CULTURAL STUDIES OF SCIENCE EDUCATION | 2

Wolff-Michael Roth
Editor

Re/Structuring Science Education

ReUniting Sociological and Psychological Perspectives

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ReUniting Sociological and Psychological Perspectives

Springer

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Preface

Conceptions and conceptual change have become a dominant paradigm in science education ever since the seminal study on the topic was published in a science education journal. The framework fundamentally is concerned with supposed mental frameworks human beings are said to develop for understanding, among others, scientific phenomena. Since then, however, numerous other theories and disciplines have emerged that not only challenge the conceptual change paradigm language but also the conception of language as a neutral means for reading out and accessing contents of (solipsistic) minds. Discourse analysis, discursive psychology, cultural-historical activity theory, theories of language and multiliteracies, social semiotics, and so forth all challenge the usefulness of thinking about (a) human activities in terms of the public confrontation and interaction of individual human conceptions, and (b) learning as conceptual change, a change that requires the reconfiguration of mental structures.

The purpose of the *2008 Springer Forum*, held on held on March 29, 2008 in the Graduate Center of the City University of New York, was to establish a broader context for rethinking conceptions and conceptual change, a context that takes into account more recent developments in thinking human activities, such as cultural studies, cultural sociology, discursive (social) psychology, and so forth. The participants were asked to articulate in their papers new ways of thinking about conceptions and conceptual change—that is, new theoretical perspectives—or to provide case studies of conceptions and conceptual change that question the very idea of mental structures that can be identified independent of human activities in which they are mobilized for the purposes at hand. We subsequently extended our focus by thinking about how the dominant psychological paradigm could be expanded to include sociological theories of knowing and learning in science education specifically and in science, technology, engineering, and mathematics education generally.

Following the very successful *Forum*, a success to a large extent brought about by its highly interactive nature, we planned to reproduce the interactive nature in this book that was planned as one of the *Forum's* outcomes. Furthermore, together with Ken Tobin I conceptualized this book for graduate level courses and as a scholarly volume for a wide range of academics and policy makers in science education interested in overcoming the gulf between sociological and psychological approaches in and to science education. I had set as my specific goal to make sure that language and style are appropriate to address the diversity of the intended audiences.

All contributors to this volume have endeavored to produce texts that contribute to the effort of overcoming the still existing divide between sociological and psychological approaches to science education research and practice. From very different positions—gender, culture, race—they provide valuable insights to re/uniting approaches to doing theory and method in our field. As an ensemble, the contributions constitute a rich array of thought from which new forms of science education can emerge.

A book such as the one presented here is impossible without the assistance of others. Most importantly I am grateful to the continued support *Springer Verlag* generally and Harmen van Paradijs particularly have provided to their endeavor of making cultural studies of science education an acknowledged and legitimized way of working in our field. This book also is the first of a new Springer series entitled, as the journal associated with this endeavor, *Cultural Studies of Science Education*. Ken Tobin and I have been the founding editors of this series, as we have been the founding editors of the journal. I am also grateful to the contributors, who willingly subscribed to the goals that we had framed for the *Forum* and for this book. Finally, I am grateful to all those individuals and organizations who have contributed in making the original *Springer Forum* not only possible but also a success. Above all I want to thank Ken Tobin for his continued support and encouragement, which facilitated and accompanied my career for the past 20 years.

Victoria, BC
September 2009

Chapter 1

ReUniting Sociological and Psychological Perspectives in/for Science Education An Introduction

Wolff-Michael Roth*

> [C]onsciousness, provided that we do not lose sight of its content, is *not just a psychological phenomenon* but also, and above all, an *ideological phenomenon, a product of social intercourse*. (Vološinov 1976, pp. 114–115)

How we think about phenomena of interest is a function of the cultural and historical position of the field in which the phenomenon of interest appears—in science education phenomena of interest include learning concepts, teaching concepts, teacher and student identities, and motivation. Take the following excerpt from an interview between a graduate student of science education, interested in conceptions and discourses about natural phenomena, and another student at her university. The two have come together, as part of a largely tacit social contract, to produce an interview that has as its content the way in which the interviewee (Mary) thinks about diurnal and seasonal changes. The interviewer utters what Mary clearly hears as a question, but the specific nature, as indicated in her own turn, is not clear to her (turn 02). The question concerns the specific position of the sun in the sky at the moment of the interview. Mary offers a possible hearing of the question, which we might gloss as, "So you are asking me 'Why is the sun in the sky?'"; the interviewer affirms this hearing (turn 03). After a brief pause, Mary offers an answer, where the position in the sky is explained by the facts that it is daytime and that the sun is moving.

```
01 I: um (0.48) and do you think why the sun is over there?
      (0.90) its in the sky?
02    (1.12)
03 M: why? the sun is in the sky?
      (0.19)
```

