	705 (M:176)
Subject	7	43	28	50	9	22	15	29	59 (18.0%)	144 (20.4%)
Object	47	42	50	58	9	65	18	24	124 (37.8%)	189 (26.8%)
Instrument	7	11	9	30	0	61	22	49	38 (11.6%)	151 (21.4%)
Rule	42	55	60	118	15	33	19	75	136 (41.5%)	281 (40.0%)
Outside /Inside	O I	O I	O I	O I	O I	O I	O I	O I	O I	O I
Community	5 3	10 0	2 2	0 0	12 1	5 0	16 6	9 0	35 (10.7%) 12 (3.7%)	24 (3.4%) 0
	8	11	4	0	13	5	22	9	47 (14.3%)	24 (3.4%)
Division of labor	1 2	0 0	0 3	0 0	2 0	0 0	2 1	0 0	5 (1.5%) 6 (1.8%)	0 0
	3	0	3	0	2	0	3	0	11 (3.4%)	0
Outcome	4	4	0	0	1	0	0	5	5 (1.5%)	9 (1.3%)
Historical	3	0	1	0	2	0	0	0	6 (2.0%)	0

*M: Mean

There was a substantial difference when presenting the moment of community. Technicians spent about three times efforts of students to address the moment of community (T: 14.3%; S: 3.4%). In particular, students only addressed the collaborative community outside the laboratory (3.4%) and did not address the community inside the laboratory at all (0%).

Another significant difference between the two presentations is that students did not present the moment of division of labor either inside or outside the laboratory (0%). Nevertheless, technicians spent equal efforts to address the division of labor inside (1.8%) and outside (1.5%) the laboratory.

In students' presentations, the historical aspects of science projects were invisible (S: 0%). In general, technicians put relatively more effort into including a historical dimension in their presentation (T: 2.0%). Concerning the historical aspects of scientific activity, in addition to history of other communities' contributions and results as illustrated in the previous demonstrative episode (Group C), other moments of activity had been addressed. For instance, technicians presented the historical development of rules ("I've been helping Samson [a scientist] develop a method, that's 'relatively new and novel' for analyzing these drugs"). They also described the moment of objects historically ("you guys are probably too young to know about the Walkerton outbreak 'a couple of years ago' but basically Walkerton, Ontario had a big *E. coli* contamination in their water and I believe something like 40 people was it died from it. *E. coli* infection is seriously not fun and can be fatal").

These two forms of representation of science practices, therefore, were very different. Technicians' presentations of science practice were activity oriented and carried out by different communities, whereas students' representations of science practice are action-oriented and carried out by individuals and groups. In other words, the moments of science community and division of labor are not salient for students. This phenomenon led me to ask the following questions: "Why do the high school students present science practice as being achieved by one technician rather than a collaboration between different communities and a division of labor?" and "Does the internship provide these dimensions for high school students to observe?" From these technicians' presentations, we understand these dimensions had been presented to students at the beginning of the internship, but what about activities in the internship practice itself?

9.4.2. Experiencing Authentic Science during An Internship?

Why did students not present community and division of labor of science practice? Do the internships allow high school students to experience these two moments of the activity? To clarify my concern about students' understanding of community and the division of labor in internship practice, I examined the video recordings of their internship activities. I found that, in different ways, students had conversations about these moments during the internship as demonstrated in the following sections.

9.4.2.1. Collaboration within the Technician's Work

In the section, I illustrate one episode from Group B's internship activities to demonstrate the conversations about collaborations within their technicians' work *during* the internship. Before students went into the laboratory to practice science, these technicians presented the general ideas of the scientific projects and suggested students should read some overview papers. Therefore, students came to the laboratory with a general understanding of the projects. In the following episode, which was taken from the first day of Group B's internship, other students were practicing techniques that Nora (technician) had demonstrated to them. Cindy (student) asked questions about how Nora learned to do what she was doing in the project (i.e., to operate many techniques such as bacteria [*E. coli*] purification to identify bacteria DNA). To respond Cindy's questions, Nora explicitly introduced collaboration with other personnel, paper reading and discussion to assist her work.

(022112545)

01 Cindy: Ya, I just wondered like how do you learn to do `something` so random, like E. coli, purification, like it's a pretty random thing?

02 Nora: Yeah.

03 Cindy: If you're to do like specially if you're going to do a whole bunch of stuff and how do you like learn it all and like…

04 Nora: Well, a lot of it comes from papers, reading scientific papers, um, the papers I gave you guys, are just review papers, so there is no actual experiment going on, usually, um, but in actual scientific journals, um, it'll have a method section, and you basically see what other people did, and how, what they did transfers over to what you did and you can kind of copy different steps, and kind of add a few things, like, Bob and I have kind of sat down and gone okay well we want

this outcome, where should we, how should we get it, and you know, well we can use this or we could use that, or…

05 Cindy: So you pretty much like had a task like to get a pure thing of E. coli, and it was like up to you to like go around and like find out how all this stuff, pretty much.

06 Nora: Basically.

07 Cindy: Wow, that's cool.

08 Nora: Ya, actually all of this, was actually taught to me, but, different parts of the experiment I had to go and figure out myself, like the gel software we'll be using in a couple weeks, that was all me. I came in at like seven thirty one morning, with a big cup of coffee, and I'm like, I gonna learn how to use this. Of course the guy there was the only one other person in the building that knew how to use it, and he was on vacation, and I needed the data by like the next day, so I'm like mm, how can I figure this out?

09 Cindy: I'm gonna have to find this out, ya.

10 Nora: Ya but…

11 Cindy: That's really cool, I had no idea how that like all worked or anything so…

12 Nora: Ya, no it's, it's and like I said, I was in the networking or not the networking, in the ah the meeting on Friday, you piggy back off each other, right?

13 Cindy: Ya.

14 Nora: Like Norris helps me and I help him, or even Colin, has to come up to me and say, you know, I'm looking at doing bacteria stuff, what do I do? Point me in the right direction, so…

15 Cindy: Ya.

16 Nora: You gotta get a good networking base and everyone kind of helps out everybody else, everybody's happy and blessed.

Attending science practice on the first day of the internship, Cindy described a technique such as bacteria purification as something "random" (turn 01) and so she wondered how Nora learned to choose these specific techniques among "a whole bunch of stuff" (turn 03). To respond to Cindy's questions, Nora said that she learned "a lot" from scientific papers that have "a method section" and that one could either "transfer" or "copy" suitable techniques from other people's experiments to "what you did" (turn 04). Her discussions with Bob, a post-doctoral fellow who participated in the project, would help her to determine which techniques they needed for a particular kind of "outcome" (turn 04). To confirm her understanding, Cindy repeated Nora's previous statement by giving the example of the technique of *E. coli* purification. Cindy had identified "to get a pure thing of *E. coli*" (turn 05) as a particular outcome described by Nora (turn 04) and so the necessary steps to get the particular outcome could be determined. Her example application then got an affirmative response from Nora ("basically" [turn 06]). After describing the lessons that were taught to her (turn 08), Nora introduced another dimension of required effort in order to move the project on. Although there was help from Bob, she sometimes needed to "go and figure out" (turn 08) techniques by herself. She took the example of learning to operate "software" to illustrate that she had to handle some urgent situation on her own, because she had no available help from the only knowledgeable technician at that time. Responding to Nora's explanation, Cindy expressed her astonishment "That's really cool, I have no idea how that like all worked" (turn 11).

To respond to Cindy's comment, Nora first confirmed "Ya" (turn 12) and then uttered "no" (turn 12) as if there was something more or different from her previous description. Subsequently, she provides more explanation ("like I said, I was in the networking . . . meeting . . . you piggy back off each other" [turn 12]). Here, the utterance "like I said" indicates that Nora had already mentioned this help and collaboration with others before. She listed some technicians that lead other groups' students such as Norris (a undergraduate student) and Colin (a graduate student) and emphasized that "even Colin" sometimes "has to come up to me" and asks for "directions" (turn 14). Here, the term "even" suggests that Colin was assumed to know more than Nora, but he has to ask for help as well. Therefore, Nora concluded that "getting a good networking base" is one of the important elements of making projects work for "everybody" (turn 16).

In this episode, I identify many complex layers of collaboration and division of labor that were introduced to students during their internship practice: the use scientific papers to identify suitable methods from other personnel in the science community; the relation with Bob (the post-doctoral fellow) who can discuss matters or give Nora advice in choosing particular techniques; the relation with other laboratory technicians (who can provide specialized help if she needs it, such as using software); and the networking relation with other technicians in the same laboratory (such as Nora, Norris and Colin who can help each other). In conclusion, the community collaboration and division of labor were thoroughly addressed at different levels during the internship.

9.4.2.2. Collaboration beyond the Technician's Work

In addition to the division of labor in helping individual technician's work, I demonstrate yet another dimension of division of labor beyond the techniques introduced to students during the internship. On the second day of Group C's internship (after reading overview papers and practicing fieldwork on the first day), three students followed Nancy and Rachel in turn to practice different stages of the project. The students (Mandy and the other two) followed Nancy on the first day to do fieldwork. The next episode occurred when Nancy led students to meet Rachel who carried out most of the scientific techniques in the laboratory for this project.

(031510630)

01 Nancy: So that's all we got, so after, we get our samples from the three communities, we bring them back here, and we put them in the freezer, and then we analyze them. That's the really time-consuming part. It takes about ten days to do about twelve samples.