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```
04 I: yea:
      (0.65)
05 M  because=a its=a ^moving ((hand gesture of movement against
      the horizon)) and a its a (0.44) now today- (.11) now is
      (0.13) 'day↑time
      (0.23)
06 I: uh hm:
```

As a result of about 30 years of research in the field, science educators have come to see in such answers evidence for the presence of a misconception in Mary's mind. She thinks what we can gloss as "the movement of the sun across the sky," which is a way of talking about this phenomenon typical to Western culture prior to Galileo Galilei, who, in an acrimonious debate with the (Catholic) Church, attempted to convince others that it was the rotation of the Earth that led to the impression of the sun's movement across the sky. In the science education literature, largely conducted from psychological perspectives, such interview excerpts are used to postulate individually held mental frameworks and (mis-, alternative, naïve) conceptions. Because Mary uttered the words in this manner, it is easy to be convinced that she thinks what she said and, if we accept that a computer metaphor for the mind, that there are structures in her mind that make her say what she says. But is this the only way of thinking about the episode? Is turn 05 evidence for a phenomenon that has to be analyzed using the individual (mind) as the unit of analysis?

It turns out that there are many reasons why we might want to think very differently about this situation than from a traditional individual psychological perspective—though such ways of thinking have not yet taken hold widely in our field. Thus, Mary responds to questions about phenomena that she has not or little thought about before, as she says to the interviewer a little later in the conversation. If she has not talked and thought about such phenomena before, she cannot have a mental framework or conception, which, according to conceptual change theory, is the outcome of an intentional construction. How then can Mary talk about something that she has not yet thought about and has no framework for? One answer lies in the nature of language, which provides us with resources to speak about phenomena even if we have never talked or thought about them before. A second reason for thinking about this excerpt in a different way comes from the fact that Mary does not just talk to herself. She addresses the interviewer, with whom she has entered into a social contract by promising to participate in and complete an interview. With this social contract comes that she responds to make the interview a success, that is, that she speaks in a manner and presenting content such that the interviewer understands what she is talking about. What she says therefore is explicitly directed to the interviewer for the purpose of helping this other person understand what she, Mary, has to say about the position of the sun in the sky. That is, Mary inherently presupposes that the interviewer hears and understands what she has to say. This means that her way of talking inherently is presupposed to be understood and therefore a realization of a cultural possibility of talking rather than an idiosyncratic, solipsistic, highly singular way of talking. In fact, the very phenomenon of language is premised on the presupposition that *another person* can hear and understand, understand and hear. Even when the very first word was uttered in the history of humanity, the speaker presupposed to be heard and understood. Speaking, in fact, presupposes hearing, and hearing presupposes understanding (Heidegger 1977). We talk only because we can presuppose the intelligibility of what we say, even if at times it turns out that this presupposition was wrong for one or the other reason. That is, even in its brevity, this analysis already points to the fact that the proper unit of analysis might be language and social interaction, the domain of sociology and social psychology, rather than that of individual (cognitive, developmental) psychology.

There is then a tension between the fact that language offers us ways of talking about relevant phenomena in inherently shared and intelligible ways, on the one hand, and the fact that such talk is always delivered in concrete and singular manner by an individual. How are we to think this tension? How are we to think knowing, learning, teaching, or instruction in and from this tension? How are we to think if we decide that it should not be from one or the other side of the apparent abyss between the psychological and the sociological? How are we to think about science education phenomena without reducing the differences to the hegemony of the same that comes with a master discourse? Are there ways of thinking | speaking about learning where the difference between the sociological and psychological becomes undecidable even in the undeniable presence of both? We may then have to look not only for a dialectical sublation (*Aufhebung*) of the opposites in a synthesis that arrives with a new unity but also for new ways of thinking. What would such new ways of thinking be? How do you bootstrap out of the old ways of thinking in dichotomous manner typical of classical logic—A, not-A, and *tertium non datur* [a third is not given]—into new ways of thinking that accepts and is based on difference as such? These new ways of thinking, if we admit hints from philosophies of difference (e.g., Derrida 2003a, b), my take us into domains where the process of thinking no longer fits the computer metaphor. This metaphor makes decisions computable, that is, it suggests that you can make fully informed decisions about choice alternatives. The notion of undecidability, which allows us to understand diverse human experiences—including forgiveness, democracy, law, giving and gifts, time and temporality, the relationship of thought and language, and memory—takes us beyond computability and into the domain of chaos and catastrophe theory, where future events, even if they are only seconds away, can no longer be predicted with accuracy.

Introduction

Psychological approaches to knowing and learning have dominated science education since its beginning, as evidenced in the importance that behaviorism, cognitivism, Piaget's developmentalism, or constructivism have had on theorizing salient phenomena. These approaches have almost entirely focused on establishing the mental as an individual phenomenon to the exclusion of sociocultural, cultural-historical, sociological, or anthropological moments of human life generally and learning specifically. More recently, a number of other theories and disciplines have emerged that challenge language as a neutral means for reading out and accessing contents of (solipsistic) minds. Discourse analysis, discursive psychology, cultural-historical activity theory, theories of language and multiliteracies, or social semiotics all challenge the usefulness of thinking about (a) human activities in terms of the public confrontation and interaction of individual human conceptions, and (b) learning as a solely psychological phenomenon (e.g., as conceptual change, a change that requires the reconfiguration of mental structures).

Two recent papers in particular present alternative perspectives on conceptions and conceptual change, one grounded in cultural studies (Roth et al. 2008) and the other one in discursive psychology (Roth 2008b). The common tenor of these papers is this: if there is anything like the psychological that exists independently of the cultural context, then it always constitutes a social achievement in which society and culture generally and researchers specifically have an active part. The psychological therefore cannot be legitimately attributed to individual minds, especially because the very linguistic resources for producing them in talk are cultural rather than individual possibilities. But of course, there cannot be a culture and the associated collective consciousness without the individuals and their consciousness that constitutes it. The two aspects, the sociological and the psychological, go hand in hand when it comes to understanding social life generally and learning in and of the sciences specifically.

Thinking the two perspectives differently, sociology and psychology, is the tenor of the message in the Vološinov quote that opens this introductory chapter. With this book, we aim at beginning such a rethinking of psychological and sociological approaches in and for science education. That is, prior to and outside of science education there have been approaches to studying knowing, learning, mind, consciousness, and so on that embodies the dual approach, the sociological and the psychological. In fact, the very etymology of the word consciousness, from Latin *con-*, with, and *sciēre*, to know, points us to the social at the very center of what it means to think, reflect, and be aware of. The purpose of this edited collection is to establish a broader context for rethinking science education generally and knowing and learning in science specifically. This context takes into account more recent developments in thinking human activities, such as cultural studies, cultural sociology, or discursive (social) psychology. The chapters and discussion forums articulate new ways of thinking about knowing and learning, that is, about new theoretical perspectives—or provide detailed case studies of important issues related to science education that question the very idea of the psychological that can be identified independent of human activities in which they are mobilized for the purposes at hand. The ultimate purpose of each chapter and the edited collection as a whole is to prepare the ground upon which sociological and psychological perspectives in science education can be reunited to provide more encompassing theoretical frameworks that allow us to capture the complexity of science learning as it occurs in and out-of schools. As a whole, the book moves theorizing into new and uncharted terrain. But we do not and cannot claim to give a final answer: such an answer is forever on the remove, forever withdrawing, and therefore forever to come. This is the underlying idea of *dialogism*, where ideas are in continuous exchange, continuously working and reworking each other, therefore undergoing continuous change for the purpose of self-improvement. If there were the hope of achieving a single answer, this would be the death of dialogue and the arrival of a mono-logical—both in the sense of one logic and one discourse—way of understanding human nature. To anticipate such unrealizable hopes, Ken Tobin invites us in chapter 2 to think beyond the hegemony of any single narrative about knowing and learning in science education.

Learning Theories Across the History of Science Education

A recently published history of the *National Association for Research in Science Education* shows how this science education organization emerged in the course of the twentieth century (Joslin et al. 2008). The paper reports, among others, on the struggles that the journal of the organization, the *Journal for Research in Science Teaching*, had problems with the quality of the articles generally and the theories and methods specifically. In his contribution to the collaboratively written history, Roger O. Anderson notes that at the time, science education researchers began to draw on theories and methods in cognate fields including "cognitive developmental psychology, learning theories, scientific epistemology, and theories of assessment and evaluation" (p. 179). It was at this stage, especially because the unit of analysis and teaching in science education was viewed in terms of the individual, that knowing and learning came to be framed in terms of the *dominant* psychological theory of the day. These included, in historical order, behaviorism, developmental psychology and Piagetian stage theory, David Ausubel's reception learning paradigm, information processing, and finally radical constructivism followed by social constructivism. Associated with the psychological theories were the methods of investigation also adopted from psychological research: experimental and quasi-experimental studies focusing on the relationship between pedagogy (e.g., teaching method, curriculum materials), on the one hand, and achievement levels, on the other hand.

The latter part of the 1980s witnessed the emergence of qualitative observational and ethnographic research methods perfectly suited to the emergence of (radical) constructivism on the scene. The ethnographic research designs gained in importance during the 1990s within a new generation of researchers in science education associated with an increasing role of researchers from diverse backgrounds heretofore ill represented in the science education community: the research community now included increasing numbers of women, visible minorities, individuals of different culture, or race. However, despite the increasing differentiation in the nature of the participants, the main paradigm concerning the locus of knowledge remained to be the individual mind. Moreover, the dominant paradigm emphasizes forms of thinking rooted in metaphysics and the Greco-Roman forms of logic and rationality. It is not surprising, therefore, that postmodern scholars would find delight in the associations created by term *phal-logocentrism* (e.g., Derrida 1992), which points to the historically dominant influences on philosophy: male (phallus), language (*logos*), and logic (Gr. *logos*). This influence continues in the way science is practiced today, including psychology and sociology. But despite the changes in Continental philosophy in particular, research continued with the traditional in-the-head orientation that has dominated thinking about epistemology. Thus, we witnessed research that seemed to focus on cultural variation but that read like it had a psychologically oriented conceptual change orientation. That is, the individual (differential) psychological approach dominated even when researchers outwardly displayed a discourse about culture as the relevant unit for understanding knowing and learning.

The orientation to and focus on learning from a psychological perspective was also observable in the, at the time most radical theoretical shift toward communities of practice and situated cognition. Typical for this orientation is the conceptualization of learning in communities of practice, which is said to occur *as the individual is moving from the periphery to the core of the community*. That is, the theory concerning communities of practice and the trajectory of learning with *legitimate peripheral participation* still focused, at least in the research realized, on the individual as the unit of analysis (Roth and Lee 2006). The community of practice was taken as a more or less stable box with a periphery, where the cultural practices were less authentic than in its core, where the leading practitioners and the most characteristic and community-defining practices were to be found. Learning was still thought to occur in the individual thought to become competent and in so doing moving from the periphery to the core.

A very different way of thinking about knowing and learning was offered in the latter part of the 1990s in a series of studies concerning the *discourse* found among high school students concerning knowing, learning, beliefs, epistemology, and so on (e.g., Roth and Lucas 1997). The approach was grounded in a relatively new sub-discipline of psychology that came to be known under the name of *discursive psychology*. The fundamental idea of this approach is to take discourse as the unit of analysis rather than the individual. The individual then is thought to realize possibilities that exist at the collective level. The need for such a shift in thinking comes from the fact that in talking, an individual student or teacher participating in a research project addresses the researcher or a research assistant. But in addressing this other person, the form and content of the discourse is automatically adjusted to the social situation and made what is—without reflection necessary—to the listener. Any stretch of discourse, therefore, is characteristic not of individual participants but of the coparticipants in the communicative effort and the type of social situations in which they take part. Thus, from this perspective it is to be expected that a conversation between a high school teacher and his student changes when it takes place in the context of a lesson that is part of their physics course or when it takes place in the context of an interview that the teacher conducts as part of his research on knowing, learning, or epistemology. Just as the introductory quote states, consciousness is a function of ideology and social interaction—and all three, consciousness, ideology, and social interaction use language as their ground, material, and tool for their realization (e.g., Roth in press). If a high school student talks about a hand and arm transferring a force to a baseball that a pitcher throws (a "misconception"), then, from this perspective, we ought to understand it as a shared phenomenon realized by *this* student but understandable by many others speaking the same language. *This* student merely realizes a widely recognized possibility of English to explain the flight path of a baseball.

In this shift that I describe in the course of last two paragraphs, from psychology sociology (social psychology), the unit of analysis changed from the individual to culture or a cultural dimension (discourse). We can easily understand why for educators such a shift is difficult to understand and make. Whereas researchers can use a cultural lens for understanding, teachers still are confronted with the task to educate and test individual students. Even when students are allowed to learn in collaborative settings, the institutional requirement of evaluating learning at the individual level orients the endeavor of science educators to the individual. This is the case even though ways of talking are shared, so that the talk used to realize "(mis-, alternative, naïve) conceptions" constitutes a cultural possibility. This cultural possibility is not eradicated in the teaching of an individual child or student, allowing us to understand why "misconceptions" are so resistant to the endeavors of those science educators interested in eradicating them. The discourse approach provides us with an answer to a question that conceptual change researchers have been unable to provide.

The foregoing suggests that to understand what students say and write we need to study culture, even though we know that it is the individual who, especially when reflexively pointing to him/herself using an indexical "I" or "me." There are other reasons why science educators may have to shift perspective to include cultural and sociological perspectives not only in their theoretical frames but also in their teaching. In an increasingly complex world, an increasing division of labor defines any task. Whereas it was still possible for many individuals to repair the engine of their cars into the 1980, an increasing computerization and the associated change in car engines makes it almost impossible for the person without specialized competencies, tools, and instruments to conduct a repair. Similarly, environmental problems, for example, are so complex that it takes not only scientists and engineers but also individuals with many different competencies to solve. Thus, the question whether to put a water main to an outlying area of a municipality cannot be solved by drawing on hydro-geologists and town engineers (Roth 2008a). There are many others involved, the fire department, the local people with their local ecological knowledge, politicians at the municipal, provincial, and federal levels, the regional health authorities, lawyers, and so on. The different members do not need to know what others know, even in its most basic and rudimentary form. But the participants in the decision-making process need to be able to evolve a form of discourse that allows them to settle the issue. It has therefore been suggested that scientific literacy ought to be rethought in terms of a collective praxis, something people do together in real time of the relevant here and now (Roth 2007). The question then becomes this: If we want to teach for competent participation in collective practices, what do we need to change in the classroom? The present book has been conceived in part as an opportunity for providing the ground for thinking about how to change not only our research foci but also for rethinking how we might think about curriculum design so that it does not privilege the psychological to the detriment of the sociological. It is only when sociological thinking accompanies psychological thinking that we can re/structure science education to address the needs of humanity as a whole rather than only the needs of (a few) individuals. The various real and imagined crises facing humanity require more than we have done in the past; and science educators need to do more or rather differently than producing the forms of scientific (il-) literacy that they have produced in the past.

Social-Psychological Approaches

Outside science education specifically and education generally discourses that focus on the collective nature of knowing and consciousness have existed for a long time. Thus, in contrast to Immanuel Kant, whose theories underpin the work of Jean Piaget and (radical) constructivism, G.W.F. Hegel (1806/1977) suggested already at the beginning of the nineteenth century that consciousness, and therefore knowing and learning, is a collective dimension. The term consciousness literally means knowing together, refers us to forms of knowing that are shared between people and within a culture. Anything we can think is shared and always is articulated in terms of a shared language. The term self-consciousness therefore denotes a consciousness of the self that always is in terms of the other, in terms of a shared consciousness mediated in and by language. Thus, any "action has double significance not only because it is directed against itself as well as against the other, but also because it is indivisibly the action of one as well as of the other" (p. 112). Any two interlocutors "*recognize* themselves as *mutually recognize* one another" (p. 112). The work of Hegel is important because it influenced, in part via Karl Marx, a number of scholars whose work has begun to influence science education only in more recent years.[1] These scholars include the members of the Bakhtin circle (Mikhail Bakhtin, Valentin Vološinov, and Pavel Medvedev) and a lineage of social psychologists ranging from Lev Vygotsky via Alexei Leont'ev and Alexander Luria to the present day.

One can observe influences of the Bakhtin group on science education on the part of some scholars who attempt to rethink science education in terms of the theoretical notion of *discourse*. The term—etymologically deriving from the Latin

1. For a general review of this literature see Roth and Lee 2007; for a review of this literature pertaining to science education alone see Roth et al. 2009.

discurrere, to run back and forth, to converse (itself deriving from Latin *conversare*, speaking with)—at its root, requires multiple individuals involved in a give and take, involved in a passing back and forth of language. The importance of the Bakhtin group derives from the fact that it conceives of language generally and the individual word specifically as something inherently yoking speaker and listener (e.g., Bakhtine [Volochinov] 1977). The individual word cannot ever be attributed to the speaker but always already is characteristic of two. Moreover, the individual word never can be understood on its own but always as part of a language (and therefore culture) as a whole. It is part of a web of signifiers that constitutes differences (Derrida 1967). This understanding of language is captured in and denoted by the adjective *ideological*, which itself is set in contrast to the *material* aspects of everyday human life. As the introductory quote states, every psychological phenomenon is an ideological phenomenon, and therefore, inherently, a sociological phenomenon. But realized in and through individual tongues—etymologically, language derives from Latin, *lingua*, via the French, *langue*, tongue—and ears, language is a material phenomenon through and through. This inseparability between the material and the ideological is evident especially in Bakhtin's (1984) analysis of Rabelais' *Gargantua* and *Pantagruel*. Therefore, relative to science learning, Bakhtin's work implies that the body and mind can be separated as little as psychology and sociology, a point made relative to science education in detailed analyses of concept mapping sessions (Roth et al. 2009). Rigorous applications and developments of the work of the Bakhtin group remain to be conducted within our discipline, but at this instant they promise a lot to the endeavor of including both sociological and psychological perspectives.

Despite living at about the same time, there is little evidence of interaction between the thinking and theorization that occurred in the Bakhtin circle and the budding social psychology that Vygotsky and his students and co-workers evolved.[2] Most fundamentally, attempting to articulate a rigorous Marxist psychology, Vygotsky (1978) held that *any higher psychological function* has existed in and as *social* relation. That is, anything that science educators historically have attributed to the individual (mind) is, following Vygotsky, observable in social interactions, which have been the object of sociological studies. Whereas some science educators acknowledge the provenance of higher psychological functions from social relations, they tend to seek the functions in the individual rather than in social interaction. Moreover, it became evident especially in the work of his students and followers that the social relations, psychological functions, and relevant forms of consciousness are a function of the *collective* activity. Thus, it can be expected that thinking about the physics of flying in the context of a school lesson versus thinking about the physics of flying in the context of a real competition flying model planes will be different; this expectation bears out and has been tested empirically (Leontjew 1982). The phenomenological sociologist Alfred Schutz

2. Vološinov (1976) references an article by Vygotsky. But I am not aware of any other points of contact between the Bakhtin group and the psychologist. But there are several texts in which Vygotsky articulates his Marxist position; and it is in this that he has a lot in common with Vološinov, who apparently introduced Marxist thinking and theory into the Bakhtin group.