02 Mandy: Yes that is what we are doing today?

03 Nancy: Ya, we are going to do a condensed version, Rachel has set the thing up and gotten it ready, so you can see how it kind of works and what you would be doing but you don't have to sit there and watch samples evaporate.

At the beginning of Group C's second day, Nancy introduced an overview of the internship practice for that day. First, she guided students to see some samples brought from "three" (turn 01) collaborative First Nations communities and then introduced the "real" time that it takes to process (turn 01). Later, Nancy informed students that they would follow another technician "Rachel" to "do a condensed version" (turn 03) of regular work in the laboratory. Here, Nancy's overview introduction illustrated the collaborative communities outside the laboratory and the collaborative relationship between Nancy and Rachel. After the overview, Nancy left and let Rachel lead students to practice and observe. In the middle of the practice, Mandy asked a question about the sequence of techniques that Rachel demonstrated.

(031536213)

04 Mandy: Why do you start with the DCM solvent and not hexane? Why do you switch over?

05 Rachel: I think, my own theory, you can ask my supervisor and he may give you a better answer but my own thing I think DCM must be a better extracting solvent because I know hexane dissolves PCB very well, maybe not pesticides very well.

Mandy observed that Rachel had changed the solvent sequences that she used for a previous technique and then clarified Rachel's "switch over" action (turn 04). To respond to this question, Rachel said, "I think, my own theory, you can ask my supervisor and he may give you a better answer" and then explained her understanding of the different sequence (turn 05). Here, Rachel's statement illustrated uncertainty "my own theory" and her relation to another person "supervisor" participating in the project. Not only did Rachel or Nancy participate in the project but so did someone who had more knowledge and was in a position to supervise Rachel, so Mandy might get a "better answer" if she asked him. In other words, the episode shows that Rachel was not the one who designed the experiment, so she can provide only a tentative theory to answer Mandy's question. At the end of the scientific practice in the laboratory, Rachel concluded the second day of the internship with the following episode:

(031540700)

06 Rachel: So what goes next is that our scientist, Samson, will come (?) with a nitrogen can and he will actually add another solvent to sharpen up the process and he will put the insert, the small insert, into the gas compound machine and will analyze the PCB and pesticides. I think that is it for today.

Rachel demonstrates a condensed version of her daily work to students and then she connected to the next step that is conducted by "a scientist, Samson . . . he will add another solvent to sharpen up the process" (turn 06). This episode illustrates how Rachel did only part of the technique required in the whole project and other part needs to be done by another person to get the results.

These episodes in Group C show that division of labor has been introduced during the internship and beyond the individual technician's (e.g., Rachel's) work. Not just Rachel's work had been introduced but also different stages of scientific practice. For instance, the sample-collecting stage and collaboration with First Nations communities outside the laboratory (turn 01), the transitional stage between Nancy and Rachel (turn 02), other personnel's collaboration for designing the project (turn 5), and the later stage of another scientist's work (turn 06).

The examples of Groups B and C's internship activities indicate that students had a chance to observe the moments of community or division of labor in scientific projects. They had even participated in conversations about them. The ethnographic data lead me to claim that high school students had these conversations and observations about the collaboration or division of labor within and outside the laboratory. However, they did not present these moments in their final presentations, as reported in previous sections. So, students had gleaned these moments of community and division of labor from technicians' presentations at the very beginning of the internship, had conversations about them during the internship, but in the end these moments remained invisible in students' presentation.

9.5. Conclusion and Discussion

This study was designed to investigate high school students' understandings of (the nature of) science practice during and after their internship in a university biology laboratory focusing on water quality. The study was conducted in a context where science educators often assume that students can better understand nature of science when they experience science more authentically (Schwartz & Crawford, 2004). However, students who work at the elbow of scientists do not necessarily increase their understanding of the nature of science (Bell, Blair, Crawford, & Lederman, 2003). To further address the debate, I examine in this study ethnographic data of students' public presentations at the end of their internship and their activities during the internship. I also draw on technicians' presentations at the beginning of the internship to compare the representations of science practice identified in students' presentations. Because technicians are more experienced practitioners in the biology laboratory, their presentations served as useful referents for situating students' understanding of science practice.

Using activity theory to examine these presentations, I found similarities and differences between technicians' and students' presentations: (a) both students and technicians spend most efforts in presenting "rule"; (b) "outcome" is not salient in both technicians' and students' presentations; (c) representations of activity moments are incomplete in students' presentations; (d) the moment of "community" inside the laboratory is invisible in students' presentations; (e) the moment of "division of labor" either inside or outside the laboratory is invisible in students' presentations; and (f) the moment of "historical" aspects of science practice is invisible in students' presentations.

These findings show that students' representations of science practices are action-oriented focusing only on what was carried out by individuals or groups. Students' incomplete representations of the science community and its division of labor leads me to wonder whether students had experienced these moments in their internship activities. In fact, the video ethnographic data of students' internship activities show that students had relevant experience and conversations. That is, students had heard about these moments at the beginning of their internship from these technicians' presentations, and they had experienced and conversed about them during the internship. However, they did not present the moments in their final presentations. This leaves us to wonder: "Why this discrepancy?"

To better understand the issue about authentic science activities, I draw on activity theory to explain the contradiction. When students presented the science practice after completing their internship, they did not simply "mirror" what they had experienced or learned during their internships, but their presentations were designed for the audience. The internal structure of such accounts of what has been done refracts what actually has been done *because* of the audience (Bakhtin/Medvedev, 1978). That is, what students present and report are for the audience and so they would report what they deem as important or valuable things to the audience. The activity of presentation and the activity of science practice (internship) are two different activities, primarily occasioned by the different objects/motives: laboratory work produces scientific data, presentations produce audience-oriented accounts. Therefore, the question of the influence of authentic science of students' understandings of nature of science practice is not simply one of having authentic science activities or not. What students say about science is also related to what the values and beliefs expressed when reporting science practice. This makes the findings of previous studies intelligible: When students are asked to report their understandings about science practices, they are in a position to convince and speak for their audience (e.g., interviewers, researchers, teachers, scientists). What they reported therefore does not exactly reflect what they had experienced but likely to fit the general understanding of science practice (e.g., the stereotypical image of science practice).

My study shows a contradictory phenomenon. On the one hand, students do not appear to develop complete representations of the nature of science practice after they participated a science internship. More specifically, students did not thoroughly present in their final presentations the laboratory community and its division of labor. On the other hand, students' conversations and interactions during their internship activities show that student had experienced and even had conversations about the laboratory community and its division of labor. In other words, participation in an authentic context did provide opportunities for students to gain a better understanding of an authentic-science enterprise in the way some science educators suggest (e.g., Bencze & Hodson, 1999). Nevertheless, students did not reflect these authentic science experiences and understanding in their representations as if these authentic science activities did not enhance students' understandings of nature of science practice as reported by a experimental study (Bell, Blair, Crawford, & Lederman, 2003).

When I step back and look at the whole internship (or apprenticeship) research from a remove, I recognize that it was actually constituted by different layers of activities (see Figure 9.2). When students participated in internship, the activity was the scientific production of knowledge that the motive for which is scientific publication and elaboration of water policy. When students presented what they learned at the end of internship, they participated in an activity of presenting science. In this, the motive was articulating and reporting "important" things that they had learned in their internship activities. These two are different activities, which means, very different social and cognitive factors are at play. Because actions of an individual become understandable only in the context of an activity (Cole & Engeström, 1993), it is understandable that the presentations did not mirror what students had done or experienced in their science practice but mixed with their prior experience of science and their values and beliefs of what is important and worthy to report to their audience in the presentation situation. In fact, any narrative about some aspect of the world only refracts reality because the internal structure of the narrative follows its own laws (Bakhtin/Medvedev, 1978).

The debate about participations in authentic science therefore is not simply about whether an authentic science context can provide students with a better understanding of science practice, but also related to the messages that students received in everyday life, such as from their school, the public media and the whole society. These messages may be dominant to lead students to see what kinds of things they could see in authentic science and even to guide students to present what they felt worthy to present. For example, students often present stereotypical images of science practice, which comes to be attributed to individuals (e.g., Mead & Métraux, 1957; She, 1995). These stereotypical images of scientists and science are powerful mediators of understanding among elementary, middle school, high school, and undergraduate students and remain as such apparently even in the case of an internship. Therefore, even though students had experienced these aspects of community and division of labor, they still devalued or even ignored their importance.

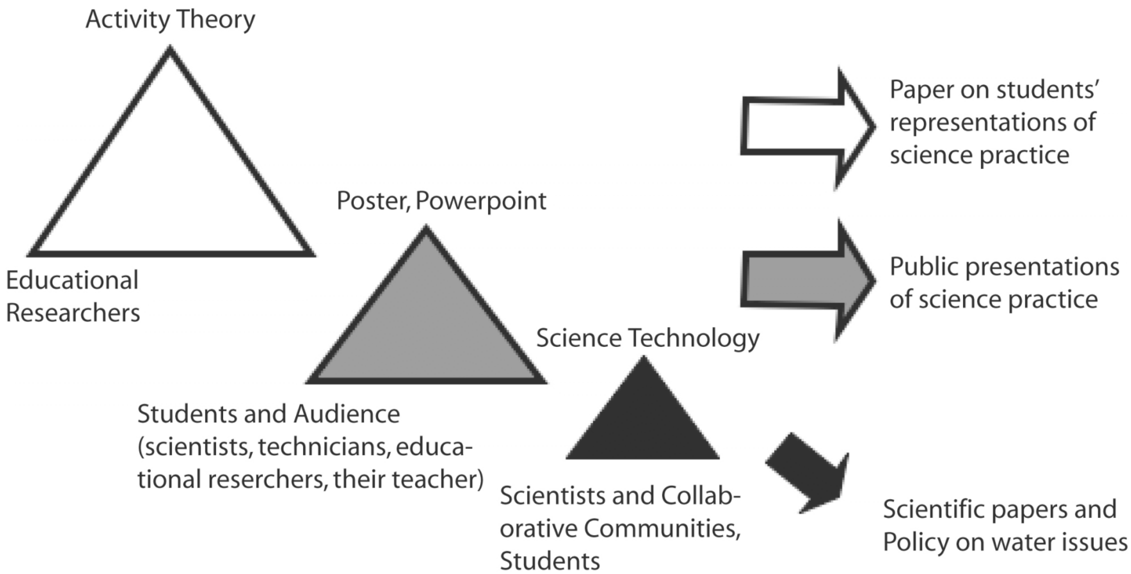

Figure 9.2. Different layers of activities involved in the study.

In this study, instead of using conventional instruments such as questionnaires, tests or interviews to detect students' understandings of nature of science, I videotaped students' internship activities throughout and also videotaped scientists' and technicians' presentations. This allowed me to capture the natural talk of all participants in a variety of settings. My analyses of these natural conversations and interactions allowed me to articulate the different orientations in different activities defined as such by the different object/motives that participants pursue. In fact, I understand that even in similarly oriented activities, students may act differently for different audiences. Thus, in the case of presentations at the end of open-inquiry projects in schools, the audience at students' presentations mediated how they used science language (Crawford, Chen, & Kelly, 1997). That is, teachers find it easier to assess students' ways of using science language when the audience is naïve (e.g., elementary students) rather than knowledgeable (e.g., teachers), because students tend to offer more explanations to naïve audiences than they do to expert audiences.

9.6. Suggestions: Making Invisible Visible

My study shows that students' understanding of (the nature of) authentic science practice is not just about whether they participate in authentic science activities but also is related to what students perceive as important. As in other situations (Suchman, 1995), there are aspects of scientific work that remain invisible—especially because participation does not make salient these invisible aspects much like swimming with the proverbial fish would not make visible the water. Therefore, ways of making the "invisible" aspects of scientific laboratory work "visible" for students becomes an important topic for discussion among science educators. In my case, how do we single out what appears to be the invisible community and the invisible division of labor, and help students to see the "authentic" in an authentic science setting? Three candidate answers are suggested to serve as possible solutions to "make invisible things visible" in authentic science contexts.

First, students might be assisted in reflecting on their experiences during and after the authentic science activities, as reflection is a metacognitive form of engagement that allows learners to inform their own learning process and thereby attain deeper understanding (Paris & Ayres, 1994). Guided journal writing and seminars may enhance participants' understanding of the scientific enterprise (Schwartz, Lederman, & Crawford, 2004). Also, through reflective activities such as discussions and writing, people often discern their experiences from active reflections or interactions with others, and so enhance their learning (Linder & Marshall, 2003).

Second, the collaboration between educators and scientists in structuring internship programs may make these invisible moments more visible. Scientists' epistemological views of science are not always consistent and vary across different disciplines (Schwartz & Lederman, 2008). Collaboration with science educators may provide a context within which scientists themselves become more aware of the tacit (invisible) aspects of their work. For instance, scientists and researchers could design more activities for students to interact with a variety of people within and outside the laboratory, such as scientists, fieldwork technicians, laboratory technicians, data analysts, and report writers, and collaborative science communities.

Third, providing students a greater degree of ownership in investigating science issues in authentic science context may increase their understanding of the process. There are studies that illustrate that students' motivation is greater when students choose the context, problem and method of investigation (e.g., Tuan, Chin, Tsai, & Cheng, 2005). Hence allowing students to design their own scientific projects with the support of technicians and scientists in authentic science contexts likely engages students deeper in these projects; give them more chances to explore all different aspects of science practice. They may therefore experience all different layers of community collaboration in science practice.

CHAPTER 10: DISCUSSION AND IMPLICATION

To understand the issues and phenomena related to the science internship, I conducted investigations before, during, and after an internship experience that brought high school science students into a university research laboratory. This chapter describes the findings of and reports the contribution of these findings to science education. The implications for teachers, students, science communities, and suggestions for future research are discussed.

10.1. Conclusions and Contributions

As discussed in chapter 1, the topic of high school students' science internship is relatively new research in science education. After conducting the literature review, I chose six research questions to explore new territory in science internships. In general, the dissertation made new contributions to theoretical development, research methods and debates in science education (see Table 10.1). In the following, the three main contributions are discussed in terms of chapters as below.

10.1.1. Contributions of Chapters 4 and 5: Before the Internship

Before high school students arrive at the university laboratory, it is important to understand their school culture and discourse because they serve as background information for me to understand participants in a cultural and historical manner. In chapters 4 and 5, I used discourse analysis as my main research tool to analyze the discourse. How an experienced teacher introduces science activities to her students had become an important question for me to understand in chapter 4, because teachers are the frontline personnel in school education and their discourse has the ability to encourage students into taking science.

Table 10.1. Contributions to theoretical development, research method, and issues of science education in the dissertation.

Chapter	Contributions to		
	Theoretical Development	Research Methods	Debates or issues in science education
Chapter 4 (Introducing science)	• Discursive resources • Discursive device	• DA + Ethnography • DA + Quantitative prevalence	
Chapter 5 (Talking science careers)	• Discursive resources	• DA + Ethnography • DA + Quantitative prevalence	• Do science internships have positive effects on students' pursuing in science?
Chapter 6 (Internship Transaction)	• Transactional structure • Preference organization • Formulating	• CA + Ethnography • CA + Quantitative prevalence	
Chapter 7 (Science Expertise)	• Emergent expertise • Knowledgeability	• CA + Ethnography • CA + Quantitative prevalence	• Are "experts" and "novices" experts and novices?
Chapter 8 (Internship Experience)	• Categories of experiential descriptions	• Phenomenographic techniques improvement	
Chapter 9 (Students' understanding of science practice)	• Using CHAT to examine students' understanding of science	• Analyzing presentations as an alternative way of understanding students' view of science practice	• Do science internships enhance students' understanding of science practice?

I identified six interpretative repertoires in the high school teacher's discourse of introducing science activities to her students. They were: (a) science is special and specialized, (b) beyond lab coats: a-stereotypical science, (c) fun and enthusiasm in science, (d) science is relevant to us, (e) science includes empirical disciplines, and (f) rareness of science opportunities. One discursive device was identified as "just-a-side-issue" to prefer one repertoire to the other and solve the tension. It is important to understand how students talk about their possible science career choices, because their discourses helps us understand their ways of articulating science enterprise and how they connect themselves to science. Four interpretative repertoires were identified in high school students' discourse in chapter 5 when they talked about science-related careers. These were (a) formative, (b) performative, (c) consequential, and (d) potential dimensions of actions. These discursive resources served as a foundation for future discursive analysts' use and the development of analysis validation, because "the accumulation of findings from different studies allows new studies to be assessed for their coherence with what comes before" (Potter, 2003, p. 86).

Another new contribution of chapters 4 and 5 is the combination of discourse analysis and ethnography. I used multiple methods to identify interpretative repertoires. This approach is quite different from most previous discourse studies that used interviews to identify interpretative repertoires (e.g., Lawes, 1999; Wetherell & Potter, 1992). In fact, there are suggestions that new studies ought to challenge "methodological monotheism" (Bourdieu, 1992); "the fact of combining discourse analysis with ethnographic description will be hailed as a breakthrough and a daring challenge to methodological monotheism" (p. 226). Furthermore, in previous studies, one of the limitations in the analysis of interpretative repertoires is that it is difficult to make clear and consistent judgments about the boundary of particular repertoires (Potter, 1996a). To overcome the limitation, I used SFL theory to assist me in identifying the boundary of interpretative repertoires. Therefore, the frequency of interpretative repertoires could be counted so that its prevalence and pattern became accessible.

One frequent assumption in science education is that students' participation in authentic science activities may encourage them to pursue science. However, through the investigation of discourse before and after the internship in chapter 5, I found that most students said that they might choose not to pursue science after experiencing "real science." Their reasons were the tediousness and lengthy procedures of university science. This finding challenged the naïve assumption about internships in science and provided a rationale for possible barriers and obstacles when students meet "real science."