(e.g., 1996) arrived at the same expectation based on somewhat different intellectual grounds (European phenomenology). Thus, the forms of consciousness are a function of the project at hand; our apperceptions are a function of the project, which realizes our situation-specific, contingent interests in a (personal) world "organized around the self who lives and acts in it" (p. 13). The world of everyday life, in terms of which we understand our experiences, always already "existed before we were born; it is given to our experiences and interpretations" (p. 26). That is, consistent with Vygotsky, Schutz articulates individual consciousness as concrete realization of collective consciousness.

There is more to Vygotsky than his focus on the development of (scientific) thinking. One part of his theory that has merely begun to be of interest to science educators is the integral role of affect to cognition. Thus, whereas in most psychological theories affect is theorized as a factor external to cognition that affects and generally diminishes cognitive powers, Vygotsky (1986) suggested that affect and cognition are irreducible moments of the same phenomenon.[3] If it were not like this, we would not be able to understand how emotion and cognition could mutually mediate and influence each other such as when success in a cognitive task increases emotional valence and negative valence (e.g., potential punishment) decreases cognitive performance. Most importantly, together with the theory of the origin of higher psychological functions, we can understand that an understanding of emotions and emotion talk is itself a cultural sociological phenomenon. Emotion as phenomenon and construct that is part of the dialectic of the individual and collective is central to a relatively new sociological domain: the sociology of emotions (e.g., Collins 2004). Focusing on the interaction between individual and collective affect, mediated by rhythmic phenomena made available in voice, tapping with pens, rocking body parts, or emphatic gestures has contributed to science educators understanding of learning in complex culturally diverse settings (Roth and Tobin in press).

A better understanding of affect will also lead science educators to a better understanding of the relationship between thought and language, a topic particularly salient in chapter 9, "Thinking and Speaking: A Dynamic Approach" (Roth, this volume). Why might thinking and speaking continually push on and develop? Why should anyone endeavor to change his or her thinking, that is, why should anyone endeavor to learn anything? This is precisely the problem Vygotsky (1986) framed in saying that the separation of the study of thought and affect, a weakness characteristic of "traditional psychology … makes the thought process appear as an autonomous flow of 'thoughts thinking themselves,' segregated from the fullness of life, from the personal needs and interests, the inclinations and impulses of the thinker" (p. 10). Affect and emotions have their source in and are mediated by, as Vygotsky's successor Alexei N. Leontjew (1982) points out, the collective, entirely practical endeavors and projects. This is precisely the

3. In dialectical theories, *moments* are identifiable structures within some phenomenon that cannot exist on their own (Roth and Lee 2007). They are a function of other moments and of the whole. Moments therefore are different from elements, which are parts that can be used as they are to build the whole. Moments do not exist apart from the whole.

perspective that Schutz also takes when he emphasizes that the social actor will consult emotions and affect as much as rational deliberation in making a decision in and about a situation; moreover, the situation itself, by means of the actors practical interests in it, is the root of emotions and affects. Again, an integrated approach to which both sociological and psychological ways of theorizing contribute or find their place will offer science educators a much more extensive and holistic tool for researching and teaching science than any individual approach taken in and by itself.

Structure of This Book

The body of this edited collection consists of the papers and plenary talks presented during the *Second Springer Forum*. Each paper or paper set was followed by a discussion of the central features of the text. To capture the dynamic aspects of the original discussions, each chapter or chapter set in this book is followed by a forum in which scholars discuss, based on the videotapes of presentations and discussions, the salient issues raised. As a whole, this book captures the dialogic and interactive nature of the *Forum* from which the papers and discussions derive. It therefore also represents the ways in which scholars do much of their theorizing work.

As I introduce each of the three parts of the book with a brief text and summaries of the chapters, I outline here but the structure of the book. It begins with an overarching chapter entitled "Tuning in to Others' Voices: Beyond the Hegemony of Mono-logical Narratives" in which Ken Tobin exhorts us to get out of the traditional practices that forced us into intellectual silos that then confronted each other in sometimes acrimonious debates and to begin new practices modeled on dialogue and dialogism. The chapter sets the stage for three parts within and across which authors engage in wrestling with questions surrounding the problem of sociological and psychological approaches. Part A of the book centers on the three plenary talks presented at the *Forum* by Greg Kelly, Anna Stetsenko, and myself. Yew Jin Lee and Donna DeGennaro, Regina Smardon and Wesley Pitts, and Eduardo Mortimer and Pei-Ling Hsu are, respectively, the discussants of the three main papers. In Part B, I collected together chapters in which the authors contribute articulations of positions and perspectives on the theme of this book. The authors include Kathryn Scantlebury/Sonya Martin, Michiel van Eijck, Jean-François Maheux/Wolff-Michael Roth/Jennifer Thom, and Chris Emdin. Giuliano Reis provides a commentary on this chapter set as a whole. In Part C, I collected chapter contributions that focus on science agency and structure across the life span. Katherine Richardson Bruna, Maria Varelas/Justine Kane/Christine Pappas, Edna Tan/Angela Calabrese Baron/Miyoun Lim, and Maria Rivera Maulucci contribute chapters to this section. Jennifer Adams/Christina Siry/Koshi Dhingra/Gilian Bayne discuss, literally, the four contributions to this third part of the book. I contribute an epilogue to conclude the book.

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Chapter 2

Tuning in to Others' Voices: Beyond the Hegemony of Mono-logical Narratives

Kenneth Tobin*

I will learn from you, but can you learn from me? With so much being published, what criteria are used to ascertain what is relevant to a scholarly project? A dichotomy that is central to research in science education typifies an all too familiar standpoint—I am speaking, but are you listening to me? We have all endured the experience at professional meetings of a critic who fails to address the capital in a paper or paper set and instead rails against what has been done as she launches into an exposition of her preferences. (To avoid cumbersome constructions I use feminine pronouns whenever male or female pronouns might have been used.) The authors of the papers being critiqued experience violence because the merits of their work are not explicated and the critic reifies her own standpoint as she presents alternatives. I regard such practices as dangerous to the welfare of science education.

In a recent rejoinder to several critics Anna Stetsenko (2008) addressed what each of three critics had contributed to her understanding of cultural historical activity theory based on review essays each had authored. Instead of reiterating her stance and tearing apart critiques, Stetsenko addressed each point of criticism and each alternative that was presented, showing how difference can be used as a foundation for further learning. In so doing she endeavored to build coherence around difference and go beyond what any of the previous texts had done. That is, her original paper and the three review essays became a foundation on which further learning could build. In authoring her rejoinder she addressed the points she considered most salient in the three review essays and seemingly asked what more is there? She did not assert that her position was right and theirs wrong, and she did not create an alternative that excluded the positions of her critics. Instead, Stetsenko created something more, a rendering that included her own initial articulations, points raised in the review essays, and fresh ideas that build from the dialogue. Though she may not have been thinking of Kwame Appiah (2006) when

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she wrote her paper, the approach is reminiscent of having built cosmopolitanism based on difference, whereby each of the authors was respected for her difference and Stetsenko's final paper emerged as one that acknowledged the value of others' standpoints and did not seek to persuade them to accept her standpoint. Stetsenko showed that she was able to learn from difference.

In this chapter I use an autobiographical approach to address issues that are central to the purposes of this book, including the role of theory in explicating research issues, the methods used, and the values attached to theoretical products and transformed practices. I also discuss ways in which psychological models for teaching and learning science have saturated scholarship in science education and I identify pathways for moving forward, not by establishing dominance over our former oppressors, but by creating scholarly alliances with them. Such an approach sets the stage for learning from the different standpoints presented in the remainder of the book.

Reflexively Choosing My Own Theoretical Frameworks

Throughout the 1980s I searched for ways to theorize teaching and learning to teach science. In some respects my doctoral work at Georgia interrupted a process that began with Jean Piaget in the mid 1970s and embraced radical behaviorism during the time in which I studied for my doctorate. However, on my return to Australia I took a position as a science teacher educator. The theories I used for teaching were inadequate for my roles as a scholar and as a professional. At the time I was interested in better understanding teacher learning, especially how to use conceptual knowledge to improve teaching. This concern became paramount and in a period of 15 years I moved through an array of theories, employing them as a basis for my science teacher education programs and framing research questions and methods. There were many contradictions that demanded solutions. For example, reductionism, based on a tendency to describe social life in terms of variables, greatly expanded the scope of research and focused on better understanding the connections between the variables. However, a methodology that employed statistics necessitated at least some effort to conform to the assumptions underlying the validity of statistical tests. An example is the assumption that the subjects involved in research are independent and that their learning (or changes in the dependent measures) is attributable to and represented by the relationships included in the statistical model—that is, by the variables and relationships between them. Also, the focus on variables prevented me from researching issues, such as macrostructures, that were of most importance in science education. These included the impact of national and state policies, international "movements" such as those associated with the curriculum reforms catalyzed by the launch of Sputnik, and an increasing emphasis on external (high stakes) examinations. Accordingly, I began to use ethnography to study some of the issues in science education that transcended building models in terms of variables.

In a search for viable theory to make sense of teaching and learning it became clear that the methods I used to do research had to get into step. The theory of method, that is, methodology, presupposed research foci, and to an extent that I had not fully realized, the research foci presupposed the methods of investigation. Methods and foci were dialectically related, as were the theories on which they were built. Hence, changes in either methods or foci would perturb the whole and be evident in all parts of it.

Given the dialectical relationship between research foci and research methods it is no surprise that in my 35 years as an educational researcher there is connectedness between foci and method. In making this claim I do not want to create an impression of a mechanistic lock-step situation in which a change in focus produced a change in method. The relationship is much more subtle and at any stage there are contradictions, probably associated with other dialectical relationships that allow me to enact research being both conscious and unconscious of what I do. In such circumstances it is not surprising that my methods as a researcher would reflect what I have done in the past and would be responsive to the goals of a study and unfolding exigencies arising in doing the research. Before examining the relationships between research foci and methods in more detail I digress to briefly discuss some social theory that is germane to my goals for this chapter.

Dialectical Perspectives on Research Foci and Methods

The complexity of any social activity is such that, in trying to cope, knowledge comes to hand in resonance with structures of the fields in which participants are engaged. When events unfold as intended much of what happens occurs without particular awareness and it is only in a situation where breaches occur that an actor becomes aware and consciously enacts repair rituals. There are several theoretical frames that address social life in ways that cohere with my standpoint on the conscious | unconscious dialectic. For example, Pierre Bourdieu's theory of habitus and Alfred Schutz's stocks of knowledge at hand illuminate ways in which resonance occurs between knowledge at hand and the dynamic structures of a field to afford the enactment of culture. As I have explained elsewhere, fluency occurs when culture is enacted in ways that are timely, anticipatory, and appropriate (Tobin 2007). In these circumstances participants have a sense of the game and the unfolding encounters in a field produce[4] capital. Encounters involve interaction and transaction, each of which presupposes the other; hence, interaction and transaction are dialectically related and integral to capital production in a field.

4. I theorize production to always involve reproduction and transformation. That is production is equivalent to reproduction | transformation.

Setting aside tendencies to invoke either–or reasoning and to organize variables in causal, temporal sequences, I began to examine social life in terms of an array of coexisting entities that were constitutive of a whole. Sometimes, as in the example of patterns of coherence and contradictions, these entities might be thought of as recursively linked opposites, and in other cases, such as schemas and practices (i.e., culture), they are recursively linked, but not regarded as opposites. The adoption of a dialectical view of social life affords a more holistic way of thinking about experience and dispositions to consider questions associated with presupposition of coexistence and complex, recursive models depicting relationships among social entities (setting aside models that include unidirectional, causally linked variables, especially if the implication is that one set of conditions must precede another). The dialectical perspective opened up different possibilities within our urban science education project. As a way of thinking, co-presence raised questions that otherwise may never have arisen. For example, if in any social encounter a person is simultaneously a teacher and a learner, questions arise about how individuals are simultaneously both. A more complex picture then arises from our research. Similarly, if agency and passivity are dialectically related then encounters can be viewed in term of co-presence of these entities and simultaneous consideration of other salient dialectical relationships, including interaction | transaction, reproduction | transformation, and individual | collective.

Synchrony, Asynchrony and Lag

A reflexive approach to what is to be done in a study affords synchronies between the methods employed and foci. However, what is planned and what is enacted necessarily differ and the dynamic structures of the research field, methods enacted, and research foci are mutually constitutive (i.e., co-related). In a context of my research in urban high schools my concern is to improve the lives of social minorities through science education. How this manifests in particular urban schools, for example in the Bronx of New York City, is to understand how to create productive learning environments in science classes characterized by differences that are often regarded in terms of categories having salience for students, such as race, ethnicity, native language, and social class. Similar categories also apply to teachers, who are usually significantly older than students. The focus for our research is the creation of solidarity in different social fields associated with science education (e.g., whole class discussions, small groups, labs). Hence, my approach to research involves broad foci and a history of having been involved continuously in similar studies for many years.

When we meet as a research group to consider what to do next an initial consideration is what we have done in the past and what we know of what others have done and learned. What is on the table is an extant literature, an evolving understanding of what we have learned from our ongoing projects, the motives of the research squad, and goals of individual researchers. The questions we have are broad: what more is there to do and know? In an important sense the approach we adopt is ethnomethodological in that we attempt to learn about social life by looking beyond the equilibria associated with what Ann Swidler describes as "settled times" to probe the culture that presents itself in "unsettled times" as breaches occur, efforts at repair are enacted, and capital production reveals reproduction and transformation of macro-, meso-, and micro-culture.

In our consideration of what we know already we turn to an extant literature that has been produced from standpoints that differ greatly from ours. We regard it as important to incorporate diverse forms of scholarship that might have salience to our projects. What is regarded as salient is left to the researchers who comprise our squad. Not surprisingly, the theories and research we find most appealing is associated with scholars most closely aligned with our foci and methods. For example, our projects are informed significantly by the work of Wolff-Michael Roth and his coworkers such as Yew Jin Lee (e.g., Roth and Lee 2007). What we appropriate from their scholarship usually concerns methodology and theoretical frameworks from the genre of social and cultural theory. The substantive foci of their research rarely involve urban education and issues of social justice as primary. However, their written and spoken theories and methods are central to our work and are discussed in the context of what more needs to be done in almost every research meeting. Other criteria include foci and concern issues such as urban education, cogenerative dialogues, and coteaching. We know where to look within a network of scholars for ongoing research we regard as relevant to our projects. Mostly the researchers in this network have been close collaborators for many years and have now created their own research squads in cities and countries around the world.

New theoretical insights are continuously sought in endeavors to shine different lights on social life. The search is expansive and intensive with general reading in cultural studies, sociology and associated areas being supported by focused reading and understanding of particular scholars whose work is considered relevant. For example, my efforts to expand radical constructivism to include "the social" and a better understanding of action led me to the work of French scholars such as Pierre Bourdieu and Paul Ricœur. During a decade of collaboration with Roth I expanded the list of theoreticians I sought to understand, gradually including them in a bricolage of theories that comprise a dynamic framework. Colleagues within my own institution also have played a significant role in expanding the theories I use in my research. For example, Elijah Anderson's *Code of the Street* (Anderson 1999) introduced me to the salience of respect in my research, and Randall Collins' work afforded me including theories of emotions and emotional energy as central parts of my frameworks for studying teaching and learning. Eventually I realized how important it is to reach out to others to learn about fields, such as cultural sociology, and I enrolled in some of the graduate classes in theoretical sociology taught by a colleague. The courses I took allowed me to navigate areas such as cultural studies and cultural sociology, leading me to Stuart Hall and William Sewell as theoreticians whose work was central to my projects.

Having identified the work of a scholar such as Randall Collins as having salience, my next move was to understand the scholars whose work underpins Collins' theories. In this specific case I began to study other researchers who had done work on emotions, such as Jonathan Turner and Thomas Scheff. Over a period of years I then began to study Erving Goffman's sociology, especially in relation to the interaction order and encounters. Goffman's work on the sociology of interaction provides a basis for much of the research I undertake and a necessary next step was to move on to Harold Garfinkel's ethnomethodology and the value in studying "what more?"

Making decisions about what is included in a bricolage is no slam-dunk. As is evident from the genealogy presented in the previous paragraph, starting with Collins necessitated the co-presence of many others on whom Collins and his peers had built their work. However, my project is mediated by more theory and empirical work than Collins and those involved in the sociology of emotions. For example, Stuart Hall and his work on diaspora and the creation of interstitial forms of culture is central and leads to important work by Homi Bhabha, Kwame Appiah, and others involved with creating solidarity around difference. From here the road leads to philosophers of difference, such as Paul Ricœur and Gilles Deleuze. A perspective we sought to adopt was to regard difference as capital; a basis for solidarity that takes advantage of differences within a collective without regarding them as deficits. For example, Jacques Derrida's *cities of refuge* involve a form of cosmopolitanism built around the rights of refugees to live in a city and to benefit from hospitality (Derrida 2006). His proposal broke from a tradition of building solidarity around sameness to include the acceptance of moral stances that respect the rights of individuals to remain different, while preserving full rights of citizenry. Assimilation is not a requirement. Participants have the right to pursue their goals while contributing to the collective attaining its motives. Evidently, this value is the beginning of the thin coherence that kick starts the creation of solidarity within a field—each individual having the right to be different and the responsibility to contribute to the motives. These ideas are compelling when they are applied to the diverse students that turn up to science classes in New York City. Irrespective of their differences, from the teacher and one another, these students have a right, not just to be there, but also to reap the benefits of science education. It is regarded as a civic duty of all participants belonging to the cosmopolitan class to act in ways to promote the learning of others. Perspectives such as these have the potential to be used as referents for science teachers in diverse classes such as those found in the Bronx.

As is evident from the foregoing, there is a significant amount of theoretical flux in our research frameworks and theoretical shifts perturb research foci and methods continuously. For example, Bourdieu's construct of field is salient to our work. We regard a field as a site for cultural production (i.e., reproduction | transformation) in which participants pursue motives in ways that are structured. Related to motives are activity (Roth and Lee 2007) and a plethora of dialectical relationships, such as agency | structure, self | other, and agency |passivity, that I use to make sense of social life. Initially we thought of the field more as a pasture with a porous border (Sewell 1999). The concept of weak boundary, as distinct from strong boundary, had implications for method as we began to look within fields for culture that did not belong there. For example, in schools we observed that street culture was enacted to the detriment of students seeking to become educated as a means for social advancement. Theorizing a border shone light on transitions and comparisons between those who were close to the border and those who were immersed "deep" in the field. Of course questions also arose about what constituted a boundary. We decided that boundaries were structures, in which case there was no need to regard boundaries as separate entities. This realization led us to see the parallels between social fields and those from physics, such as in electric, magnetic, and gravitational fields. The possibilities began to excite us as we were suddenly freed from a reluctant tendency to relate fields to particular times and spaces. Freed from this restraint we were able to allow fields to move freely with individuals through space and time. Hence, border crossing became a phenomenon that was no longer salient in our research since there were no borders. The situation of street culture entering the school then invited a different way of doing research on the issue and the possibility of solving such problems in very different ways, perhaps through the lenses of creating and legitimizing interstitial cultures. Also, the dialectical relationship that constitutes macro-, meso-, and micro-lifeworlds could be explored quite differently because it was now clear that at any time and in any space individuals could be involved in activities in multiple fields. As our theoretical perspectives evolved, so too did the research foci and methods used in our studies.