10.1.2. Contributions of Chapters 6 and 7: During the Internship

The microgenetic scale of investigation in chapters 6 and 7 illustrate the moment-to-moment transactions between technicians and high school students during the internship. Because technicians did not have educational training, how can they teach high school students and how can students learn science from technicians? In chapter 6, I identified three main natural pedagogical conversational mechanisms for teaching and learning: (a) transactional structures (i.e., I-C-R [Initiate-Clarify-Reply] and I-R-C-R [Initiate-Reply-Clarify-Reply]), (b) conversation organization (i.e., ambiguous preference), and (c) conversation features (i.e., self- and other- formulating). These findings contributed new conversational mechanisms to conversational studies in general and to science education in particular, demonstrating pedagogical conversations in science discourses. It is not usual to see an analysis of conversation mechanisms in science-education literature. Therefore, the analysis and findings serve as a model for further theoretical development in science education. As discussed in chapter 6, many theoretical concepts were introduced in education to depict the process of apprenticeship, such as *modeling*, *scaffolding*, and *fading* (Collins, Brown, & Newman, 1989) and *legitimate peripheral participation* (Lave & Wenger, 1991). However, when I looked closely at the moment-to-moment transactions of the internship, these theoretical concepts did not always match what I observed and analyzed. Thus, based on the dialectic concept of margin and center (Goulart & Roth, 2006), the theoretical concept of "emergent expertise" was proposed to describe the mutual transactions of apprenticeship (internship) in chapter 7.

Emergent expertise is 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 non-verbal) and tools. I propose *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." The notion of "emergent expertise" helps us to elevate students' positions in teaching and learning; it could lead us to achieve an equitable, student-centered, and empowered education.

Concerning contributions to research methods, I combined conversation analysis and ethnography to analyze micro-scale interactions in the science internship. It is a relatively new development to combine the method of conversation analysis with ethnography. In the past, conversation analysts often investigated particular themes (e.g., preference organizations) in terms of data sources collected from random settings, such as from telephone conversations, everyday conversation, or lectures. For instance, in studying the topic of preference organization, Pomerantz (1984) collected conversations from different settings about different topics, such as a conversation about a lake, about kitchen painting, about the weather, about a movie, etc. Conversation analysts may not situate in or collect their data sources in person. However, there is a movement to integrate conversation analysis and ethnography, because these are methodologically compatible (Seedhouse, 2005). In fact, combining conversation analysis and ethnography can strengthen the *emic* perspective, because the production of valid knowledge presupposes an understanding between researcher and research participants about what they are talking and doing, and achieve the concept of "a community of interpretation" (Apel, 1972).

Another contribution to research methods in chapters 6 and 7 is the use of quantitative prevalence in conversation analysis. In the past, conversation analysis has got along without quantitative evidence. However, it is considered that conversation analysis will become quantitative during the next stage of development, because the frequency or distributions of interactional practices allow researchers to illustrate different scales of conversational phenomena (Heritage, 1999). For instance, in my study, the frequency of conversation structures allows me to illustrate conversational change in three different stages (beginning, middle and end) of the science internship.

A large body of research has demonstrated numerous differences between experts and novices (Chi, Glaser, & Farr, 1988). It is common for people to determine the roles of expert and novice in terms of their previous experience, status, or position, so students are often deemed novices. However, the unreflective assumption may underestimate students' capability, creativity, or even affect their learning. Chapters 6 and 7 illustrated that and how students can be the center of their learning and even teach others to guide them. The pedagogical conversations in chapter 6 demonstrated *what it looks like* when students are in the driving seat regarding their learning. The proposed theoretical concept of *emergent expertise* in chapter 7 illustrated *how we may think* to help both teachers and students achieve a student-centered education. These findings help "experts" and "novices" to rethink their presupposed roles and so "everyone" may allow the emergence of expertise during their transactions.

10.1.3. Contributions of Chapters 8 and 9: After the Internship

Two important research questions that I investigate are the way students experience the science internship and the way they understand science practice. In considering these questions, I chose phenomenography and cultural-historical activity theory as my research tools to illustrate their experiences and understanding of science. In chapter 8, five experiential categories of the science internship were identified from 19 participants (11 students, their high school teacher, 2 scientists, and 5 technicians): (a) authenticity of university science, (b) channeling and connecting different communities, (c) advanced knowledge and lengthy procedures in university science, (d) selves' exploration and reflection, and (e) comprehensive science learning. As illustrated in Table 8.1, the structural and referential aspects of experiential categories and the variations in the structural aspects were identified. The identification of different levels of variation supported the development of phenomenography; in addition to the different ways of experiencing (the first face of variation), the variation that corresponds to the critical aspects of the phenomenon (the second face of variation) has become an important component in the recent studies in phenomenography (Pang, 2003). For students' understanding of (the nature of) science, the fact that disagreements exist in the literature about the tenets of the "nature of science" described in previous studies (e.g., Alters, 1997). That is, the discussion in literature shows that there is no consensus about the definition of the nature of science. Thus, using the well-established activity-theoretic framework provides a generic and useful tool to analyze human activities such as science practice. It opens up another horizon for science educators to examine students' understanding of science practice.

Concerning the contribution to research methods, chapter 8 provided some techniques to improve the techniques of interviewing and analyzing the interview. For interviewing, I used a card-sorting activity in which students wrote down the key words of their experiences. The key words serve as an important resource in assessing the important elements in participants' descriptions (Sjöström & Dahlgren, 2002). Further, viewing the video recording of interviews helps analysts to examine the interviews afterwards. We know that transcription is a transforming process that may distance researchers from the interview situation and participant (Dortins, 2002). In particular, reading and re-reading the transcript with the video allows researchers to avoid de-contextualisation (Bowden, 1996), found in the early phenomenographic studies (i.e., through arranging and rearranging selected quotes into piles).

In terms of the method contributions of chapter 9, most of the previous studies on students' images of science enterprise depended on conventional instruments to detect conceptions such as questionnaires (e.g., Aikenhead & Ryan, 1992), interviews (Ryder, Leach, & Driver, 1999), or the Draw-A-Scientist Test (e.g., Chambers, 1983). However, these approaches for assessing students' understanding about the nature of science are not flawless (Aikenhead, Fleming, & Ryan, 1987; Leach, Millar, Ryder, & Séré, 2000; Lederman, Wade, & Bell, 1998; Losh, Wilke, & Pop, 2008). Therefore, I decided to find an alternative way by taking students' public presentations (video recorded) as data sources to understand their view of science practice after the internship. Thus, problems such as students trying to "guess" what researchers want to hear or misinterpreting researchers' questions or questionnaires were in all likelihood avoided.

The findings in chapter 9 addressed the debate in science education about whether authentic science activities enhance students' view of (the nature) of science. My analysis shows participation in an authentic context did provide opportunities for students to gain a better understanding of an authentic-science enterprise in the way some science educators suggest (e.g., Bencze & Hodson, 1999). However, students did not reflect the authentic science experience and understanding in their representations. It was as if the science activities did not enhance students' understanding of science practice as reported in an experimental study (Bell, Blair, Crawford, & Lederman, 2003). Therefore, the question of the influence of authentic science on students' understanding of science practice is not simply one of doing authentic science activities or not. What students say about science is related to the values and beliefs expressed when reporting science practice. This makes the findings of previous studies intelligible: When students are asked to report their understanding of science practice, they are in a position to convince their audience (e.g., interviewers, researchers, teachers, scientists). What they reported therefore does not reflect what they had experienced but in fact fits the general understanding of science practice (e.g., the stereotypical image of science practice).

10.2. Implication

The dissertation not only discusses various important issues and phenomena related to science internships, but also indicates educational implications for improving science education in general and science internships in particular. In the next sections, I discuss the implications for teachers, students, science communities, and researchers

10.2.1. For Teachers

Discursive Resources for Introducing Science. In the dissertation, chapters 4 and 5 provide concrete interpretative repertoires for science teachers to use. Chapter 4 demonstrated an experienced teachers' "introducing science" discourse and chapter 5 illustrated students' discourse of identifying and dis-identifying science-related careers. Six interpretative repertoires were identified in chapter 4: (a) science is special and specialized, (b) beyond lab coats: a-stereotypical science, (c) fun and enthusiasm in science, (d) science is relevant to us, (e) science is empirical disciplines, and (f) rareness of science opportunities. Four interpretative repertoires were identified in chapter 5: (a) formative, (b) performative, (c) consequential, and (d) potential repertoires. These repertoires can be posted in classrooms for science teachers to use when teachers (a) want to introduce or promote science activities to students in general (e.g., rare-opportunity repertoire, “this internship is a unique opportunity, you should take the chance”), or (b) try to recruit students into science in particular such as choosing university majors (e.g., potential repertoire, “there are so many marine animals needing to be investigated and discovered, you will always learn things all the time when you are a biologist”).

Pedagogical Conversations and Theoretical Concepts for Student-Centered Education. Student-centered education is often promoted and suggested by educators, but how do teachers interact with students and place students in teaching and learning to achieve a student-centered education? The dissertation provided some directions for teachers. The natural pedagogical conversations identified in chapter 6 demonstrate concrete and exemplary conversations for teachers. These conversations include Initiate-Clarify-Reply (I-C-R), Initiate-Reply-Clarify-Reply (I-R-C-R), *ambiguous dispreferred modes*, *self-formulating* and *other-formulating*. Understanding the difference between traditional conversational structure (e.g., I-R-E) and student-centered conversational structure (e.g., I-C-R) provides an opportunity for teachers to reflect on their own discourse in school. For instance, simply audio- or video-recording a few lessons and analyzing their conversational structure would give teachers some indication of their discourse style. In addition, the theoretical concept of emergent expertise proposed in chapter 7 would help teachers to “see” students as capable people who can contribute to and guide teachers’ teaching. In fact, if both teachers and students recognize the concept of *emergent expertise*, teaching and learning would become a heterogeneous phenomenon. Students may become “teachers” to guide teachers’ teaching for the needs of individual students and so make teaching more efficient.