From what I have said it is easy to see that lags will occur and it might be inferred that I am arguing for temporal ordering whereby a change in focus causes a change in method. Such an inference is not implied and I regard it as a dangerous stance. Method and focus presuppose each other and there is no temporal imperative. In fact changes in method can elicit fresh theoretical perspectives and new research foci.

Hegemony of Psychological Models

For as long as I have been a science educator, psychological models have been the mainstay of theory supporting science education. During my days as a high school science teacher my theories mainly were tacit. I had a sense of students needing to engage and stay focused in order to learn. I also knew that through their efforts they could learn from me and from their peers. Later I learned about the psychology of Piaget, when I became a curriculum designer who wrote teachers' guides and students' workbooks. Having such an emphasis meant that the activities we recommended for teachers were intended to get students actively involved and to learn science in terms of what they knew already and were interested in learning. To a significant extent the approach emphasized the importance of individual students making sense of their experiences by resolving cognitive conflict.

When I went to the University of Georgia to do my doctorate I joined one of the most behaviorist science education groups in the USA. Although the faculty members were open to the use of other frameworks for making sense of teaching, learning and curriculum, most of them were committed to behaviorist ways of thinking about education. This was especially true in regards to methodology, since most of the faculty used methods built around positivism. In required courses I had to show an understanding of and value for Julie Vargus's radical behaviorism and apply it in numerous contexts. However, when I returned to Australia and endeavored to apply radical behaviorism to my research, I had little success. To advance my research project I needed to move beyond methodological positivism and identify frameworks to illuminate teaching, learning, and learning to teach in a more productive light. I searched avidly for new ways to think about methods and especially to make sense of teaching, learning and learning to teach. I explored neo-Piagetian theories and then radical and social constructivism. Fortunately, Ernst von Glasersfeld's work in language and mathematics education seemed highly applicable to my experiences and perceptions of the pressing problems in science education. Glasersfeld's insights encouraged me to adopt radical constructivism and consider the potential applicability of other theories such as George Lakoff and Mark Johnson's work on metaphors. My understanding of theory was changing in that I regarded theorizing as akin to shining lights on experience, providing fresh perspectives and catalyzing research projects that could evolve continuously based on the adaptation and adoption of chosen theories. Also, I was learning how to not regard discarded theories as wrong. It was apparent that the use of any set of theoretical lenses illuminated certain aspects of social life while failing to discern others.

"I don't believe in that sort of research," was the preamble to a question from a scholar at the back of the conference meeting room. "The audacity of the guy," I thought as one of Australia's most eminent scholars admonished a master's degree student who had just given his first presentation at a national conference (Berry and Tobin 1984). Like so much of the work done in my research squad in the early 1980s, this study reflected a transition toward ethnography, from process product research that explored teacher and student variables in relation to one another, students' perceptions of the learning environment, and science achievement. Though I did not realize it at the time, the first shot had been fired in an exchange that was to continue to the present day. Apart from the public comment being discouraging from the student's point of view, this eminent scholar's stance was imperialistic. From the east coast of Australia, he was signifying to those in attendance that our way of looking at science education was not up to par, and that such work in the future would receive public rebuke.

A year or 2 earlier the signs of this first public salvo were evident in a meeting of the Australian Science Education Association (ASERA) at Macquarie University in Sydney. I had just returned from the United States, where I had done my doctorate in science education. I was involved in my first meeting of ASERA and noticed the dominance of scholars from Monash University (in Eastern Australia). One of them, Peter Fensham, was the first professor of science education in

Australia and his presentation to the group involved an innovative way of examining student misconceptions. The topic was concept mapping, an approach that was new to me and did not align with my current orientation to doing research on teaching and learning science and learning to teach science. Although I was an enthusiastic participant in the exercises Fensham used to introduce participants to the theory and methods, I had little inclination to use concept mapping in my research or to embrace conceptual change theory. My stance was very much in a minority and I felt I was being shown the approved way to proceed with research in science education. There seemed to be an expectation that one "tried-and-tested" way of looking at science education was preferred and conceptual change theory was oriented in the right direction.

The growing oppression I experienced in Australia did not deter me from plotting my own course and before I left for the United States in 1987 I continued to develop my own frameworks, foci, and methods. My pathway toward theory-rich, qualitative studies of teaching, learning, and learning to teach science developed in my research squad on the west coast of Australia as the conceptual change approach swept from coast to coast, becoming the predominant theoretical voice in Australian science education.

What I experienced in the early 1980s in Australia was just the tip of an iceberg. Conceptual change theory was to sweep the world of science education and dominate the ways in which science educators did their work. The theory did not fit my way of looking at science teaching and teacher education and my search for appropriate theory took a path that increasingly diverged from the ones chosen by my colleagues in science education. Because my foci were different, the extent of the divergence increased with time and for the most part I only noticed it as an issue when peer review occurred. When peers from the conceptual change group reviewed my proposals to seek external funds for research, present papers at national meetings, and publish books and papers, I often experienced their ire at my failure to conform to their senses of what was of value, how to think about knowing and doing, and which methods to use. If my work was to be accepted in peer review, I felt pressure to conform. Alternatively I could accept a minority status whereby rejection would occur with a higher incidence because of the objective blades of peer review and the consequences of failing to conform in a monosemic field.

I regard my experience of peer review in the past 30 years as evidence that there is an effort at work in our community that intends to create a master narrative for science education. Powerful brokers in Australia and other parts of the world developed a theory focused on the concepts of science and for this reason there was appeal to scientists who could look at their work and make sense of what was being done. Failure of students to learn key concepts from the science canon clearly was an important problem to scientists and massive support was given to those who focused squarely on science subject matter, the misunderstandings of youth, and ways to extinguish wrong ideas and replace them with scientific truths. An irony in what was happening is that my standpoint, though different than the mainstream view, embraced polysemy. It was fine by me for good scholars to do formal analysis through the theoretical lenses of conceptual change supported by methodological positivism. Yet, others' adherence to monosemy led them to view my standpoint as incorrect, a misconception that needed correction! To be accepted in most peer review contexts I would have to change my ways of thinking and doing or pay the price for my difference.

The combined impacts of conceptual change and positivism on research in science education have been totalizing, saturating sensibilities to the extent that to raise alternatives has been difficult in terms of risking rejection and marginalization. Yet, even within the dominant paradigms there is now a realization of a need for change. David Treagust and Reinders Duit (2008), two of the leading proponents of conceptual change theory, noted that "certain limitations of the constructivist ideas of the 1980s and early 1990s led to their merger with social constructivist and social cultural orientations that more recently resulted in recommendations to employ multi-perspective epistemological frameworks in order to adequately address the complex process of learning" (p. 299). One of the early pioneers of conceptual change theory in science education was Peter Hewson, a nuclear physicist who turned to science education. Hewson noted:

> My physics background gave me a view of the world that stressed the importance of unique, exact, confined, causal accounts of natural phenomena. Initially I did not see that this needed to be adjusted when I stopped focusing on atoms and nuclei, and turned my attention to a student learning physics. While I knew there was a context in which people learned, the notion of an isolated system was a conceptual device for effectively ignoring it. In time, however, the limitations of trying to identify unique causes became apparent, and I came to appreciate the complexity of factors that influence learning, and their interactional nature. While there clearly is an individual, cognitive character to our learning, we are also social, cultural, affective creatures who respond to those around us in a variety of ways that are strongly influential of the questions we ask, the opinions we espouse, and the understandings we create. (Hewson 2007, p. 131)

I maintain that a fertile approach to research in science education is grounded in the adoption of a fresh theoretical framework for learning and doing science. I use theory in the spirit of Karl Popper (1974) that "our theories are our inventions; but they may be ill-reasoned guesses, bold conjectures, hypotheses. Out of these we create a world: not the real world, but our own nets in which we try to catch the real world" (p. 46). I argue that tinkering with the dominant ideology does not offer the fertile insights needed in science education. In making a case for change I am not arguing for a new way to replace the old. My stance is in opposition to the idea that there is a correct way to see the world, to interpret the work of others, and to apply theory to science education. I am arguing for polysemy.

Accepting Difference

Adherence to monosemy, an ontological stance, may be at the root of a dire problem in science education. As I mentioned in the previous section, my polysemic stance supports a multilogical foundation for science education. In contrast, monosemy can motivate moves toward assimilation; a one-size-fits-all approach to science education with winners and losers, oppressors and oppressed. This has been the status quo during my career as a science educator. Throughout the history of science education there have been paradigm wars, debates in the literature in which the expectation was that one way of seeing the world would prevail. In a sense the view of our field was shaped by Comtean positivism that there was a correct theory for learning and teaching science and the role of scholars was to find that theory through careful conceptual analysis supported by formal empirical analysis. Obviously polysemy is an alternative to this quest for the Holy Grail.

There are numerous stances that can be taken to others' scholarship. Our first inclination was to ignore most conceptual change research. Even the best of the research had little relevance to our projects and to an increasing extent the foci and methods were such that there was little overlap with our chief concerns. Perhaps our approach might be thought of as telling the group to go play in some other sand patch. There was no room for conceptual change research or researchers in our projects. There were exceptions. For example, in a large collaborative study in Australia we intentionally included diverse perspectives in the design. Leading researchers in that study included David Treagust, Barry Fraser, and John Wallace. However, the book project we planned to disseminate what we learned from the study was never a priority and was not published. Instead, papers and chapters were eventually published separately. This example of involving scholars with diverse perspectives in collaborative research highlights the difficulties of navigating difference within the field of science education. There seems to be greater payoff for the hard work of being a scholar, to collaborate with those with whom our approach is commensurable, where the theories comprising our bricolage are complementary.

My theoretical journey from 1980 to the present day might be described in terms of six epochs, though with a finer grain size it seems as if each year (at least) might be listed as a significant point on a continuously evolving trajectory. As Thomas Kuhn pointed out in relation to scientific discoveries, such as the discovery of oxygen, it is not easy to pinpoint a date at which a particular way of thinking was predominant, even in autobiography. Given this caveat, the six points on my theory trajectory are: neo-Piagetian, radical constructivism, metaphors, social constructivism, theories of action, and cultural sociology. As is the case in any trajectory any one point can be examined with a finer grain size to reveal an extensive bricolage consisting of theories that are to some extent complementary. In an endeavor to show how this works, I take cultural sociology as a point of departure for the remainder of this chapter.

Social and Cultural Theory

The search for new theoretical spotlights is relentless. In 1997 I took a bold step in pronouncing that learning involved cultural production. The stance included learning to teach, learning science, and in fact learning anything. Alienation was almost immediate since scientists did not want to even consider that the canons of science were culture and conceptual change advocates insisted that models for learning cohered with what we knew about cognitive processes at increasingly microlevels—reiterating the centrality of individual sense making. The National Science Foundation in its various calls for proposals shows a strong emphasis on science learning as conceptual change as do reports such as the recent study of learning and teaching science in elementary and middle school grades. Somewhat undeterred, my project focused on urban schools and especially my own struggles to become a successful urban science teacher. This move to ground theory use and development in auto/ethnography addressed a central concern that theory and practice cannot and should not be separated.

Since I was the teacher in the study it was imperative that I resolve classroom problems to allow me to succeed in my teaching of science to urban youth. Anxiously I searched the literature, collaborated with other scholars and professionals within the city in which I did my research, and closely dialogued with Roth, who was using similar theories, though in quite different settings. In this study above all others in my experience, the stakes were high for my research to make a difference in the here and now, to benefit the participants in this study and not only to regard what we were learning as having potential value for future generations of urban youth and their teachers. I make this point here to emphasize this as an important component of my present standpoint. Our research project does not elevate theoretical ways of knowing above the imperative of research improving the social lives of those involved in the research. As Hannah Arendt (1958) noted, the tendency to privilege theory as a way of knowing dates back almost 2,400 years to Plato and Socrates. As a researcher in schools, classrooms, and impoverished communities I regard this as a serious problem that can be addressed through adherence to authenticity criteria (e.g., ontological, educative, catalytic and tactical), such as those I describe in a chapter on research methods (Tobin 2006). Reflexively, this research provides a context in which beneficence to participants is recognized as central to my methodology. There is no justification in my research to privilege the development of theory over the production of practices that can lead to improved social conditions for all participants.

My quest for theoretical and empirical help was broad and focused. I sought assistance in literatures I had not previously engaged, including African American psychology, sociology, reflexive sociology, cultural sociology, cosmopolitanism, globalization and neocolonialism, sociology of difference, and cultural studies. Even more salient were conversations with Roth, who pointed out alternative interpretations that were often painful for me to accept since I was a participant in the study. For example, his suggestion that my inability to succeed in teaching urban science might reflect a breakdown in my teaching habitus was a violent idea that initially shook my feeling of self-worth and core identity as a successful science teacher. However, the suggestion was a breakthrough in my research as I began to make sense of my experiences in terms of cultural fluency and a conscious | unconscious dialectic.

My graduate students were resources I could appropriate in two senses, suggestions of publications I should read and practical knowledge based on recently teaching in urban schools. Other sources of wisdom were teachers and administrators from within the school in which I did my research. I learned the hard way not to judge their approaches to teaching as deficits but to ask instead why they were doing what they were doing and how it helped them to succeed. It was essential that I set aside deficit perspectives of others and instead try to make sense of the rationale they had for what happened and why they did what they did. Eventually reflexive sessions with teachers, school administrators, and urban youth would catalyze the changes that underpinned my success in becoming an urban science teacher.

In making choices about what to include as resources to support my learning and doing of research I also excluded literature I regarded as not salient and incommensurable. I did not include many scholars and their publications from the fields in which I undertook science education, however, I regarded them as doing good work within their frameworks and of course accepted their rights to belong to the macro field of science education. The issue of commensurable and incommensurable is important to my analysis and is associated with issues of acceptance and rejection, inclusion and exclusion. I turn to this issue next.

Commensurability and Incommensurability

Basically I do not find a theory of incommensurability very useful. My stance has been that whether or not a theory fits is for an individual to decide on the grounds of viability. A position is not inherently this way or that. While retaining that view, I acknowledge that for all practical purposes my action in deciding a piece of research is not salient is akin to declaring it incommensurable (or not belonging to) with my bricolage of theories. That is to say, it is fine for others to have done this work, but it does not connect with what I do in ways that raise issues that warrant research. It is not so much that I cannot make it fit, but that I do not choose to do so. The grounds for omission are axiological. To use the metaphor of shining light onto experience, the patterns of illumination are not those I value as worth pursuing further. I emphasize that I do not seek for the authors to change to my perspective and I value what they do as contributing to the field of science education even though what they do does not impact noticeably on my project. My purpose in addressing this is to make my present position clear, even though it is in the process of changing.

Recently I re-read Garfinkel's (1996) paper in which he reviews ethnomethodology's program in a context of what has been done under the banner of ethnomethodology. Interestingly he addressed the issue of incommensurability in ways I find appealing. Garfinkel describes formal analyses (FA) as those using an approach that is not ethnomethodological (EM). EM then asks the question: What more? Garfinkel goes on to argue that EM approaches necessitate careful attention being paid to FA studies, considering them as alternatives in the sense that they provide a springboard for research using EM. What more can be learned using ethnomethodology to go beyond what has been projected in the basis of FA-oriented publications? Studies considered as incommensurable are brought to that table along with those regarded as commensurable and the dialectic between them provides a springboard for inquiring: what next? Presumably what emerges from the dialectical tension between commensurable and incommensurable is a form of interstitial culture that shines light on experience in ways that hitherto fore were not possible. Intellectually this seems like a reasonable way to proceed, but actually doing it may not make as much difference as it seems.

What I just described as the theoretical underpinnings of my research may have sounded as if coherence was a major selection criterion—but from the lived experience perspective; that is, a first person perspective, that is not how I experience what we do. The theories we add to our dynamic bricolage add something discrete, and yet they have to complement what we have learned and intend to learn next. Our intentions are never entirely agential and we are receptive to changing our focus, but always within the context of our field and its structures. What we will do is ill defined in the sense that we are always conscious of our goals and motives. Instead our activity is purposeful and when it comes to theory diversity is welcome, but it never is a case of anything goes. For example, historically we have taken something from Bourdieu, something from Roth, something from Turner, and something from Collins. Then we populate these "somethings" with our own intentions and what emerges is interstitial culture that orients toward what we do in our research. The interstitial culture produced as research is a response to asking "what more?" As we learn from research, our theoretical frameworks become enriched with empirical examples and nuances, or fine structure, and emerge during reflexive squad meetings during which we scrutinize what we know in relation to others' scholarship—that is, in the sense of engaging in a metalogue, as we ratchet up what we know by recursively examining theory in relation to experience in the research fields. In our research we endeavor to get a balance between creating theoretical products (ontological and educative authenticity) and ensuring that the participants involved in the research benefit from their participation (catalytic and tactical authenticity).

If I stick to my idea that incommensurability is all about lack of fit then the researcher gaze, when it is cast on a region of what looks like homogeneity, will reveal heterogeneity or lack of coherence. Zooming in on the fine structure of a theoretical bricolage will reveal lack of fit, regions in which it makes sense to ask "what more?" and set about the task of finding out. From this stance commensurability presupposes incommensurability and vice versa. The tension arising from the realization that any theory embodies a commensurability | incommensurability relationship can drive curiosity about the "what mores?" and the research that goes with it.

The Problem of Reification

It only seems like good citizenship to avow polysemy, however, a scholar's practices may reify her perspective over others, not just in her field of specialization but also in the larger field of educational research. Reification produces tacit monosemy, where a standpoint is regarded as correct and others are seen as inferior and in need of change. To admonish a field for being other is to enact monosemy—albeit in a context of avowal of polysemy. It is a paradox that we can reject conceptual change research because it does not meet the challenge of taking account of social and cultural phenomena and then assert that when it comes to this social theory or that one, the others have got it wrong. Of course this is a gloss. The crucial issues are not so much conceptual change theory and sociocultural theory but monosemy and polysemy. Researchers can be free to pursue their own agenda and should give the same rights to others—as long as what they do is ethical and contribute to attaining the motives of the science education field. In acknowledging our frameworks as viable for our projects we must not insist that others become like us—assimilation can be grounds for cosmopolitanism, in which case the inevitable feelings of social violence that go with colonization should not be ignored. In the spirit of Derrida's cities of refuge we must make others welcome and show them the respect of listening and learning from them. To allow them to participate in a field, and then to ignore them is tantamount to exclusion. To insist on one reified standpoint may qualify as indoctrination and produce determinism (such as the insidious achievement gaps that seem to persist despite mainstream's efforts to eliminate them).

On the Road Ahead