10.2.2. For Students

Remember, “YOU” Are the Center of Learning. One of the important messages from the dissertation is that students should be deemed capable learners who can contribute as much as teachers, and experts rather than knowledge receivers or novices. Students are the centers of their own learning and they can even facilitate knowledge generation. The concept of expertise does not belong to individuals but emerges after participation and transactions among participants. Therefore, it is important to acknowledge the phenomenon and encourage students to speak out and be aware that in this way they not only help themselves to learn but also help their teachers to teach. The forms of pedagogical conversations in chapter 6 (e.g., I-C-R and I-R-C-R) demonstrate what type of student-centered discourse may be performed. The concept of *emergent expertise* in chapter 7 helps students to place themselves as leader of their responsible learning. Furthermore, students' awareness of their crucial roles in learning can help teachers and schools to achieve an equitable, student-centered, and empowered education.

Reflective Learning. The study shows that when students were provided with opportunities to reflect their own learning in the science internship, they reflected something they did not even know before. For instance, one student explained her awareness of this phenomenon in the post-interview:

> That's just part of life. You go into things you don't know but when you go back and think about it, it was a really foreign situation . . . and I was surprised that I felt like that but I'd never really realized until I had to think about it.

She first described her feeling of uncertainty at the beginning of the internship and then found herself realizing the uncertain feeling when she had a chance (e.g., interviewing) to reflect on them. Through reflection, students can learn something more about themselves and about the internship at a different level. It has important implications for education in general. Teachers or educators could provide more activities for students to reflect their learning and so allow individual students to observe themselves. For science internships in particular, chapter 8 identified different types of experiences. The experiential categories provided a broad spectrum of experience concerning science internship, so they could serve as resources for students to reflect their learning experience through other students' eyes (Linder & Marshall, 2003). For instance, students who did not discern the experience of "comprehensive learning" in the internship may start to learn to appreciate that aspect of the internship. Teachers may use the findings as resources and materials to conduct reflective activities to help students "see" a science internship differently and make the most of these collective experiences.

10.2.3. For Science Communities

Emphasizing Particular Dimensions of Science Practice. Through the analysis of students' science-related career discourse, I identified four main interpretative repertoires that students often use to describe their preference and dispreference. In chapter 5, students often acknowledged their enthusiasm for pursuing science when they understood the special and beneficial process of becoming a science agent, the practicable performances of science practice, the influential contributions of science, and the wide and new possibilities of being a science agent. Therefore, if we want to recruit students into science, these findings provided science communities (scientists and technicians) useful directions for guiding students to see these dimensions of science practice. These dimensions are not necessarily "seen" naturally by students when they participate in science activities, but are much valued by them when they consider their career choices. Meanwhile, in chapter 9, the moments of community and division of labor are not deemed as important enough to report on in their presentations. Thus, it is suggested that networking or collaborative activities that guide students to see the importance of science enterprise would be beneficial.

10.2.4. For Researchers

Explorations of More Pedagogical Conversations. Conversation analysis is a well-known tool to investigate conversation; however, it is not yet a common tool for researchers in science education. Chapter 3 demonstrates the use of conversation analysis and identifies different organizations and features of pedagogical conversations in a science internship. Future researchers may use similar strategies to identify more pedagogical conversations in different settings, such as in science museums, in science fieldtrips, or in science classrooms. Therefore, different patterns of conversation can be illustrated and compared in different situations and educators can appreciate science teaching and learning discourses.

The Concept of Emergent Expertise. By proposing the concept of *emergent expertise*, I bring to focus the fact that expertise is not constituted in individuals but emerged during participants' transactions with available resources. Therefore, creating the space for essential transactions to bring out the best in each other is the crucial question for future research. Important research questions for further studies include: "What are the possible structures of the space to increase the depth and width of emergent expertise in the transactions?" "How do resources mediate transactions in these structures?" "How do we apply the concept of *emergent expertise* to practice?" and "How does *emergent expertise* enhance the learning and participation in their community?" These future studies will help us to understand *how* to achieve an equitable, student-centered, and empowered education.

Suggestions for Conducting Similar Internships. The participants of the science internship project made many suggestions for conducting similar internships. Different groups of participants had different suggestions. For instance, some suggestions from high school students and teachers included (a) expanding the length of time for internship participation and (b) allowing teachers to participate in internships with students. The science community suggested (a) providing more samples for students to practice and discuss plans and exchange ideas with technicians and scientists, (b) having scientists or technicians go into the classroom and interact with students before the internship, (c) considering students' background and prior knowledge when designing a plan, (d) inviting more students and create more opportunities for students to participate in similar activities, (e) ensuring available resources for internships, such as adequate equipment and samples, and (f) choosing technicians who can naturally articulate scientific knowledge to a younger audience. Researchers suggested (a) conducting reflection activities in the internship such as writing reflective journals or discussion and (b) providing students with an opportunity to conduct their own projects and collaborate with science communities. These suggestions serve as general considerations for conducting science internships, but a more rigorous way to find out how to conduct an ideal internship for participants is “experiment with design” (Brown, 1992) or “co-generative dialogue” (Roth, Tobin, & Zimmermann, 2002) to negotiate, communicate and explore participants’ needs.

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.
↑ or ?	Up arrow or question mark	Indicates rising pitch or intonation.
,	Comma	Indicates a temporary rise or fall in intonation.
-	Hyphen	Indicates an abrupt halt or interruption in utterance
=	Equal sign	Indicates the break and subsequent continuation of a single utterance.
(.)	Period inside single parentheses	A brief pause, usually less than 0.2 seconds.
(# 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 or *italics*	Underlined or italic 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 inhalation or exhalation.
((text))	Double parentheses	Annotation of non-verbal activity.

BIBLIOGRAPHY

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

Aikenhead, G., Fleming, R. W., & Ryan, A. G. (1987). High school graduates' beliefs about Science-Technology-Society. Ⅰ. Methods and issues in monitoring student views. *Science Education, 71*, 145–161.

Aikenhead, G., & Ryan, A. (1992). The development of a new instrument: 'Views on science-technology-society' (VOSTS). *Science Education, 76*, 477–491.

Alters, B. J. (1997). Whose nature of science? *Journal of Research in Science Teaching, 34*, 39–55.

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

American Association of UniversityWomen Educational Foundation. (1999). *Gender gaps: Where schools still fail our children*. New York: Marlowe.

Antaki, C., Billig, M., Edwards, D., & Potter, J. (2003). Discourse analysis means doing analysis: A critique of six analytic shortcomings. *Discourse Analysis Online*, from http://www.shu.ac.uk/daol/articles/v1/n1/a1/antaki2002002-paper.html

Apel, K. O. (1972). The a priori of communication and the foundation of the humanities. *Man and World, 5*, 3–37.

Atkinson, J. M., & Drew, P. (1979). *Order in court: The organization of verbal interaction in judicial setting.* London, Macmillan.

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

Bakhtin, M. M. (1986). *Speech genres and other late essays*. Austin: University of Texas Press.

Bakhtin, M. M./Medvedev, P. N. (1978). *The formal method in literary scholarship: A critical introduction to sociological poetics*. Baltimore: Johns Hopkins University Press.

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

Barab, S. A., Hay, K. E., Barnett, M., & Squire, K. (2001). Constructing virtual worlds: Tracing the historical development of learner practices. *Cognition and Instruction, 19*, 47–94.

Barab, S. A., Squire, K. D., & Dueber, B. (2000). A co-evolutionary model for supporting the emergence of authenticity. *Educational Technology Research and Development, 48* (2), 37–62.

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

Bencze, L., & Hodson, D. (1999). Changing practice by changing practice: Toward more authentic science and science curriculum development. *Journal of Research in Science Teaching, 36*, 521–539.

Bianchino, J., & Cavazos, L. M. (2007). Learning from students, inquiry into practice, and participation in professional communities: Beginning teachers' uneven progress toward equitable science teaching. *Journal of Research in Science Teaching, 44*, 586–612.

Billig, M. (1985). Prejudice, categorization and particularization: From a perceptual to a rhetorical approach. *European Journal of social Psychology, 15*, 79–103.

Billig, M. (1989). The argumentative nature of holding strong views: A case study. *European Journal of Social Psychology, 19*, 203–23.

Billig, M. (1995). *Banal nationalism.* London: Sage.

Bleicher, R. (1994). High school students presenting science: An interactional sociolinguistics analysis. *Journal of Research in Science Teaching, 31*, 697–719.

Bleicher, R. (1996). High school students learning science in university research laboratories. *Journal of Research in Science Teaching, 33*, 1115–1133.

Boudett, K. P., Murnane, R. J., City, E., & Moody, L. (2005). Teaching educators how to use student assessment data to improve instruction. *Phi Delta Kappan, 86*, 700–706.

Bourdieu, P. (1992). The practice of reflexive sociology (The Paris workshop). In P. Bourdieu & L. J. D. Wacquant, *An invitation to reflexive sociology* (pp. 216–260). Chicago: University of Chicago Press.

Bowden, J. A. (1996). Phenomenographic research—Some methodological issues. In G. Dall'Alba & B. Hasselgren (Eds.), *Reflections on phenomenography* (pp. 49–66). Göteborg: Acta universitatis Gothoburgensis.