Did we participate in a dialogue in the recent special issue of *Cultural Studies of Science Education* (Volume 3, Issue 2) in which we brought together conceptual change researchers and sociocultural researchers? Even though the papers often do not speak directly to one another there is no doubt that in writing each of them the others' perspectives were considered carefully in what might be regarded as ongoing dialogue. Perhaps we have the start of something that extends beyond stance taking and re-taking. The chapters comprising this book, subsequent papers published elsewhere, and papers presented at recent international conferences suggest that there is an extant, vibrant, and continuous dialogue on theorizing learning that will be productive to the field of science education.

Like sociology, psychology has numerous branches, many of which endeavor to make sense of social and cultural phenomena. Blurring these boundaries has the promise of making it easier to consider theory and research from psychology in sociocultural projects. The challenge for sociocultural researchers is to find promising alternates and ask of them "what more?" It is not appropriate for us to admonish conceptual change researchers to become more like us or require them to consider our work respectfully. This is for them to decide for themselves—we give them the right to create their own standpoints and we can assure them that we will struggle to learn what we can from their formal analyses. So, what then are the grounds for progress? As I see it, we demand from others the same rights we offer. Allow us to pursue our own agenda and undertake our own formal analyses. Do not colonize our projects and when we seek funding for research in our field show respect for what we do and what we have learned from what we do. Monosemy, taking the form of reification or determinism, is a plague that can fragment solidarity within science education and oppress those who dare to be different. The challenge of our times and for our field is to build solidarity while retaining difference.

Setting the Stage for the Remainder of the Book

"She's not listening to me!" Her eyes danced and a smirk appeared on her face. Frustration welled up within me, but I continued to explain what we had learned in the latest research we were doing. "She disagrees with my interpretations. But who really cares? Why had she set up the meeting? Was it to learn from me? No! My hunch is that the meeting was scheduled to set me right, show me the correct way to think about my work, and point out my limitations while emphasizing a superior way of knowing and doing." As the excitement drained out of my voice, my mind filled with images of scholars I greatly admired, including Mary Budd Rowe and Ernst von Glasersfeld. A characteristic they shared is that they listened, learned, and then contributed to the conversation—thereby affording my listening, learning, and adding of something more. I regard their approach as an embodiment of what Paul Ricœur (1992) referred to as a privilege of being able to join the conversation of life. Is it an elusive ideal to expect scholars to participate in a polysemic dialogue in which they learn from differences by listening, commenting on what is said, and then adding more? Whether the dialogue is written or oral, it seems not only respectful, but also the epitome of good scholarship to listen attentively and then to build on what has been said already. It is in this spirit that I exhort readers to join the conversation as they dialogue with the chapters and associated forums that comprise the remainder of this book.

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Part A

Social Psychological Frameworks

This first part of our book is devoted to presenting some fundamental ideas concerning sociological and psychological perspectives. Although in the West, sociological and psychological perspectives have developed largely independently—but for some overlap in social psychology—there has been a long tradition in the Russia/USSR for thinking sociology and psychology together. All three lead articles in this Part A have been influenced by and are taking positions that derive from the sociocultural and cultural-historical schools that have their roots in theoretical developments in Eastern Europe, especially through Lev Vygotsky and his students and followers. But Vygotsky himself was strongly influenced by the ideas of Karl Marx and Friedrich Engels, about the relationship between human culture and the individual person ("man"). Vygotsky's dictum that all higher order mental functions have been and are the results of prior social relations can be traced back to Marx and Engels. This then led to the often-used description that psychic functions first occur on the interpersonal plane before appearing at the intrapersonal plane. It should be clear, however, if a child or newcomer participates in a practice, thereby participating in the sociological (intrapersonal) appearance of the functions, his/her brain already needs to enact these functions. It therefore is not the case that there is a transfer of these functions from outside to inside. The inside is always enacted; and so is the outside part. Having an internal monologue still uses words, which are, as already Vygotsky (1986) and Bakhtin/Vološinov (1973) point out, always matters of two people, the user its Other. The true story therefore is that the interpsychological (sociological) and intrapsychological appearances of psychic functions occur together, from the first time. (See also the points Smardon makes on this issue in chapter 7 as part of her discussion of the Stetsenko contribution.)

For Marx and Engels (1978)—as for Georg Wilhelm Friedrich Hegel, whose idealist theory of the development of consciousness they gave a solid grounding in the material world and material processes—the relationship between the individual and collective is dialectical. The individual concretely realizes possibilities that exist at the collective level; and the collective only exists in and through the individual. This is why the individual always already recognizes itself in the actions of others; we understand the (possible) intentions underlying the actions of others. But whereas anthropologists theorize culture in terms of tools, artifacts, and practices, the Marxist approach theorizes the collective in terms of action possibilities, the extent of which exceeds the realized (observable) practices (Roth and Lee 2007). The advantage of this approach is that we do not end up searching how a cultural system such as language could get off the ground—which would be the case if there had been but one person saying the first word who would have then had to teach others to hear and understand. From the Marxist position, which is also that arrived at in postmodern analyses of the beginning of language (e.g., Derrida 1967), the first word already is a word for the speaker and the listener. This is so because "the word is a thing in our consciousness … that is absolutely impossible for one person, but that becomes a reality for two" (Vygotsky 1986, p. 256). In a strong sense, therefore, no discourse situation can be reduced to the individual; but, because it is the individual who concretizes and thereby singularizes the speech act, it cannot be reduced to the collective. It is not the collective that speaks in the singular act but the individual, who, nevertheless, in speaking, realizes a more general possibility that is always already (assumed to be) intelligible on the part of the other, the specific and the general listener for whom the utterance is designed. It is in the concrete speech production—modulated by such prosodic features as pitch, pitch contours, speech rate, and speech intensity (volume)—that repeatable and therefore generalized and generalizable words become specific in and to the concrete here and now of a situation.

The group around Mikhail Bakhtin, which, besides Bakhtin, included Valentin Vološinov and Pavel Medvedev, took up a very similar project concerning speaking. In their group, these scholars were able to bring together literary theory and Marxist theory of society. Thus, for example, Bakhtin and Vološinov (1973)—the exact authorship of their text is debated to the present day—produced a text in which the continual reproduction of language was tied to Marxist principles of the reproduction and transformation of society. Although some scholars question the amount of work done by Bakhtin, the theory concerning the reproduction of language clearly can be found in other works attributed to Bakhtin alone. Most importantly, Bakhtin alone and in the work with the members of his group, emphasizes the dual nature of the word, which, metaphorically spoken, yokes together speaker and listener. Each and every word integrates elements of the person uttering it and the person for whom it is intended. This idea also appears in the work of Jacques Derrida, who emphasizes that each text not only has a signatory, an author/speaker, but also a countersignatory, a reader/listener (Derrida 1988). He extends this idea emphasizing the ear of the other as the organ most important to communication. In particular, autobiography always also is otobiography (Derrida 1984), biography befitting the ear of the other—because it makes use of genre and language inherently those of the other. There is therefore no divide between the sociological and the psychological in the work of Bakhtin and his group, as each word in concrete use is singularized in the sense that it has an irreducible and irremediable effect on someone else and on the context; but each word transcends the individual in the sense that it constitutes a collective possibility and therefore always already belongs to all those of the community in which a word is currency.

Interestingly, and coming from a very different philosophical background, phenomenologists arrive at the same conclusion. Martin Heidegger (1977), for example, emphasizes that speaking is premised on hearing. There would not be the phenomenon of speaking if there were not already the phenomenon of hearing. And both are premised on understanding. Without always already existing understanding there would be neither hearing nor speaking, and this is valid on both individual developmental (ontological) and cultural-historical (phylogenetic) developmental levels.

The three main contributions all are rooted in cultural-historical background that rests on the shoulders of giants—to take up the words of Stetsenko—which include Plato, Hegel, and Marx in the more distant past, and then Bakhtin, Vygotsky, and Heidegger in the twentieth century.

In chapter 3, Kelly and Sezen consider paradigms for research in science education and future directions by focusing on the epistemic subject. They take a long view of science education research based in conceptual change and constructivist perspectives and identify some alternatives for future directions. Their comments focus on four central ideas. First, behind much of the past research in science education (e.g., conceptual change, constructivism, nature of science) is the individual as the epistemic subject. These research paradigms generally start with the knowing subject as the individual, and from there examine issues of learning and knowledge. Alternatively, the emerging research in science education tends to re-conceptualize the epistemic subject as a relevant social group. This social epistemology leads to a number of implications for research. Second, building on the social epistemology theme, they explore some emergent issues around discourse and knowledge. There are unanswered questions about how we think about language and learning. The authors suggest that knowing is a process of participation in a set of contextual epistemic practices. Third, the authors consider how learning is connected to participation and identity. It seems clear that viewing learning as a change in cognitive structure has limitations. Kelly and Sezen articulate additional ideas concerning learning as changes of ways of being in the world and how participation may be related to affiliation and common ways of being. Finally, a thoroughly social view of learning and epistemology raises renewed questions regarding curricular legitimation.

Yew Jin Lee and Donna DeGennaro each contribute a commentary to the chapter by Kelly and Sezen. With an understatement and self-effacing style characteristic of the person I have come to know while he did his PhD dissertation under my supervision, Lee begins his chapter 4 by stating that it is difficult to construct a text when one agrees with every point the author(s) make(s). He begins stating "been there" and "done that" and then rhetorically asks "Have we (really)?" In her response (chapter 5), DeGennaro offers a reflection on how the field of cultural sociology assists in uncovering the complex process by means of which the landscape of science education changes and what it means for potential research directions. She extends the conversation in the areas projected by the authors of the lead chapter.

In the second feature presentation at the Springer Forum (here chapter 6), Stetsenko draws attention to the need of a critical self-reflection about reciprocal relations and synergies between the methods applied and the conceptions developed within epistemic inquiries as a potential remedy against undesirable gaps between them. Epistemic method and concepts of knowing and conceptual understanding are discussed as these can be developed on the foundation of Vygotsky's project with its grounding in the mutually complementary dialectical method and its worldview-level dialectical outlook on reality, both predicated on the idea about infinite movement and interpenetration of any and all aspects of reality including activities of knowing and theorizing. Implications include a re-conceptualization of traditional epistemic notions overcoming the false dichotomy between the social and individual dimensions of human Being and knowing.

Regina Smardon and Wesley Pitts articulate their responses to Anna Stetsenko's text in chapters 7 and 8, respectively. Smardon is a trained sociologist, who also knows cultural-historical activity theory very well, the theory in which Stetsenko has been trained and in which the latter is very well grounded. Smardon links the Vygotsky project articulated by Stetsenko with Marxist-oriented microsociology. She sees a lot of possibilities that arise from carrying on the project Stetsenko outlines. Pitts is a science educator who works in urban context. In his chapter, he provides possible linkages that can be made between the project outlined in chapter 6 (Stetsenko) and science education offered to the students with whom he is dealing and whom he is teaching in inner-city schools.

In chapter 9, I (Wolff-Michael Roth) provide a careful, social-psychological reading of some concrete episodes from a course in thermodynamics in their historical context. The reading shows—consistent with the work of Lev Vygotsky (1986)—that thinking, speaking, and the relation between the two in real concrete situations are incompatible with a theory that hypothesizes conceptions as fixed structures that undergo (developmental) change as an individual learns and develops. Rather, thought, language, and the thought-language relationship are dynamic processes that change at three time scales: moment-to-moment (microgenetic) scales experienced in continuously unfolding situations; ontogenetic, individual-developmental (mesolevel) scales experienced as changes over longer periods (days, weeks, months, and even years); and at historical scales (macro-, phylo-genetic levels) experienced in the course of decades and centuries. As a result, a model is proposed in which thinking is a generative process that changes in and because of speaking so that structure ought to be sought not in the thinking itself but in "deeper" processes that generate ever-changing thinking, the consistent patterns of which are as much to be sought in the situationally and contingently available social and material resources in the setting.

The two commentators on chapter 9, Eduardo Mortimer and Pei-Ling Hsu are both very well grounded in sociocultural theory and in discourse analysis. Both return to the actual analyses I provide in my chapter and ask readers to reconsider such issues as unit of analysis, an important point that Vygotsky asked us to head in research on knowing and learning. Mortimer asks readers to extend the analysis not only from the word to communication but to all those aspects that are part of the communicative situation. Hsu takes a Bakhtinian spin and encourages readers to theorize thinking and speaking through the perspective of dialogism, a Marxist approach to language and its development. Dialogism keeps research in a state of non-finalization, continuously allowing different ideas and expressions to transform one another (see also chapter 2).

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Chapter 3

Activity, Discourse, & Meaning Some Directions for Science Education

Gregory J. Kelly, Asli Sezen*

This chapter emerged from dialogues at the 2008 Springer forum held at Graduate Center of the City University of New York. The forum considered paradigms for research in science education. The conversations began by examining a prominent paradigm in science education, conceptual change theory, which was the subject of a recent special issue of *Cultural Studies of Science Education* (Roth and Tobin 2008). Conceptual change theory, and its relatives, cognitive constructivism and studies of student's alternative frameworks, thus are a starting point for a thorough reconsideration of research on science learning. We have been asked to consider paradigms for research in science education and propose some future directions. In this chapter our contribution will be to try to take a long view of science education research based in conceptual change and constructivist perspectives and identify some alternatives for future directions. Since these theories have generally focused on student learning, and the various cognitive, social, and pedagogical contexts around learning, we limit the discussion to these areas. Through this consideration of learning in science, we identify a number of challenges and unresolved questions for the field. We do not presume to assess the entire field or offer a research agenda for science education. Rather, we note only some of the many promising areas, acknowledging that there are many others.

We begin our reconsideration of the conceptual change paradigm by identifying its contribution to the field. We then consider a number of theoretical developments since the inception of conceptual change views. These developments bring into light some basic assumptions of the conceptual change view of learning, including its reliance on an individual learner as the central epistemic subject. In the

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second part of the chapter we examine consequences of considering a thoroughly social view of the epistemic subject and its consequences for research in science education. Behind much of the past research in science education (e.g., conceptual change, constructivism, nature of science) is the individual as the epistemic subject. These research paradigms generally start with the knowing subject as the individual, and from there examine issues of learning and knowledge. Alternatively, the emerging research in science education tends to re-conceptualize the epistemic subject as a relevant social group.

The development of a social epistemology leads to a number of implications for research, some of which we consider. First, building on the social epistemology theme, we examine the relationship of discourse and knowledge. There are unanswered questions about how we think about language and learning. We suggest that knowing is a process of participation in a set of contextual epistemic practices. Engaging in such practices entails learning how to think, act, speak, and so forth through dialogue with others. Science poses particular restrictions on how discourse is used in social settings, and thus poses challenges for students. Second, we consider how learning is connected to participation and identity. It seems clear that viewing learning as a change in cognitive structure has limitations. We explore some ideas around learning as changes of ways of being in the world and how participation may be related to affiliation and common ways of being. This suggests that a sociocultural view of the learner needs to attend to the social and personal construction of identity. Finally, a thoroughly social epistemology raises questions regarding curricular legitimation. Choices about science curricula will always be contentious. Considerations of discourse, identity, and social epistemologies render questions about knowledge legitimation more visible.

Conceptual Change in Context

The development of a conceptual change model for accommodation (e.g., Posner et al. 1982) brought together Piaget's cognitive theories with perspectives derived from the history and philosophy of science. Once formulated, the conceptual change model itself could be interpreted as a research program with certain theoretical assumptions, directions for empirical work, and limitations in perspective. Over the past 30 years the attention to students' conceptions and understandings of natural phenomena has made significant contributions to theory and practice of science teaching and learning. The focus on how students conceptualize phenomena, the development of programs to introduce students to scientific concepts was a clear step away from behaviorist learning approaches that were inadequate for supporting the deep understanding required to engage in science. The introduction of a conceptual change approach was a theoretical advance.

Conceptual Change and the Need for Change

Conceptual change theory sought to base learning on reasoning from an initial position of understanding to some more developed, socially validated point of view. The focus on reasoning and examining evidence for an idea or set of ideas situates the learner as an inquirer into their world. This represents an active learning process and conceptualizes knowledge as the result of a constructive process. Thus, the conceptual change model, grounded in a rationalist framework, challenged the empiricist epistemology of behaviorism.

Second, conceptual change theory brought into focus the range of plausible cognitive artifacts relevant to learning a particular concept. By introducing the conceptual (or intellectual) ecology, the theory provided a view of accommodation that sought an expansive view of cognition. This leads to many studies of analogies, epistemological commitments, ontological assumptions, and so forth. This opened up research directions and led to studies examining the many relevant factors related to accommodation.

Third, conceptual change approaches, particularly when influenced by the related constructivist approaches, paid attention to students' epistemological beliefs (e.g., Vosniadou 2007). By starting with students initial knowledge state, the research paradigm provided teachers with ways of understandings their students, and importantly, ways of seeking to understand students' thinking through evaluative tools (e.g., interviews). Close attention to students and their ways of conceptualizing phenomena offered a shift away from research focused on teaching behaviors.

Although cognitive theories lead to dramatic change in educational research, there have been a number of critiques and modifications in the theory over the years. One of the critiques centers on the isolated nature of the study of scientific concepts. These concepts were often taught and assessed as discrete, and were thus identified as inadequate for providing a sufficient account of science learning. Absent a history of ideas, these concepts were often taught without "the context and processes of conceptualization and nominalization that led to their invention in science" (Fensham 2001, p. 30). Another limitation of the theory was due to its lack of attention to the process of knowledge constructed needed for students to develop the scientific point of view. Whereas the research was attentive to students' initial knowledge states, the processes of changing their conceptions through reasoning were limited by a lack of attention to the language use of students. In this way, students' initial knowledge was construed as misconceptions, rather than plausibly useful concepts that could potentially assist them to develop more robust, generalized concepts. Despite these and other limitations, the focus on students was effective and brought about change in the teaching of science.

The theory was designed as a way to think about accommodation to formal scientific concepts, rather than develop a comprehensive learning theory. Furthermore, the attention to student thinking and relevant conceptual ecologies was helpful to a certain degree. Even though studies continue to document taxonomy of students' alternative frameworks, they often do not produce comparable solutions for addressing these alternatives. Thus, the continued taxonomy of students' alternative conceptions has been limited in its usefulness for practicing teachers.

Whereas conceptual change research continues, and there may be points of contribution, the paradigm has serious challenges to face. Developments in cognitive science and the expansion of the learning sciences offer many insights to the development of science learning. The recent interest in learning environments and learning progressions represent just two ways that some of the central premises of conceptual change theory have been re-conceptualized while maintaining an interest in the cognitive aspects of science learning.

Theoretical Developments

Science education is not a research field that adheres to any one paradigm. This is both an empirical observation, and a normatively sound choice—the complexities of learning science are such that multiple frameworks are needed to fully examine the relevant range of issues. For more than decade, research on learning in science has developed new directions by examining the assumptions of discourse, activity, identity and knowledge. These directions pose challenges for and to the conceptual change paradigm. Drawing from developments in activity theory, science studies, and discourse analytic frameworks, we propose a few plausible directions to consider for science learning. Our goal is not to lay out the research agenda for the field, or to try to identify the most fruitful directions, rather, in a more limited manner, we seek to provide topics and questions to consider for paradigms in science learning. These topics and questions may be most immediately relevant to the other chapters in this collection. Each of the directions we examine emerges from a rethinking of some of the central ideas of science education research, as exemplified by conceptual change theory. The theoretical changes concern the loci of meaning, a thoroughly social view of knowledge, and participation as identity development. Drawing from activity theory, we consider how meaning is derived from active participation in a social group. The rules for use of language are determined interactively and intersubjectively. Thus, whereas individuals may derive meaning from participation, and concretize meanings for uses in other situations, these meanings occur among people in interaction, mediated by cultural artifacts. In contrast to many individualist approaches to learning, which view the personal construction of meaning, this view examines how meanings are constructed through interaction among people and internalized by individuals.