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of girl does science? The construction of school science identities. *Journal of Research in Science Teaching, 37*, 441–458.

Brown, A. L. (1992). Design experiments: Theoretical and methodological challenges in creating complex interventions in classroom settings. *The Journal of the Learning Science, 2*, 141–178.

Brown, B. A. (2004). Discursive identity: Assimilation into the cultures of science and its implications for minority students. *Journal of Research in Science Teaching, 41*, 810–834.

Brown, A. L., Ash, D., Rutherford, M., Nakagawa, K., Gordon, A., & Campione, J. C. (1993). Distributed expertise in the classroom. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 188–228). Cambridge: Cambridge University Press.

Brown, B. A., & Kelly, G. (2006). When clarity and style meet substance: Language, identity, and the appropriation of science discourse. In W.-M. Roth & K. Tobin (Eds.), *Science, learning, and identity: Sociocultural and cultural historical perspectives* (pp. 283–299). Rotterdam: SensePublishers.

Brownlie, F., Feniak, C., & Schnellert, L. (2006). *Student diversity: Classroom strategies to meet the learning needs of all students* (2nd ed.). Markham, Canada: Pembroke Publishers.

Burman, E. (2003). Discourse analysis means analysing discourse: some comments on Antaki, Billig, Edwards and Potter 'Discourse analysis means doing analysis: a critique of six analytical shortcomings'. *Discourse Analysis online*, from http://extra.shu.ac.uk/daol/articles/open/2003/003/burman2003003-paper.html.

Carlsson, B. (2002). Ecological understanding 1: Ways of experiencing photosynthesis. *International Journal of Science Education, 24*, 681–699.

Chambers, D. W. (1983). Stereotypic images of the scientists: The draw-a-scientist test. *Science Education, 67*, 255–265.

Charney, J., Hmelo-Silver, C. E., Sofer, W., Neigeborn, L., Coletta, S., & Nemeroff, M. (2007). Cognitive apprenticeship in science through immersion in laboratory practices. *International Journal of Science Education, 29*, 195–213.

Chi, M. T. H., Glaser, R., & Farr, M. J. (Eds.). (1988). *The nature of expertise*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Chinn, C., & Malhotra, B. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science Education, 86*, 175–218.

Christidou, V. (2006). Greek students' science-related interests and experiences: Gender differences and correlations. *International Journal of Science Education, 28*, 1181–1199.

Cole, M., & Engeström, Y. (1993). A cultural-historical approach to distributed cognition. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 1–46). Cambridge, UK: Cambridge University Press.

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

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453–494). Hillsdale, NJ: Lawrence Erlbaum Associates.

Colwell, R., & Kelly, E. (1999). Science learning, science opportunity. *Science, 286*, 237.

Cope, C. J. (2002). Using the analytical framework of a structure of awareness to establish validity and reliability in phenomenographic research. *Proceedings of Current Issues in Phenomenography Symposium*. Canberra: CEDAM, Australian National University.

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

Crawford, T., Chen, C., & Kelly, G. J. (1997). Creating authentic opportunities for presenting science: The influence of audience on students talk. *Journal of Classroom Interaction, 32*, 1–13.

Crawford, T., Kelly, G. J., & Brown, C. (2000). Ways of knowing beyond facts and laws of science: An ethnographic investigation of student engagement in scientific practices. *Journal of Research in Science Teaching, 37*, 237–258.

Cross, S., & Markus, H. (1991). Possible Selves across the life span. *Human Development, 34*, 230–255.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. London: Sage.

Cunningham, C. M., & Helms, J. V. (1998). Sociology of science as a means to a more authentic, inclusive science education. *Journal of Research in Science Teaching, 35*, 483–500.

Dahlgren, L. O., & Fallsberg, M. (1991). Phenomenography as a qualitative approach in social pharmacy research. *Journal of Social and Administration Pharmacy, 8*, 150–156.

Daniels, H. (2001). *Vygotsky and pedagogy*. London: Routledge.

Davis, E. A., & Linn, M. C. (2000). Scaffolding students' knowledge integration: Prompts for reflection in KIE. *International Journal of Science Education, 22*, 819–837.

Denscombe, M. (2002). *Ground rules for good research: A 10 point guide for social researchers*. Buckingham: Open University Press.

Dick, T. P., & Rallis, S. F. (1991). Factors and influences on high school. students' career choices. *Journal for Research in Mathematics Education, 22*, 281–292.

Donovan, C. A., & Smolkin, L. B. (2002). Children's genre knowledge: An examination of K–5 students' performance on multiple tasks providing differing levels of scaffolding. *Reading Research Quarterly, 37*, 428–465.

Dortins, E. (2002). Reflections on phenomenographic process: Interview, transcription and analysis. In A. Goody, J. Herrington, & M. Northcote (Eds.), *Quality conversations: Research and development in higher education* (Vol. 25, pp. 207–213). Perth: HERDSA.

Drew, P. (1995). Conversation analysis. In J. A. Smith, R. Harré, & L. van Langenhove (Eds.), *Rethinking methods in psychology* (pp. 64–79). London: Sage.

Ebenezer, J. V., & Erickson, G. L. (1996). Chemistry students' conceptions of solubility: A phenomenography. *Science Education, 80*, 181–201.

Ebenezer, J. V., & Fraser, D. M. (2001). First year chemical engineering students' conceptions of energy in solution processes: Phenomenographic categories for common knowledge construction. *Science Education, 85*, 509–535.

Edley, N. (2001). Analysing masculinity: Interpretative repertoires, ideological dilemmas and subject positions. In M. Wetherell, S. Taylor & S. Yates (Eds.), *Discourse as data: A guide for analysis* (pp. 189–229). London: Sage.

Edwards, D. (1993). But what do children really think?: Discourse analysis and. conceptual content in children's talk. *Cognition and Instruction, 11*, 207–225.

Edwards, D., & Potter, J. (1992). *Discursive psychology*. London: Sage.

Ellis, R. A. (2004). University student approaches to learning science through writing. *International Journal of Science Education, 26*, 1835–1853.

Engeström, Y. (1987). *Learning by expanding: An activity-theoretical approach to development research*. Helsinki: Orienta-Konsultit.

Fadigan, K. A., & Hammrich, P. L. (2004). A Longitudinal study of the educational and career trajectories of femaile participants of an urban informal science education program. *Journal of Research in Science Teaching, 41*, 835–860.

Farenga, S., & Joyce, B. A. (1999). Intentions of young students to enrol in science course in the future: an examination of gender differences. *Science Education, 83*, 55–75.

Feuer, M. J., Towne, L., & Shavelson, R. J. (2002). Scientific culture and educational research. *Educational Research, 31* (8), 4–14.

Fowler, F. C. (2006). Struggling with theory: A beginning scholar's experience with Mazzoni's arena models. In V. A. Anfara & N. T. Mertz (Eds.), *Theoretical frameworks in qualitative researc*h (pp. 39–57). Thousand Oaks, CA: Sage.

Fox-Keller, E. (1983). *A feeling for the organism*. New York: W. H. Freeman.

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

Garfinkel, H. (1967). *Studies in ethnomethodology*. Englewood Cliffs, NJ: Prentice-Hall.

Gee, J. P. (2001). Identity as an analytic lens for research in education. *Review of Research, 25*, 99–125.

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

George, R., & Kaplan, D. (1998). A structural model of parent and teacher influences on science attitudes of eighth graders: Evidence from NELS 88. *Science Education, 82*, 93–109.

Gilbert, N., & Mulkay, M. (1984). *Opening Pandora's box: A sociological analysis of scientists' discourse*. Cambridge: Cambridge University Press.

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

Giorgi, A. (1999). A phenomenological perspective on some phenomenographic results on learning. *Journal of Phenomenological Psychology, 30*, 68–93.

Goffman, E. (1981). *Forms of talk*. Philadelphia: University of Pennsylvania Press.

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

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

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

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

Heritage, J. (1989). Current developments in conversation analysis. In D. Roger & P. Bull (Eds.), *Conversation: An interdisciplinary perspective* (pp. 21–47). Clevedon, PA: Multilingual Matters.

Heritage, J. (1999). Conversation analysis at century's end: Practices of talk-in-interaction, their distributions, and their outcomes. *Research on Language and Social Interaction, 32*, 69–76.

Holzkamp, L. (1993). *Lernen: Subjektwissenschaftliche Grundlagen.* Frankfurt: Campus-Verlag.

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

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

Jacobs, J. E., & Simpkins, S. D. (2005). Mapping leaks in the math, science, and technology pipeline. *New Directions for Child and Adolescent Development, 110*, 3–6.

Jarman, R. (1997). Fine in theory: A study of primary-secondary continuity in science, prior and subsequent to the introduction of the Northern Ireland Curriculum. *Educational Research, 39*, 291–310.

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

Johansson, B., & Lybeck, L. (1978). “proportions-och proportionalitetstänkande hos gymnasieelever, åk l, N-och T-linjerna.” *Rapporter från Pedagogiska institutionen*, Göteborgs universitet, nr 164 (Reasoning in proportions and proportional reasoning).

Jones, M. G., Howe, A., & Rua, M. (2000). Gender differences in students' experiences, interests, and attitudes toward science and scientists. *Science Education, 84*, 180–192.