The second theoretical development concerns a thoroughly social view of scientific knowledge. Much of the work in conceptual change research places importance on epistemology, particularly in terms of the epistemological commitments of the learners and the roles such commitment play for the acquisition of new concepts. The theoretical shift to a more social and interactive view suggests that epistemological commitments, indeed epistemology as an enacted theory of knowledge, are part of the sociocognitive artifacts constructed, modified, or examined in social contexts. Thus, this view suggests that theories of knowledge relevant to learning situations are a local accomplishment.

Finally, a third theoretical development is to situate learning in broader developmental theories. Conceptual change theory and many constructivist theories are centrally concerned with understanding how individuals' cognitive structures change over time through assimilation and accommodation. This focus has the advantage of examining one aspect of learning and is successful at generating interest in how students conceptualize phenomena. A shift to a more sociocultural view of learning examines how, through the appropriation of social knowledge, including psychological tools, changes in participation and identity formation accompany learning. Furthermore, students' appropriation of knowledge through participation in social action is situated in the historical and cultural contexts.

Shifting the Epistemic Subject

Learning theories in science education have generally begun with the individual as the epistemic subject. Early cognitive theories of learning focused on the internal mental structures, memory, and cognition of individuals. Those cognitive theorists try to understand how external reality has been transmitted in the brain of individuals. This conceptualization offers many research directions. However, these directions often are overly individualistic in the ways in which they interpret cognition. Radical constructivism emerged as a learning theory that criticizes the "external reality" and views individual as the constructor of his or her own reality (von Glasersfeld 1995). This position is most glaring when the personal construction of meaning is a central premise. As soon as we shift the epistemic subject, however, problems of teaching and learning in science change. In this section, we articulate a sociocultural view and some of the changes this shift entails.

Toward a Sociocultural View

An alternative to the individualist position is a more social view of knowledge construction. Empirical studies of scientific action in professional settings, demonstrate the important ways that knowledge is part of practical actions taken by members as they participate in collective work. Studies by Michael Lynch (1993) and others demonstrate the ways that the construction of meaning and knowledge occur through the concerted action of members of a cultural group, as they interact with each other, specific tools, and semiotic resources. Therefore, in education, the move to a consideration of a relevant social group can be seen in many emerging research paradigms.

Cultural-historical activity theory (CHAT) is one such research paradigm that considers learning as constructed by social groups. This theory originated in 1920s and 1930s by Russian Psychologists Lev S. Vygotsky as well as his students Alexei N. Leont'ev and Alexander R. Luria, who focused on the activity itself to understand human development. Following Vygotsky's works on mediated tools as motives to reach purposes in an activity, Leont'ev (1978) states:

> We always must deal with specific activities, each of which answers a definite need of the subject, is directed toward an object of this need, is extinguished as a result of its satisfaction, and is produced again, perhaps in other altogether changed conditions … *the concept of activity is necessarily connected with the concept of motive.* Activity does not exist without a motive. (p. 62)

The mediating tools (motives) in this triadic relationship are embedded in culture and history. Leont'ev focuses on the involvement of other people in the completion of the activity and at the same time, he differentiates this collective activity from the individual activity by exemplifying the division of labor. He illustrates this relationship with an example of collective action constructed among people during the primeval collective hunting activity. Some members became responsible for frightening the animal and sending them to other hunters in the group. These hunters kill the animal and leave the animal to other members to prepare food or use the skin of the animal for clothing.

Since the inception of CHAT, a second generation of the activity theory has been developed (e.g., Engeström 1987). These emerging developments of CHAT maintained a commitment to goal directed, mediated activity. In this second generation, new dimensions come to be added to the triadic relationship of the activity system. One of the elements he adds is the *community*, the group of the people in which subjects belong. Another element is the rules, either explicitly or implicitly stated, regulating the social interaction in the community of which the subject belongs. Engeström also includes *division of labor*, an idea originated from Leont'ev's works, as shared participation of responsibilities in the activity determined by the community members. The resulting product of the activity system enters the relationship as *outcome*. The inclusion of these new elements to the activity system would, according to Engeström, have more focus on "the societal and collaborative nature" of the actions. To understand the interactions between activity systems, Engeström proposes a third generation of the CHAT. This third version of the activity theory model aims to look at dialogues between different activity systems from multidimensional perspectives and improve conceptual tools to understand these interactive dialogues.

Originating as a theory of psychology, CHAT has influenced the research on teaching and learning, computer education, and work place education. Recently, science education researchers have started to base their research on CHAT. For example, Roth et al. (2002) analyzed a collective teaching and learning paradigm that they call "coteaching/cogenerative-dialoguing" during the lesson on the dihybrid cross. These authors defined two activity systems. The participants of the first activity system are the authors of the article: university student, new teacher, supervisor, researcher, and methods professor. In the second systems, the participants are the high school students in the class. Their analyses showed how each participant interacts, that is, their contradictions and accomplishments of their responsibilities (System 1), what students learn from these interactions (System 2), and the effects of individual histories of each participant on their interaction and student learning. The study shows the potential of this research approach to contribute to research in science education grounded in a social epistemology.

Although there is a growing interest to the use of CHAT in different fields of education, the model has obstacles for educational researchers aiming to analyze practical teaching and learning environments. Currently, there remains work to be done sorting through the meaning and applications of important constructs in activity theory such as community, rules, and outcomes.

Another example for the move to the consideration of the social groups also appeared among cognitive psychologists due to a need to combine the social and organizational perspectives of cognition. As opposed to the conventional cognitive theories, which consider information processing at the level of individual, Ed Hutchins proposes a theory of distributed cognition. This view of cognition "is a new branch of cognitive science that is devoted to the study of: how knowledge is represented both inside the heads of individuals and in the world (environment, culture, social interactions); the transmission of knowledge between different individuals and artifacts; and the transformations through which external structures go when acted on by individuals and artifacts" (Flor and Hutchins 1992, p. 36). As the definition implies, the theory considers how individuals interacting with other people construct their own culture, including the artifacts (e.g., technological devices) in their social lives. Researchers using this theory have analyzed the contributions of the environment of the social activity, the representational media, the interaction between individuals and cooperative uses of artifacts to see the coordination within the functional systems, which can be anything from hospital wards to a software development company.

Studies using the theory of distributed cognition have analyzed the functional systems of engineering company, navigation on a ship, air traffic control, and cockpit flight crew. Distributed cognition has been most beneficial for understanding the complex organization of the work settings in which technological artifacts and other tools have been used. For example, Hutchins (1995) looked at the cultural-cognitive processes for steering a ship into harbor through looking at the coordination between people and artifacts, learning processes of people and the culture of the navy. One of the activities he observed was taking a bearing on a ship too close to land. To do this, one navigator needs to find landmarks on the shore and measure the bearing of the landmark. This activity requires a representational state mentally at the individual level as remembering the landmark sign. Next, this representational state is coordinated with a technological artifact as using an alidade, a measuring device to determine the sightings of the landmarks. Further, the socially distribution of this activity occurs through communication among personnel on the ship and from personnel on the ship to others in the pilothouse. This study shows a stark contrast to studies of students' alternative conceptions, epistemological beliefs, or processes of conceptual change. Rather than examining putative processes inside a cognizing subject, the locus of activity exists across subjects and artifacts. Ways of being, acting, thinking, and doing are drawn from and interpreted through repertoires developed over time through social practices.

Discourse, Activity, and Knowledge

An important paradigmatic shift in science education has been the thorough rediscovery of language and its role in the construction of everyday life. Whereas there has been significant interest in reading and writing in science, argumentation, and scientific literacy, the importance of language in the social construction of concepts, identity, and everyday life has attracted less attention. Through studies of classroom discourse, researchers in science education have identified the important ways that metaphor and analogy play into learning, that discourse moves establish control, that norms are established for scientific discourse, and that the semantics of conceptual knowledge rely on specific nuances in language use. Through language students come to learn to participate in classroom life (e.g., when to slot in) and how being a student is a particular kind of role. As related to learning science, scientific concepts have particular rules for use that pose problems for student learning. In principle, the use of socially derived, standardized ways of speaking offers the potential for growth in learning and future learning. The social language of science is in principle one that can be generative of new learning. Nevertheless, use of discourse and participation are closely related.

The shift from viewing language as a means for conceptual acquisition to participation is documented in a study by Carlsen (2007) that demonstrated changes in the field of science education over time. This study identified how the number of studies with the descriptors language and concept formation peaked in the early 1990s, while those with descriptors language and culture have increased steadily over time. This study of recent publications shows how the field of science education has moved beyond the central tenets of conceptual change theory to consider language, culture, and participation as more contextual and interactive.

Vygotsky's (1962) distinction between spontaneous concepts and "scientific" (socially derived) concepts offers a way to understand the shift in the epistemic subject. Spontaneous concepts arise in everyday speech while scientific concepts are learned more explicitly through participation in a discourse community. For example, before starting school, children learn about their body parts as arms, legs, toes, and so forth mostly from their families. Sometimes, this learning occurs unconsciously by just hearing people around and observing them. Then, children use these concepts for their daily life interactions. However, when they take science classes in the school, they start to learn concepts like nervous system, circulatory system, and endocrine system named by a scientific community. Students learn these concepts under a planned instruction that has been prepared through the use of scientific resources and with the help of science teachers having special scientific knowledge. These scientific concepts can be even more specialized (e.g., thoracic nerve, omohyoid muscle) should students decide to advance in scientific fields. Socially derived scientific concepts do more than just label the world in new ways. These concepts become generative of new knowledge by providing new forms of mediation and meaning making. Although spontaneous and scientific concepts differ in terms of their development and the way that people learn them, they are not totally independent. To learn scientific concepts in more specialized communities, we need to use spontaneous concepts.

Learning and Identity

A thorough consideration of learning as a social and cultural process, rather than a change in individual cognition, redirects research on learning to the everyday activities where people engage each other and the world. This shift has led educational researchers to begin to study the interactions and activities within social groups in everyday settings. To understand the way students interact with each other and are involved in activities in their classrooms, the concept of identity has became the focus of many studies of learning especially in science education. From this point of view, identity is dialogically constructed as an "achievement of the person's activity" (Holland and Lachicotte 2007, p. 118) supported and constrained by the contexts and potentials for social interaction. Taking this sociocultural perspective on learning, classrooms are not only places for potential learning, but also establish and develop cultural characteristics. Students' participation often involves a process of acculturation into certain locally defined social practices, which in turn shape and are shaped by the participants' identities. The construction of identities is not simply at an individual level. The views of self, established through engagement in social actions, change over time (Roth and Tobin 2007). For example, the ethnic groups that we belong to shape our identities, our gender mediates our choices of what we want to do due to the values and beliefs in our cultures. Research on identity studies and science learning shows that differences in students' ethnic backgrounds, gender, and status have an influence on students' identities, and thus influence students' attendance to classroom interactions and activities. Yet, these characteristics can only partially account for the development of identity over time.

There are four ways in which we may think about identity: in terms of natural forces (N-identity), institutional perspectives (I-identity), affinity perspective (A-identities), and discursive practice (D-identity). Using this framework as a starting point, Brown (2004) identified discursive-identity; he thereby attempts to understand identity through use of scientific discourse, as related to linguistic and cultural practices and the extent to which individuals are able to slot in to social action. This research generally focuses on the minority groups in the classrooms, including students from different ethnic and linguistic backgrounds. Brown study, for instance, found four different domains of discursive identity among ethnic minority students in a high school classroom. These domains ranged from students demonstrating strong opposition (Opposition Status) to participate in scientific discourse, to students demonstrating fluency in scientific discourse (Professional Status). These studies suggested the significance of co-construction of new students' discursive identities in order to meet students' communicative demands to participate in scientific discourse, and analysis of this co-construction process to understand students' science learning and their attainments in scientific literacy.

Researchers working on identity and science learning have also given importance to gender differences and they attempted to answer the question of how gender influenced students' engagement in scientific activities in classrooms and their selection of science careers. Due to biases that boys are more expected to do science, the studies on identity sought to understand how girls developed positive identities about science. An important finding was that girls, striving to attain "good student" identities for themselves or in the eyes of others, seek to figure out the survival in school subjects. For example, a study on active physics curriculum, framed around real world themes, showed the resistance of girls to this new science curriculum (Carlone 2004). Thus, the girls solve the problem of how to be successful at school science. But clearly, being successful in science may vary from engaging in school science procedures to participating in more normatively valued experiences developed by a relevant social group.

As science educators, we hope that studying science education helps students develop the potential for identities that minimally leave room for participation in science communities (e.g., in schools, activist groups, amateur scientists). However, students' inherited identities (i.e., gender, ethnic group, status) influence the way that they get involved in scientific discourse and activity and thus affect their learning processes in science classrooms. For students to develop new identities, they need to engage in meaningful learning where they actually contribute to the community work and they have the opportunity to think and act like a member of the locally-defined scientific group. This research suggests that we need to consider how to improve a gender-fair curriculum, which might help the realization of *science for all*.

Knowledge Legitimation

Science education appropriately needs to pose and tentatively answer the question: Whose knowledge counts as science for whom and under what conditions? The shift to a relevant social group, rather than the individual learner, as the epistemic subject, brings to light the very political nature of choices about science curricula, learning, and teaching. In previous research paradigms, such as that of the conceptual change model, the end goal was the final form knowledge of scientific disciplines. This normative goal masks the nature of the legitimation processes that occur to make science knowledge in the curriculum seem to be the obvious, logical choice. Indeed, alternatives are often difficult to identify. By viewing learning as situated in a context of acculturation into the knowledge and practices of some social group, the discussion of whose knowledge counts becomes more crucial and less hidden from view. This poses new problems and possibilities.

As a result of the improvement in information technology and the rapid production and dissemination of knowledge across many domains, scientific knowledge is changing, evolving, and gaining new inputs every day. Thus, even if the central curricula choice were to identify and teach the best available scientific knowledge, as defined by the traditional disciplines, the choices would be difficult. However, there are other potentially relevant social groups—for example, environmentalist, activists, and citizens groups—making the selection of legitimate knowledge is increasingly complex. The necessity to select what to teach in schools raises questions like: What is education for? What and whose knowledge is considered legitimate? Who has the right to answer these questions? What knowledge is most important? Who decides? Relevant to whom? Relevant to what? What is worthwhile knowledge? What should we teach?

The dependence of educational philosophies on the ideologies and politics of the day becomes salient when we look at historical changes in curriculum policies. One review of science education research states, "curriculum choices in the past have most often favored the status quo over a proposed humanistic science curriculum" (Aikenhead 2006, p. 5). Research thereby has only an informative role on the curriculum decisions. Rarely are curricular decisions made as a result of weighing available evidence. The decisions on what needs to be learned in schools are mostly determined through government rhetoric, framed by powerful groups trying to maintain their dominance.

One example of change driven by labor needs is curriculum change in the USSR after the October Socialist Revolution of 1917. Following the revolution, the labor (manpower) needs of the Soviet regime became different from these of the Russian empire. The goal of the Soviet regime became the creation of citizens aligned with the demands of communism. Therefore, Soviet educators believed that educational policy and practice should be used to form the "New Soviet Man," who was in line with the interests of the regime. As a way of realizing this, the communist party favored the views of Karl Marx and Vladimir Illich Lenin. The educational philosophy for the October Revolution of 1917 was developed mainly by Lenin, his wife, and the educational specialist for the new Soviet Regime Krupskaya, and the Commissar of Education Lunacharskii just before the revolution. This example shows the influence of national politics and its resulting policies on what needs to be (or gets) learned in the schools. Raising new citizens under the auspices of new state ideologies sought to align the post-1917 curriculum with state interests.

The curriculum change movements also reveal that the policies shaping the educational philosophies can be of international origin. One such example may be crucial shifts due to major scientific accomplishments in other cultures. The conditions in the United States after the orbiting of the Sputnik in 1957 by the Soviet Union can be taken as an example. After World War II, individuals in the area of education, such as Admiral Hyman Rickover and Arthur Bestor, began to criticize John Dewey's idea of progressive education and the concept of integrating education with life. They supported the idea of returning back to basics. Their debates on American education gained emphasis with the orbiting of the Sputnik by the Soviet Union in 1957. This event led the United States to a curricular reform. In 1958, the National Defense Education Act was passed in the Federal Congress. As a consequence, textbooks with instructional materials including films, activities, and readings were changed. Science and mathematics programs emphasizing information, terms and applied aspects of content were replaced with programs in which students would learn the structures and procedures of science and mathematics as disciplines. Furthermore, the educational innovation of the Sputnik era emphasized academic excellence, and high academic standards especially in the area of science and mathematics. Within 12 years after these changes, the United States sent their astronauts to space and launched satellites. However, these initiatives had shortcomings as well. Because of a lack of teacher education, teachers faced difficulty with the content and the pedagogy of the system. In the area of mathematics, parents claimed that the content became too abstract and neglected important applications such as computational skills. Another failure of the reform of the Sputnik era was related to equity problems. The results of the innovations led to major scientific accomplishments only by a few elite in the area of science and mathematics whereas students' achievement scores were below the international standards.

A more recent example of a call for change in science education, due to international policies, concerns meeting the demands of major international coalitions and bodies. The curricular reforms during the recent years in countries that belong, or are currently candidates, to the European Union are subject to educational criteria established through the treaties. The Maastricht Treaty in 1992 formally enabled the European Union (EU) to intervene in some aspects of policy-making in the fields of education, youth, and culture. Of particular importance are the Treaty's references to the necessity of "developing the European dimension in the education" (Article 126) and of "bringing the common cultural heritage to the fore" (Article 128) in the EU policy (Dunkerley et al. 2002, p. 118). The creation of a coherent, compatible and attractive European higher education area in accordance with the Bologna declaration of 1999 is the main structural means of meeting these challenges and increasingly has involved the European Community in recent years. At its meeting in Lisbon in March 2000, the European Council agreed on a strategic target "to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion" (EC 2004, p. 5) for 2010. These programs also will contribute to achieving the Lisbon objective, namely that of making Europe the most competitive knowledge-based economy by 2010.