Jormfeldt, H., Svedberg, P., Fridlund, B., & Arvidsson, B. (2007). Perceptions of the concept of health among nurses working in mental health services: A phenomenographic study. *International Journal of Mental Health Nursing, 16*, 50–56.

Kaste, J. (2004). Scaffolding through cases: Diverse constructivist teaching in the literacy methods course. *Teaching and Teacher Education, 20*, 31–45.

Katona, G. (1940). *Organizing and memorizing*. New York: Columbia University Press.

Keeves, J. P. (1975). The home, the school, and achievement in mathematics and science. *Science Education, 59*, 439–460.

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

Kvale, S. (1983). The qualitative interview: A phenomenological and a hermeneutical mode of understanding. *Journal of Phenomenological Psychology, 25*, 147–173.

Latour, B., & Woolgar, S. (1979). *Laboratory life: The construction of scientific facts*. London: Sage.

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

Lawes, R. (1999). Marriage: An analysis of discourse. *British Journal of Social Psychology, 38*, 1–20.

Lawless, J. G., & Rock, B. N. (1998). Student scientist partnerships and data quality. *Journal of Science Education and Technology, 7*, 5–13.

Leach, J., Millar, R., Ryder, J., & Séré, M.-G. (2000). Epistemological understanding in science learning: The consistency of representations across contexts. *Learning and Instruction, 10*, 497–527.

Lederman, N. G., Wade, P. D., & Bell, R. L. (1998). Assessing the nature of science: What is the nature of our assessments? *Science & Education, 7*, 595–615.

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

Lee, Y. J., & Roth, W.-M. (2004). Making a scientist: Discursive "doing" of identity and self-presentation during research interviews. *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research, 5* (1). http://www.qualitative-research.net/fqs-texte/1-04/1-04-leeroth-e.htm. (Accessed August 21, 2007)

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

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

Lent, R. W., Brown, S. D., Talleyrand, R., McPartland, E. B., Davis, T., Chopra, S., et al. (2002). Career choice barriers, supports, and coping strategies: College students' experiences. *Journal of Vocational Behavior, 60*, 61–72.

Leont'ev, A. N. (1978). *Activity, consciousness and personality*. Englewood Cliffs, NJ: Prentice Hall.

Levinson, S. (1983). *Pragmatics.* Cambridge: Cambridge University Press.

Lewis, B. F., & Collins, A. (2001). Interpretive investigation of the science-related career decisions of three African-American college students. *Journal of Research in Science Teaching, 38*, 599–621.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Newbury Park, CA: Sage.

Linder, C., & Marshall, D. (2003). Reflection and phenomenogrpahy: towards theoretical and educational development possibilities. *Learning and Instruction, 13*, 271–284.

Losh, S. C., Wilke, R., & Pop, M. (2008). Some methodological issue with “Draw a Scientist Tests” among young children. *International Journal of Science Education, 30*, 773–792.

Lynch, R. L. (2000). High school career and technical education for the first decade of the 21st century. *Journal of Vocational Education Research, 25*, 155–198.

Madill, H. M., Montgomerie, T. C., Stewin, L. L., Fitzsimmons, G. W., Tovell, D. R., Armour, M.-A., et al. (2000). Young women’s work values and role salience in grade 11: Are there changes three years later? *Career Development Quarterly, 49*, 16–27.

Markus, H., & Nurius, P. (1986). Possible selves. *American Psychologist, 41*, 954–969.

Marshall, D., & Linder, C. (2005). Students’ expectations of teaching in undergraduate physics. *International Journal of Science Education, 27*, 1255–1268.

Martin, B., Kass, H., & Brouwer, W. (1990). Authentic science: A diversity of meanings. *Science Education, 74*, 541–554.

Marton, F. (1981). Phenomenography—Describing conceptions of the world around us. *Instructional Science, 10*, 177–200.

Marton, F. (1986). Phenomenography—A research approach investigating different understandings of reality. *Journal of Thought, 21*, 28–49.

Marton, F. (1994). Phenomenography. In T. Husén and T. N. Postlethwaite (Eds.), *The international encyclopedia of education* (2nd ed., Vol. 8, pp. 4424–4429). Oxford: Pergamon.

Marton, F., & Booth, S. (1997). *Learning and awareness*. Mahwah, NJ: Lawrence Erlbaum Associates.

Mead, M., & Métraux, R. (1957). Image of the scientist among high-school students: a pilot study. *Science, 126*, 384–390.

Means, B. (1998). Melding authentic science, technology, and inquiry-based teaching: Experiences of the GLOBE program. *Journal of Science Education and Technology, 7*, 97–105.

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

Mertz, N. T., & Anfara, V. A. (2006). Conclusion: Coming full circle In V. A. Anfara & N. T. Mertz (Eds.), *Theoretical frameworks in qualitative researc*h (pp. 189–196). Thousand Oaks, CA: Sage.

Myhill, D., & Brackley, M. (2004). Making connections: Teachers' use of children's prior knowledge in whole class discourse. *British Journal of Educational Studies, 52*, 263–275.

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

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

O' Brien, V., Martinez-Pons, M., & Kopala, M. (1999). Mathematics self-efficacy, ethic identity, gender, and career interests related to mathematics and science. *The Journal of Educational Research, 92*, 231–235.

Packard, B. W., & Nguyen, D. (2003). Science career-related possible selves of adolescent girls: A longitudinal study. *Journal of Career Development, 29*, 251–263.

Pang, M. F. (2003). Two faces of variation: On continuity in the phenomenographic movement [1]. *Scandinavian Journal of Educational Research, 47*, 145–156.

Paris, S., & Ayers, L. (1994). *Becoming reflective students and teachers with portfolios and authentic assessment*. Washington, D.C.: American Psychological Association.

Peacock, A., & Gates, S. (2000). Newly qualified primary teachers' perceptions of the role of text material in teaching science. *Research in Science & Technological Education, 18*, 155–171.

Pike, K. (1967). *Language in relation to a unified theory of the structure of human behaviour*. The Hague: Mouton.

Pomerantz, A. M. (1984). Agreeing and disagreeing with assessments: Some features of preferred/dispreferred turn shapes. In J. M. Atkinson & J. Heritage (Eds.), *Structures of social action: Studies in conversation analysis* (pp. 57–101). Cambridge: Cambridge University Press.

Pomerantz, A. M. (1986). Extreme case formulations: a new way of legitimating claims. *Human Studies, 9*, 219–230.

Post, P., Stewart, M. A., & Smith, P. L. (1991). Self-efficacy, interest, and consideration of math/science and non-math/science occupations among black freshmen. *Journal of Vocational Behavior, 38*, 179–186.

Potter, J. (1996a). Discourse analysis and constructionist approaches: Theoretical background. In J. E. Richardson (Ed.), *Handbook of qualitative research methods for psychology and the social sciences* (pp. 125–140). Leicester: British Psychological Society.

Potter, J. (1996b). *Representing reality: Discourse, rhetoric and social construction*. London: Sage.

Potter, J. (1998). Discursive social psychology: From attitudes to evaluations. *European Review of Social Psychology, 9*, 233–266.

Potter, J. (2003). Discourse analysis and discursive psychology. In P. M. Camic, J. E. Rhodes & L. Yardley (Eds.), *Qualitative research in psychology: Expanding perspectives in methodology and design* (pp. 73–94). Washington: American Psychological Association.

Potter, J., & Edwards, D. (2001). Discursive social psychology. In W. P. Robinson and H. Giles. (Eds). *The New handbook of language and social psychology* (pp. 103-118). London: Wiley.

Potter, J., & Wetherell, M. (1987). *Discourse and social psychology: Beyond attitudes and behaviour*. London: Sage.

Potter, J., & Wetherell, M. (1995). Discourse analysis. In J. Smith, R. Harré, & R. van Langenhove (Eds.), *Rethinking methods in psychology* (pp. 80–92). London: Sage.

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

Puntambekar, S., & Kolodner, J. L. (2005). Toward implementing distributed scaffolding: Helping students learn science from design. *Journal of Research in Science Teaching, 42*, 185–217.

Quintana, C., Reiser, B. J., Davis, E. A., Krajcik, J., Fretz, E., Duncan, R. G., et al. (2004). Scaffolding the design framework for software to support science inquiry. *The Journal of the Learning Sciences, 13*, 337–386.

Rahm, J., Miller, H. C., Hartley, L., & Moore, J. C. (2003). The value of an emergent notion of authenticity: Examples from two student/teacher science partnerships programs. *Journal of Research in Science Teaching, 40*, 737–756.

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

Reis, G., & Roth, W-M. (2007). Environmental education in action: A discursive approach to curriculum design. *Environmental Education Research, 13*, 307–327.

Resnick, L. B. (1987). The 1987 presidential address: Learning in school and out. *Educational Research, 16* (9), 13–20.

Richmond, G. (1998). Scientific apprenticeship and the role of public schools: General education of a better kind. *Journal of Research in Science Teaching, 35*, 583–587.

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

Ritchie, S. M., & Rigano, D. L. (1996). Laboratory apprenticeship through a student research project. *Journal of Research in Science Teaching, 33*, 799–815.

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

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

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

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

Roth, W.-M. (2006a). Identity as dialectic: Making and Re/making self in urban schooling. In J. L. Kincheloe, K. Hayes, K. Rose, & P. M. Anderson (Eds.), *The Praeger handbook of urban education* (pp. 143–153). Westport, CT: Greenwood.