The shift due to labor needs at the time of the Soviet revolution, the US response to Sputnik, and the emerging curricular changes established by the Bologna agreement all are examples of how large-scale curricular changes can be set in place. In each case differing views of the relative worth of the suggested knowledge was at stake. A recent review identified the need to recognize powerful knowledge, while remaining skeptical of the knowledge of the powerful. Young

(2008) called for (a) a reassessment of the sociology of curriculum and (b) an acknowledgement that the some knowledge is unlikely to be learned through everyday contexts. A major contribution of the conceptual change paradigm was to recognize the importance of knowledge for the learning process. As we move forward with research in science education, we need not only to examine the ways that what gets taken for knowledge is interactionally accomplished, but also to step back and assess the extent to which learning provides students with knowledge relevant to their everyday experiences in the world they enter.

Conclusion

In this chapter we argue that the conceptual change paradigm has moved the field of science education forward in many productive ways. The focus on knowledge and learning, students' initial knowledge state, and the ways that people reason their way to new ideas constituted a significant set of directions that freed research on science learning from the yoke of behaviorism. As we enter a new era in science education research, we can identify the ways that a conceptual change view is limited and needs to be fully reevaluated. In this chapter, we maintain, along with the conceptual change paradigm, a focus on knowledge and learning, but reconsider how to think about how each needs to be re-specified given our current understandings of epistemology and cultural theory. Our central argument is that conceptualizing the epistemic agent as a relevant social group resituates learning, and thus opens up a range of research directions. New ways of understanding language, social practice, and identity shift the field away from (merely) considering students' conceptions and how putative knowledge states change over time and with experience. Rather, emerging studies, some presented in this book, redirect the focus of learning to engagement with social practices—and the associated discourse, identity, and knowledge required to be a member of a group. Choices about whose social practices and knowledge count raise continued questions about how decisions are made about curricula, thereby transcending the question of psychological versus sociological approaches to science teaching and learning. The complexity and interconnectedness of the world in some ways makes questions about knowledge legitimation more urgent and important, particularly given the pressures to conform to standardized, hegemonic views of science and knowledge.

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Chapter 4

Been There, Done That, or Have We?

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Writing an unbiased commentary on something that one endorses upfront is never straightforward: What else can be said if there is more than polite affirmation on the substantive points raised in this chapter by Kelly and Sezen? Will there be catalysts for extended and dialogic conversations rather than uttering a resounding but monotonous "Yes!" every time I turn the pages? Although the two authors might not be too disturbed by these potential threats to objectivity, they certainly make my task here difficult because they have sketched a succinct albeit powerful and wide-ranging agenda of what counts as quality in science education for young people over the next 2 or 3 decades. Even if a fraction of our policymakers heeded the authors' suggestions, there is little doubt that youth would have a better chance to be educated in that proper sense of knowing what and how to act in a fragile world facing impending environmental catastrophes. Yet if I maintained this congratulatory position, my role would be akin to a cheerleader who would be "pumping the crowd" regardless of how well the team actually played, a professional stance I find unsatisfactory. After some thought, I have decided to adopt instead the trickster or jester as my authorial persona. Throughout human history and cultures, these entertainers were loved (depending on who was asked) for their impudence and wit; but more crucially they were sanctioned, even rewarded, to speak truth to power (Janik 1998). Privileged to declare the nakedness of kings, jesters have assumed chameleon-like roles that are part clown, sage, folk-hero, political commentator, and social activist, which perhaps is obligatory now that critique has to be laminated with praise. Let me attempt this rhetorical juggling—a universal process-skill of my persona—along two fronts: I suggest that what Kelly and Sezen propose is consequential only because of the general state of obduracy in our field that has defied change and unfamiliar ways of viewing/doing research. It does seem that Kuhnian normal science reigns and manifests itself in the form of conceptual change research, which was the primary impetus for organizing the

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Springer forum in the first instance. Secondly, even if all these visions for science education in a post-conceptual change world were implemented, which I honestly doubt they would, a direct consequence of the previous point, the devil is always in the details. Effective and large-scale change processes in schools will continue to elude us despite our best intentions.

Been There

In a nutshell, Kelly and Sezen articulate a social form of epistemology—an important and necessary message for all educators not just in science—that is part of a more protracted development that has been described in the education literature writ large. We have heard about the verbal duels between those who describe human learning by an acquisition metaphor versus those who felt that participation in salient communities provided more holistic and reasonable arguments (e.g., Barab and Plucker 2002). It is unnecessary to revisit these age-old debates as both metaphors are valid despite one being the more fashionable currently in academia. As well, the linguistic turn that Kelly and Sezen mention has matured tremendously as a worldview within the humanities and social sciences for well over 100 years. Lest I am misunderstood, I do not oppose viewing cognition, identity, and literacy in science learning as diffusing from the singular to the plural, from accounts relying solely on computer-like brains humming in isolation towards encompassing knowing as agents-in-settings (e.g., other humans and cultural-historical artifacts consistent with activity theory). Rather, I claim that it was only a matter of time before science educators played "catch-up" with the rest of the social sciences notwithstanding rare visionaries from earlier periods. The message Kelly and Sezen present—about teaching and learning science as an indissoluble social practice—is neither radical nor surprising. What is truly astonishing is that we as a discipline in the second millennium still need to be persuaded about its value for science education.

The smoking gun in this state of affairs has been the reluctance by science educators, at least some gatekeepers and prime movers in our community, towards accepting out-of-field theories and methods. Defining legitimacy only within narrow margins, scholars have been content to refine what they have been so well apprenticed to do, thereby never having to question familiar paradigms. Thus, things have been slow to change within science education research despite the proliferation of publication outlets that exist today. For example, I still struggle with publishing in the top science education journals as a newly-minted science educator who enjoys transcending academic disciplines just as I agonize when reviewing manuscripts with less conventional approaches—how do I balance the good faith of the editor who has entrusted me with a paper and my own desire to push the envelop of possibilities and educate wider audiences? I marvel that learning science in informal settings began to achieve an identity only about a decade ago (Dierking et al. 2003) whereas a little later urban science educators started using those labels more frequently (Tobin 2009). Then, less than 3 years ago, the journal *Cultural Studies of Science Education* was formed as an avenue for those whose interests crossed the traditional boundaries of science education research. Whereas numerous other examples can be provided, suffice to say that for those who were sidelined or forced to conform so as to avoid censure and occupational disasters (see Roth and Tobin 2002), being finally able to write about science education practices in informal settings, urban education, and cultural studies and so forth was a godsend that was far too late in arrival. An old-timer in the field was surely accurate when he claimed that

> school science is arguably one of the last surviving authoritarian socio-intellectual systems in Europe (Ravetz 2002) with a teaching style which is over reliant on information transmission (Lyons 2006) and, until recently, curricula whose primary social function was that of training and selecting a future generation of scientific research workers. Presenting, as it does, a body of unequivocal and unquestioned knowledge with little opportunity to explore discursively the nature of what is offered, its relevance or applications, such a cultural practice does not naturally fit with the normative practices and goals of young people. (Osborne 2007, p. 107)

Coming back to Kelly and Sezen, they report to be merely providing "topics and questions to consider for paradigms in science learning." I do not dispute this but complain that if science educators had publicly recognized or acknowledged how scientists actually performed science or how kids learned content in complex ways in/out of school, if our discipline had been more welcoming of out-of-field developments and opportunities for cross-fertilization of theory, if scientism and the conceptual change paradigms had loosened their hegemony earlier, this chapter about the importance of social cognition in science would not have been needed, or at least its appearance would not have been so delayed until now.

Done That

The track record of curricular and pedagogical intervention work is not a happy one, even in science education. On the one hand, a promising innovation can eventually be shown to be inadequate from studies concerning its efficacy under ideal test conditions. On the other hand, effectiveness studies, that is, projects that endeavor to increase the scale of proven interventions (e.g., inquiry, scientific argumentation) will likely encounter numerous impediments in the real world of the classroom so much so that "variability in implementation can be seen as *the* major challenge for efforts to change instructional practice systematically in American schools" (Supovitz and Weinbaum 2008, p. 6). What this all means is that the kinds of new programs that Kelly and Sezen are advocating will, in all probability, suffer the same dismal fate of major curricular reforms in the past. And assuming that most of the major structural barriers, such as buy-in among stakeholders and resource provisioning—the things that I like to call the *big stuff*—can be overcome, there remain intractable problems associated with the teaching event itself. The latter are the classroom interactions writ large that over time can defy and scuttle the most robust, intricately conceptualized, and theoretically sound plans by any curriculum designer or teacher (Lefstein 2008). Preferring to call it the *small stuff*, these basic molecules of social life in schools are by no means trivial for they are cumulative in nature and have been shown to exhibit deadly effects on learning in diverse subjects, including science and mathematics.

In the celebrated cases of mathematics reform implementation in California, we were introduced to committed and knowledgeable teachers who, during the course of their everyday instruction, subverted to a large extent the original aims of the new curriculum (e.g., Ball 1990). What was interesting was that these teachers believed that they were modeling the reforms in their classrooms when in fact their teaching interactions had evacuated the meaningful learning of concepts underlying those very innovations. Similar conundrums revolving around people, policy, and place during curriculum implementation have been reported in elementary science (e.g., Lee in press) though such frustrations are indubitably pervasive across all levels. A reflexive application of activity theory here would shed light on the degree of coordination work that communities have to accomplish or the contradictions that have to be overcome to accept new innovations such as Kelly and Sezen's social epistemology frameworks. Therefore, the implications are clear: What Kelly and Sezen propose are only baby steps on the road ahead. Much remains to be done in terms of mounting a practical curriculum with all its attendant issues of legitimacy and worth, which the authors have amply recognized as difficult and having a thoroughly politicized nature. What we know is that the mechanics of implementation in schools resist simple prescriptions and will continue to confound the routine production of teacher-proof curricula. Until we adequately come to grips with how science teachers and learners are jointly engaged in making sense for each other in contingent ways on a daily basis, we are living in a fool's paradise. This is fine for jesters, but not when the stakes are impossibly high for young people today.

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Chapter 5

History, Culture, Emergence Informing Learning Designs

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New understandings about learning are reconceptualizing our definition of what it means to know. It is also increasing our questions about how knowledge materializes. What becomes eminently clear is that knowing and learning is a complex process. Kelly and Sezen refer to this complexity as they discuss the shift from an individual to a social view of learning. Their chapter *Activity, Discourse, Meaning* reflects upon the shift in science education to articulate potential new research directions for the field. The chapter describes that these prospective directions arise from the movement away from behaviorist models and toward constructivist ones. These research trajectories are not only an outgrowth of this shift, but also a reflection of the limitations of conceptual change theory. Rather than offer a comprehensive research direction for science education, Kelly and Sezen highlight three particular themes. These include examining knowing as developing within a contextualized set of practices that include thinking, acting, or speaking, attending to the social and personal construction of learners' identities and finally, questioning whose and what knowledge is true, correct, and privileged.

This response to Kelly and Sezen's analysis of the changing landscape of science education and what it means for potential research directions has a particular intention. The aim in this response is to offer a reflection of how the field of cultural sociology is assisting in uncovering this complex process. Further, its purpose is to extend the conversation in the areas projected by these authors. Like Kelly and Sezen, I do not attempt to provide a comprehensive survey of the field. Rather, I offer an extension of *Activity, Discourse, Meaning* by focusing here on their main three points: contextual learning, social and personal identity, and legitimating knowledge as a means of continuing the conversation of the shifting inspection of conceptual change. More specifically, I examine Kelly and Sezen's three points by bringing a cultural sociology theory to the forefront of these discussions to suggest the implication for the design of learning environments.

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Learning as Contextual

Over the past century, researchers have shifted their understanding of how students generate and change their conceptual understandings. No longer do researchers adhere to the philosophy that learning is an exact science where the instructor can stimulate and elicit anticipated responses from the individual. Additionally, research has extended beyond the expectation that an individual's cognitive conception is the single element affected by the learning process. Transcending these individualistic constructs, research has come to illustrate that the process of learning is an intricate dance between "behavior" (actions in the world) and cognition (learning inside the head). Behavior here is reconceptualized as developing ways of being through social and cultural practice (Vygotsky 1978). The interconnectedness of being in the world and in the head is currently understood more deeply as having historical as well as social and cultural roots. From this viewpoint, neither the individual nor the mind is the sole "organism" in the learning process that adapts, alters, and changes over time. "Knowing" is a dialectical bond that shapes and is shaped by structures of activity with and through our being in the social world. This shift from an individualistic to a collective view of learning brings to question how conceptual change relates to social learning.

Kelly and Sezen address the shift to a social view when they note the limitations of conceptual change. Specifically, they assert that conceptual change lacked attention to the process of knowledge construction. Instead, conceptual change research looked at the initial state of knowledge and this initial state was "measured" by students' language or description of concepts. This is problematic for two reasons. First, one's language cannot fully demonstrate individual "knowing" because it is built through personal experience. In their social contexts individuals develop social practices reflected in talking, communicating, acting, and sense making. These ways of knowing and being in turn influence the ways that learners not only describe what they know, but also how they enact their knowledge. Thus, to fully understand what a learner describes, he or she must also be observed in praxis (Roth et al. 2002). In either descriptions or enactments, the instructor potentially (and often times) views the learner's language and actions from a dominant perspective. Since we are products of our own social and cultural ways of coming to know and the descriptions are relative to our experiences, the validity of this interpretation comes into question. Thus it is possible that the instructor may hear the learner's description through his or her own lens of what is deemed "correct." In this light, the instructor may misinterpret the learner's meaning. What has become evident is that ways of knowing are varied across cultures and thus the learner's discussion or engagement in understanding concepts is often personally discordant with the teacher's culture and therefore misconstrued by the teacher. More frequently, we observe that social and cultural contexts are inextricably connected to the interpretation of and enactment in learning practices. For this reason, viewing conceptual change through language and descriptions alone neglects to take into account—and often misinterprets—the possible contextual understandings and methods of engagement.

This is further evidenced in questions raised by Kelly and Sezen related to another limitation of conceptual change. The authors state that, “students’ initial knowledge was labeled as misconceptions, rather than plausibly useful concepts that could potentially assist them to develop more robust, generalized concepts.” The learner’s existing knowledge cannot only be realized as an initial state of conception or misconception. Rather, it must be understood as contextual and through a social and cultural lens. Researchers have brought to light the importance of “initial knowledge” not only to assess previous and but also cultural knowledge. The combination of these aspects of student’s current knowledge is referred to in the learning sciences field as “learner-centered” environments. Learner-centered environments place the learner in the center of designing learning experiences by focusing on learner’s skills, practices, and beliefs that he or she brings to the classroom (Bransford et al. 2000). This initial knowledge is not considered a misconception, but rather knowledge with sociocultural connections. Gaining insight into and knowledge of a learner’s starting point, the teacher can build upon the learner’s initial knowledge. It is well established that all knowledge is built from existing pieces that are combined and recombined in new relational experiences. Thus, it is essential to assess these existing pieces as historically, culturally, and socially constructed knowledge. Both the concepts and the forms by which these concepts come to be constructed are part of what the learner knows and is an inherent part of how one comes to interpret and build new knowledge.

With attention to initial knowledge from a social and cultural view, we can more effectively design learning experiences that allow students to meaningfully construct knowledge. Creating learning experiences that resonate with the learners themselves offer unique opportunities. Through engaging them in their own ways of learning and from their historical, social, and cultural worlds, we can help students develop tools to identify when their concepts work and do not work. It is then that learners become agents of learning in their own right. Additionally, by creating ways for students to see where their concepts work and do not work, they can come to see the potentials and limitations of these concepts. Rather than assuming a restructuring of a conceptual map in the brain alone, it is through the social experience with and through others that brings about conceptual change. Without uncovering and examining student’s initial knowledge as contextualized, instructors are less likely to successfully bring learners to build upon or change their existing beliefs about what they know.

Social and Personal Identities

Rethinking conceptual change as connected to social experience has implications for and attachments to personal and social identities. Kelly and Sezen assert that identity research in science education has focused on, among other things, ethnic membership, gender, and social status. Specifically, the authors discuss the correlation between ethnicity and discursive practices for learning science, gender influences and the resistance of activity as well as identification with scientific roles, and status and seeing one's self as part of a science community. These themes not only arise out of social interactions, but also from the histories that emerge from our local contexts. To be sure, research related to historical influences on our social and cultural practices suggests an inextricable connection to our identities. The relationship between history and identity brings to light the possibilities for authentic participation and enhancement of progress toward group membership. This research suggests that there is a critical element of history in not only shaping one's identity but in shaping practices as learners move from one context of participation to another.

It can be alleged that consciously, but most often unconsciously, we are our histories. History shapes and is shaped by structures, representations, and rituals (Tobin 2006). This is not to assert that our histories determine our trajectories. Rather, it is to suggest that our histories relate to how we develop our ways of being and acting in the world. In our own homes and societies, we develop identities that form our perspectives, our socialization with others and our participation in the world. Our histories that shape us, however, are not static. Alternatively they are a continuous flux of social practices, to which each new generation contributes, while inevitably transforming our identities and our world (Vianna and Stetsenko 2006). Our histories are an evolution within our own ethnic groups, and as we interact across groups our identities change as well. Researchers have considered this a kind of border crossing. Studies illustrate that as students move across boundaries (streets, homes, school, etc.), they do not distinctively leave social and cultural configurations and ways of seeing themselves behind. Instead, learners' actions and expectations as well as their ways of viewing the world continue to permeate the boundaries of new experiences. At the same time, the intersecting practices in these new experiences reciprocally affect existing worldviews and in turn reshape aspects of identity. In this sense, the boundaries between the streets and learning contexts are porous. Moreover, the students' organizing social and cultural patterns in the world are carried into their learning environments as well as shaping them and being shaped by them. With each new experience, the identities of learners are enacted, constructed, and reformulated as they cross boundaries of experience. Our constructions of reality, our conceptual understandings, become shaped by our experiences and the personal lens we develop comes through our historical experiences, historical experiences that we carry with us across borders.

What becomes apparent is the dialectical relationship between personal identity and social context. That is, the experiential worlds belong to individuals, but, in the course of social interaction, these individual worlds become adapted to one another. No individual development or experience comes without his/her historical and present experience in the socially and culturally constructed world. As Roth et al. (2008) note:

> There is a mutually constitutive relation linking individual and collective—being always is being singular plural (e.g., Nancy 2000). For each individual, all other individuals constitute a (cultural) context, so that the individual can be rightfully thought only in and through its relation to all the others. Nothing that can be observed involving human beings and no observation made can be reduced to the individual; anything that articulates sense *inherently* and *always* is shared, intersubjective, and hence cultural. (pp. 253–254)