Roth, W.-M. (2006b). *Learning science: A singular plural perspective*. Rotterdam: Sense.

Roth, W-M. (2007). Emotion at work: A contribution to third-generation cultural historical activity theory. *Mind, Culture and Activity, 14*, 240–255.

Roth, W.-M. (2008a). Radical uncertainty in scientific discovery work. Science, *Technology & Human Values*. doi:10.1177/0162243907309627

Roth, W.-M. (2008b). The nature of scientific conceptions: A discursive psychological perspective. *Educational Research Review, 3*, 30–50.

Roth, W.-M., & Alexander, T. (1997). The interaction of students' scientific and religious discourses: Two case studies. *International Journal of Science Education, 19*, 125–146.

Roth, W.-M., & Bowen, G. M. (1995). Knowing and interacting: A study of culture, practices, and resources in a grade 8 open-inquiry science classroom guided by a cognitive apprenticeship metaphor. *Cognition and Instruction, 13*, 73–128.

Roth, W.-M., & Boyd, N. (1999). Coteaching, as colearning, in practice. *Research in Science Education, 29*, 51–67.

Roth, W.-M., & Calabrese Barton, A. (2004). *Rethinking scientific literacy*. New York: Routledge.

Roth, W.-M., Hwang, S., Lee, Y-J., & Goulart, M. I. M. (2005). *Participation, learning, and identity: Dialectical perspectives*. Berlin: Lehmanns Media.

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

Roth, W.-M., & Lee, Y. J. (2007). "Vygotsky's neglected legacy": Cultural-historical activity theory. *Review of Educational Research, 77*, 186–232.

Roth, W.-M., Lee, Y. J., & Hwang, S.-W. (2008). Culturing conceptions: From first principles. *Cultural Studies of Science Education, 3*, 231–261.

Roth, W-M., & Lucas, K-B. (1997). From ‘truth’ to ‘invented reality’: A discourse analysis of high school physics students’ talk about scientific knowledge. *Journal of Research in Science Teaching, 34*, 145–179.

Roth, W.-M., Lucas, K. B., & McRobbie, C. (2001). Students’ talk about rotational motion within and across contexts and teacher awareness. *International Journal of Science Education, 23*, 151–179.

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

Roth, W.-M., & Tobin, K. (2006). Aporias of identity in science: An introduction. In W.-M. Roth & K. Tobin (Eds.), *Science, learning, and identity: Sociocultural and cultural historical perspectives* (pp.1–10). Rotterdam: Sense.

Roth, W.-M., Tobin, K., & Zimmermann, A. (2002). Coteaching/cogenerative dialoguing: learning environments research as classroom praxis. *Learning Environments Research, 5*, 1–28.

Ryder, J., Leach, J., & Driver, R. (1999). Undergraduate science students' images of science. *Journal of Research in Science Teaching, 36*, 201–219.

Saari, E., & Miettinen, R. (2001). Dynamics of change in research work: Constructing a new research area in research group. *Science, Technology, & Human Values, 26*, 300–321.

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

Sandberg, J. (1996). Are phenomenographic results reliable? In G. Dall’Alba & B. Hasselgren (Eds.), *Reflections on phenomenography* (pp. 129–140). Göteborg: Acta universitatis Gothoburgensis.

Sandberg, J. (2000). Understanding human competence at work: An interpretative approach. *The Academy of Management Journal, 43*, 9–25.

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

Schegloff, E. A., & Sacks, H. (1973). Opening up closings. *Semiotica, 8*, 289–327.

Schiffrin, D. (1994). *Approaches to discourse*. Oxford: Blackwell.

Schoon, I. (2001). Teenage job aspirations and career attainment in adulthood: A 17 year follow-up study of teenagers who aspired to become scientists, health professionals, or engineers. *International Journal of Behavioral Development, 25*, 124–132.

Schoultz, J., Säljö, R., & Wyndhamn, J. (2001). Heavenly talk: Discourse, artefacts and children's understanding of elementary astronomy. *Human Development, 44*, 103–118.

Schwartz, R. S., & Crawford, B. A. (2004). Authentic scientific inquiry as a context for teaching nature of science: Identifying critical elements for success. In L. B. Flick & N. G. Lederman (Eds.), *Scientific inquiry and nature of science: Implications for teaching, learning, and teacher education* (pp. 331–355). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Schwartz, R. S., & Lederman, N. G. (2008). What scientists say: Scientists' views of nature of science and relation to science context. *International Journal of Science Education, 30*, 727–771.

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88*, 610–645.

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

Seedhouse, P. (2004). *The interactional architecture of the language classroom: A conversation analysis perspective.* Oxford, UK: Blackwell.

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

She, H. (1995). Elementary and middle school students' image of science and scientists related to current science textbooks in Taiwan. *Journal of Science Education and Technology, 4*, 283–294.

Shepard, B., & Marshall, A. (1999). Possible selves mapping: Life-career exploration with young adolescents. *Canadian Journal of Counseling, 33*, 37–54.

Shmurak, C. B. (1998). *Voices of hope: Adolescent girls at single sex and coeducational school*. New York: Peter Lang.

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

Sjöström, B., & Dahlgren, L. O. (2002). Applying phenomenography in nursing research. *Journal of Advanced Nursing, 40*, 339–345.

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

Stake, J. E. (2006). The critical mediating role of social encouragement for science motivation and confidence among high school girls and boys. *Journal of Applied Social Psychology, 36*, 1017–1045.

Stake, J. E., & Mares, K. R. (2005). Evaluating the impact of science-enrichment programs on adolescents' science motivation and confidence: the splashdown effect. *Journal of Research in Science Teaching, 42*, 359–375.

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

Suchman, L. A. (1995). Making work visible. *Communications of the ACM, 38* (9), 56-64.

Tan, K. H. K. (2008). Qualitatively different ways of experiencing student self-assessment. *Higher Education Research and Development, 27*, 15–29.

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

Terasaki, A. (1976). Pre-announcement sequences in conversation. *Social Science Working Paper 99.* University of California at Irvine.

Thomson, P., & Gunter, H. (2006). From ‘consulting pupils’ to ‘pupils as researchers’: A situated case narrative. *British Educational Research Journal, 32*, 839–856.

Tsai, C.-C., & Kuo, P. C. (2008). Cram school students’ conceptions of learning and learning science in Taiwan. *International Journal of Science Education, 30*, 353–375.

Tuan, H.-L., Chin, C.-C., Tsai, C.-C., & Cheng, S.-F. (2005). Investigating the effectiveness of inquiry instruction on the motivation of different learning styles students. *International Journal of Science and Mathematics Education, 3*, 541–566.

Unsworth, L. (2000). *Researching language in schools and communities: SFL perspectives*. London: Cassell.

Unsworth, L. (2001). *Teaching multiliteracies across the curriculum: Changing contexts of text and image in classroom practice*. Buckingham: Open University Press.

Uyeda, S., Madden, J., Brigham, L.A., Luft, J.A., & Washburne, J. (2002). Solving authentic science problems: Problem-based learning connects science to the world beyond school. *The Science Teacher, 69* (1), 24–29.

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

Verenikina, I. (2003). Understanding scaffolding and the ZPD in educational research. *Proceeding of the Australian Association of Educational Research Conference*, Auckland, New Zealand, Nov 30–Dec 3.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Vygotsky, L. S. (1986). *Thought and language*. Cambridge, MA: MIT Press.

Wang, J., & Staver, J. R. (2001). Examining relationships between factors of science Education and student career aspiration. *Journal of Educational Research, 94*, 312–320.

Weinburgh, M. (1995). Gender differences in student attitudes toward science: A meta-analysis of the literature from 1970 to 1991. *Journal of Research in Science Teaching, 32*, 387–398.

Weinstein, B. D. (1993). What is an expert? *Theoretical Medicine, 14*, 57–73.

Wetherell, M., & Potter, J. (1988). Discourse analysis and the identification of interpretative repertoire. In C. Antaki (Ed.), *Analyzing everyday explanation: A casebook of methods* (pp. 168–183). Greenwood Village, CO: Libraries Unlimited.

Wetherell, M., & Potter, J. (1989). Narrative characters and accounting for violence. In J. Schotter & K. Gergen (Eds.), *Texts of identity* (pp. 207–219). London: Sage.

Wetherell, M., & Potter, J. (1992). *Mapping the language of racism: Discourse and the legitimation of exploitation.* Hemel Hempstead: Harvester Wheatsheaf.

Wiggins, G. (1989). The futility of trying to teach everything of importance. *Educational Leadership, 47*, 44–59.

Wilkinson, S. (2000). Women with breast cancer talking causes: Comparing content, biographical and discursive analyses. *Feminism and Psychology, 10*, 431–460.

Wittgenstein, L. (1958). *Philosophical investigation* 3rd ed (G. E. M. Anscombe, Trans.). Oxford: Blackwell.

Wood, D., Bruner, J., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17*, 89–100.

Wooffitt, R. (2005). *Conversation analysis and discourse analysis: A comparative and critical introduction*. London: Sage.

Woolnough, B. E., Guo, Y., Leite, M. S., De Almeida, M. J., Ryu, T., Wang, Z., et al. (1997). Factors affecting student choice of career in science and engineering: Parallel studies in Australia, Canada, China, England, Japan, and Portugal. *Research in Science & Technological Education, 15*, 105–121.