Whereas it might be the case that individuals undergo an internalization process as Kelly and Sezen suggest, this internalization is never truly individual. Specifically, learning is never realized, interpreted, or conceptualized without the social process. "We cannot look at our experiential worlds from the outside. We construct them from the inside and have usually lived a good many years in them before we begin to wonder where they came from and what they 'really' are" (von Glasersfeld 1993, p. 29). These personal identity constructions that are seen from the "inside" are created through "dialectical reorganization and textual translations" of past and present events. There is an element of personal and social history that simultaneously shapes these aspects of identity. Starting from our histories, our socially constructed selves continue to emerge throughout our ongoing social experiences. We are becoming hybrids of our experience; a conglomeration of past, present, and future represent our identities.

Within this view, research has given us insights into how identities play into the nature of emergent learning designs. When our histories accompany our entry into the classroom, they potentially conflict or cohere with teachers' historical identities. Kelly and Sezen discuss identity as an "achievement of a person's activity that is constrained or supported by situational constraints in the field of participation." These supports or constraints can take on different forms. In situations where the identities are from markedly different worlds, constraints for our learners' agency and participation are likely. That is the structures of participation often inhibit learners from drawing upon or enacting their cultural knowledge. In this case, learning designs remain inflexible and disconnected for our learners' worlds. Supports, however, can occur under different circumstances. For one, when cultural histories are similar, there are little changes in identities and little social distance between the learners and the instructor. Thus, supports for participation and enacting one's identity often appear seamless, leaving minimal chances for identities and learning structures to undergo any change. On the other hand, when social distances are more significant, the difference between the learner and the instructor becomes salient. Awareness of social distance and personal identity can materialize and simultaneously incite developments in identity. This second possibility can be advantageous for learners and for learning designs. As I have seen in my own research and experience, when the designer of the learning environment comes to see the learners' identity and becomes aware of their own, the contradictions become forms of insight into learners' social and cultural practices. The different histories and identities offered opportunities for shifting structures of learning designs that more adequately engaged the learners.

No matter the amount of social distance, learners' and instructor's cultural worlds are often inharmonious. The levels of dissonance will vary in different learning environments. Regardless, the intersection of dissonant worlds provides extraordinary opportunities for organically emergent learning designs. On the one hand, if the instructor holds on to his or her expectation and rigidly imposed design, learners remain distant from their own learning. Lave (1997) states that "the more the teacher, the curriculum, the texts, and the lessons 'own' the problems or decompose steps so as to push learners away from owning problems, the harder it may be for them [students] to develop the practice" (p. 33). In contrast, points of contradiction can give rise to new methods of engagement. Awareness of and attention to histories, and collectively shaped identities of all participants is important in creating continuously meaningful learning experiences. This implies that to support conceptual change structures of learning must be malleable and emerge with the unfolding understandings of cultural and social practices. In such designs learners can appropriate their historical identities and the practices that accompany them. With this flexibility comes an openness to realize that historical and social knowledge must be valued and validated.

Learning Whose Knowledge?

Currently, science education has an end goal of ensuring students learn particular facts and theories of scientific disciplines. This presupposes the existence of a correct and rationalized truth or body of knowledge. This body of knowledge becomes valued over other types of knowledge. A social view of learning is in stark contrast to this model. Socially constructed knowledge is viewed as being developed with others and through various perspectives. Further, social learning values multiple knowledge sets. Researchers see a pluralistic understanding in and across the world as more fruitful. In an interview, Appiah (2006) describes the necessity of accepting pluralism in the world in order for a more cohesive democratic existence. He says, "Cosmopolitans think that there are many values worth living by and that you cannot live by all of them. So we hope and expect that different people and different societies will embody different values, yet live in harmony" (p. 6). An aspect of this new cosmopolitanism relates to knowledge in that it asserts that our knowledge is imperfect, provisional, subject to revision in the face of new evidence. In scientific communities, knowledge is constantly undergoing changes as multiple perspectives intersect, frame questions, and formulate meanings.

As different perspectives emerge, the questions of whose knowledge and under what circumstances become increasingly important. To be sure, Kelly and Sezen provide examples of how social and institutional power structures have influenced a dominant knowledge base and in addition, particular curricular choices. Further, they point to the more recent phenomenon of activists, citizens, and environmentalists as voices in the dialogue that now challenge the definition of legitimate scientific knowledge. The questioning of dominant knowledge results in these authors promoting "not only to examine the ways that what gets taken for knowledge is interactionally accomplished, but also to step back and assess the extent to which learning provides students with knowledge relevant to their everyday experiences in the world they enter." This promotion of connecting learning to relevant experiences deserves discussion as we consider the important question of "whose knowledge?" Tapping local knowledge is important not only for making curricular decisions, but also for the organization and reorganization of designed learning environments.

Various studies focus on tapping local knowledge to ensure effective and authentic participation. The following examples give rise to the ways in which structures of participation change as they connect less with a set of concepts and truths and more closely to a community connection that reflects a resonance with social and cultural practices. One example of the research in this area is from Roth and Lee (2004). These authors argue that science literacy has focused on a set of facts and theories that more often than not lack a relationship to the learner's community. These authors demonstrate their proposal that scientific literacy is not a set of disconnected facts by illustrating how becoming "scientific" is in fact a social practice. The authors demonstrate how social practice cannot be focused on teaching the individual as separate from context because the individual is inherently connected to one's community. The implication is that science can be accessible to all when it is considered as a set of resources that can be drawn upon in everyday practice from these community connections. Validating local knowledge and its association within one's community gives learners an entry point as well as a connection between home and science. Bringing in these different perspectives of knowledge interpretation may very well give rise to a fluctuating "what" and "how" in designing learning experiences and asserting a particular knowledge set. Rather than an outside entity determining what students learn, learning designers need to connect to what people need in their communities as well as when they need it.

Tan and Barton (2008) similarly scrutinize the efforts of the current "*Science for All*" initiative. In asserting that science for all be reconceptualized, these authors investigate not only at whose knowledge, but knowledge for what purpose. They argue that science for all needs to transcend the construct that science education ensures a solid national economy. With this current emphasis on skills, theories, and the economy, learning experiences remain distanced from social and cultural participation in every day life. To bring this issue to light, Tan and Barton study the individual identities of different female students to try to gain insight into how they connect to learning science. Their findings suggest that an alternative look at the personal participation practices in the community requires attending to what knowledge sets are important to or embedded in the situated and local lives of the community. Tan and Barton reinforce that the practices of students need to be connected to local participation and involvement of the family, community or science. This resonates with other research that calls for allowing students to bring in their lives and experiences to learning environments so that they can build, question truths, and incite dialogue. Students can see the "viability and comparability of alternative explanations (including Western science) testing ideas of criteria of 'being' and bringing into the open underlying assumptions about the nature of evidence" (Malcolm 2003, p. 36). In reconceptualizing learning environments as accessing and enacting community-constructed knowledge, a powerful notion of the "relationship between science, location, knowledge production and learning" (Tan and Barton 2008, p. 69) becomes recognized.

One interpretation of these studies suggests several foundational design principles. These include: a constant uncovering of community connections and needs, a formatively assessed set of experiences that make such connections, and a continued iteration of the learning goals, structures and methods of engagement. When instructors engage learners in knowledge that is not resonant with that of the local community, they run the risk of sending a message that threatens the long and rich histories of knowing. What is brought to mind in relation to accepting community knowledge is the need for altering power structures. Instead of external impositions of particular facts and theories, learning designs work toward realizing the power of local knowledge. As local forms of knowledge are supported they will intersect with dominant views to formulate new practices. Overlapping cultural forms (science communities, researchers, learners and instructors), the learning structure adapts by "enabling new forms of societal activity that is collectively generated" (Roth and Lee 2004, p. 286). This becomes increasingly visible in the technological communities that afford social and collaborative knowledge constructions.

In our learning designs, we can emulate this type of knowledge construction by pointing out to our learners that knowledge is tentative and situational. We can support the contribution of conceptual change as a learning process, while also emphasizing knowledge as a process. That is, teaching knowledge tentativeness as well as bringing to light how and why facts change over time. In doing this, we also foster fluid, flexible, and emergent learning experiences rather than rigid approaches to learning. The fluidity materializes as we shift our concentration away from teaching known knowledge and toward valuing local knowledge bases and skills that contribute to constructing a scientific knowledge community. Emergent modes of participation become visible with openness to seeing knowledge as a social and cultural process connected to our communities rather than a set of disconnected and foreign facts. This requires an acceptance of learning with and from others. It requires an awareness and assessment of our own realities and constructions. The realization of other's knowledge and validity, consideration, and acceptance of that knowledge implies the need to move toward a social view of learning and away from a particular conception of truth. When we are able to see our knowledge and ourselves as other, then we can begin to find contradictions in our learning designs and bring to question what we teach, why, and for whom. As we emphasize learning as a social process and the viability of knowledge in the moment, we can be in the constant practice of reinventing and affording the emergence of learning environments and then perhaps, science for all.

Closing Remarks

Kelly and Sezen argue that the shifts in conceptual change perspectives bring us new and positive directions in science education. In this response, my aim was to extend some of the themes that Kelly and Sezen raise and suggest how these ideas come together to inform considerations for designing learning environments. Within this conversation was a surreptitious support for rethinking conceptual change. Reorganized, conceptual change places attention on contextual knowledge as connected to initial learning, historical influences that shape and reshape identity, and the importance of local and community knowledge. In viewing science learning as a set of complex processes, we more closely examine the interrelationship between individuals and their social contexts. Learning from an altered conceptual change framework becomes an intersection of individual and collective practices that involve multiple structures, including the intersecting cultures of our teaching, learning, and scientific communities. As we realize that multiple structures overlap and give rise to the complexity of our participation, we see the importance of bringing multiple ways of knowing to the process of learning. The ways of coming together to know are invariably connected to the historical, cultural, and social knowledge that we embody.

This change asserts particular considerations for learning designs. For example, learning designs consider learners' contexts. In our designs, we must realize that contexts situate and cultivate ways of knowing and interpreting as well as developing purpose for learning science. In addition, our histories shape our unfolding identities. These identities are inherently collective and develop in practice. To foster new possibilities of engagement, our designs need to find ways to raise awareness of our own, as well as our learners' histories. Finally, our designs need to privilege local and community knowledge. This validates local knowledge and community needs and affords an expanded array of purposes for learning science. The possibility assumes collective ways of knowing as well as appreciation and acceptance for different ways of seeing the world. Like any discipline, how we define conceptual change and what this means for our design of learning environments will continue to evolve. The definition and what it means for learning science will emerge and grow based upon our own social and personal experiences, through our own identity development, and through our own emerging ideas as our "knowledges" intersect through conversation and practice with others.

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Chapter 6

Standing on the Shoulders of Giants A Balancing Act of Dialectically Theorizing Conceptual Understanding on the Grounds of Vygotsky's Project

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Defining knowledge and theorizing concepts is a difficult task if only because the target notions/phenomena are centrally (albeit often tacitly) implicated, right from the start and throughout the whole process, in the very ways and procedures employed in this endeavor. How can one define the ways through which we know the world, including concepts, conceptual understanding and thinking, while these very concepts and methods of knowing need to be applied to the task at hand? There seems to be an inherent complexity involved in resolving epistemological issues that are akin to what is infamously known as an attempt to pull oneself by one's own hair. This complexity, though rather obvious, is paradoxically not often reflected upon by researchers involved with epistemological issues—judging by the largely overlooked situation when the stated epistemic conceptualizations are often at odds with the methods employed to arrive at them. For example, claims about collective and distributed nature of knowing and concept development as never belonging to the individual realm seem to contradict methodology behind these claims employed by individual researchers that often represents a single-handedly construed process of solitary analysis apparently disconnected from collaborative pursuits. It would appear that researchers, who state the radical position on mind as being distributed and not attributable to anything at the individual level, have to struggle to reconcile their position with their own claims to individual authorship and authenticity of theoretical arguments, concepts, and views.

In view of these complexities inherent in the paradox of knowing about knowing, the twofold goal of this paper is (a) to draw attention to the need of a critical self-reflection about reciprocal relations and important synergies between the methods applied and the conceptions developed within epistemic inquiries as a

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potential remedy against undesirable gaps between the two, and (b) to explore how some warrants to guard against incommensurability in accounting for these two aspects of epistemic inquiries can be developed. To highlight the potential value of such self-reflection and suggest some warrants of this nature, I discuss epistemic methods and concepts of knowing and conceptual understanding as these can be developed on the foundation of Vygotsky's project with its grounding in the mutually complementary dialectical method of inquiry and the worldview-level dialectical outlook on reality, both predicated on the idea about infinite movement and interpenetration of any and all aspects of reality including activities of knowing and theorizing. Although it is likely not possible to completely avoid circular effects in the process of knowing about knowing—in that the applied method has to depend on some ad hoc (intuitive) understandings of phenomena before theorizing them (as well as vice versa), this critical reflective focusing on commensurability between methods and products of epistemic inquiry can serve as a step in the direction of advancing our understanding of epistemic issues.

The Dialectical Method and Outlook on Reality

For a number of historical and ideological-political reasons, Vygotsky's project (developed in the 1920s through 1930s, in the aftermath of the Russian revolution, by Lev S. Vygotsky in collaboration with A. N. Leontiev and A. R. Luria) represented the first attempt in psychology and education to apply the principles of Marxist dialectics in developing theory of human development and learning. Existing discussions in the English-language literature of how this task has been accomplished by Vygotskian scholars of this first generation are typically limited to the notion of unit of analysis and its implications (on this point, see also the epilogue). However, the unit of analysis is just a tip of an iceberg of a much broader issue of what is a dialectical approach to analyzing human development.

Within Marxism, there has been a considerable debate as to what kind of an approach the dialectical method represents and whether the term dialectics refers to the core outlook on reality and its phenomena and processes or, alternatively, only to the analytical method itself. The answer is not straightforward because Marx's own works did not explicitly address these meta-level issues and Vygotsky's scholars too did not specify them in any great detail. On my reading of Marx and the works carried out in Vygotsky's project, there is a remarkable commensurability between their broad outlook on reality and their method of analysis, with the two representing complementary and interconnected moments within the overall flow of research activities and inquiries. In particular, both Marxist method and overall worldview, also employed in Vygotskian project, are characterized by an emphasis on and attention to the constant movement and dynamism, change and transition, fluidity and historicity, and totality and interdependence, that is, on a continuous and unitary process that never ends and that, therefore, cannot be mechanically broken into distinct independent stages and self-sufficient, fixed components.

This overall characteristic, at the same time, is what makes describing dialectics, including Marx's method and broad vision, difficult and even self-contradictory—because no description, given its reliance on relatively static and reifying linguistic forms, can capture and ultimately do justice to the fluid, moving, and ever changing matters that one purports to describe.

With this idea of fallibility of any description in mind, it is nonetheless reasonable to discern the following premises and sequential steps in the dialectical method. First and foremost, this method stands out among others in that it entails self-critically acknowledging its own limitations (in addition to acknowledging fallibility of its descriptions)—in that the researchers employing this method have to keep in mind that no investigation can ever be complete and there is always some next step in inquiry to be made and some novel way of thinking to be applied. Second, the dialectical method cannot be reduced to any ready-made formula, universally fixed once and for all, that can be applied uncritically to any given task. Instead, this method itself needs to be created each time anew, in view of specific circumstances, contexts, and goals of investigation.

However, this tenet does not imply that there is nothing in particular that marks the dialectics as a distinct and unique approach, making it into a relatively stable epistemic tool. As a first approximation (amenable to further elaboration), the dialectical method can be understood as a circular, recursive and self-critical procedure where (a) observations and analysis of particular phenomena—always entailing some preliminary (empirical) conceptualizations of these phenomena—are complemented and accompanied by (b) the efforts to discern their common origins and developmental transformations based in internal connections and inherent contradictions among these phenomena, which bi-directionally entails and leads to (c) theorizing these common origins and resulting features by means of concepts of higher (abstract) order that reflect the totality to which phenomena in a chosen area belong—which, in turn, bi-directionally entails and leads to (d) a novel understanding and concrete conceptualizations of particular phenomena within a given domain of investigation in the form of now more theoretically rich, yet concrete (not to be confused with simple empirical) concepts. From these latter conceptualizations, a new cycle begins where new abstract concepts of higher order capturing the totality of phenomena in a systemic way are developed, thus launching the next step in the ongoing (and, strictly speaking, never-ending) inquiry.

Importantly, whether research begins with observations and analysis (and, accordingly, with empirical concepts) and then proceeds to abstract concepts that capture some common underlying principles applicable to all phenomena in a given domain and the overarching realm encompassing all of these phenomena or, alternatively, whether inquiry starts with abstract concepts to then proceed to concrete ones, is itself not some fixed universal principle. Instead, the sequence depends on a given task at hand, the level of knowledge and conceptual sophistication in respective domain, and so on. More important, however, is that there can be no absolute starting point that is a priori designated for an investigation—because even seemingly most atheoretical observations are always theory-laden and depend on some prior presuppositions, just like any theoretical presupposition always depends on some empirical or experiential components. What matters most, in any case, is that because both the abstract and the concrete concepts de facto are closely tied together and presuppose each other, they necessarily need to be developed in a complementary, interdependent and co-evolving fashion—in a sense all at once, so that their mutual enrichment is achieved through the movement among concepts of varying degrees of generality (on the continuum from abstract to concrete concepts) and across complementary levels of analysis. It is indeed the dynamism and movement across and among concepts, levels of analysis and stages of inquiry—as singularly ascertaining and establishing their inherent interdependence –that, in my view, is crucial to the dialectical analysis and way of thinking.

In part, this description illustrates a non-traditional interpretation of abstract and concrete concepts, where the latter cannot be reduced to either something merely particular and singular or readily (i.e., experientially, sensually) apparent. Neither can abstract concepts be understood as something general, purportedly withdrawn from the realm of the particular (the real) and opposed to it. As Evald Ilyenkov (1982) put it,

> it is only when a thing has been revealed in its interconnections with all the others, just as individual things, facts, phenomena, if it has grasped the individual through its universal interconnections, then it has for the first time perceived it concretely, even if a notion of it was formed not through direct contemplation, touching or smelling but rather through speech from other individuals and is consequently devoid of immediately sensual features. (pp. 87–88)

However, another feature of concepts that in my view often goes unnoticed is that concrete and abstract concepts are complementary levels of penetrating into phenomena where the holistic quality of systemic interconnectedness is ascertained at two levels so that (a) the phenomena in a given field of inquiry are revealed as belonging together and forming some totality (a web) of interconnectedness that unites all of these phenomena while, at the same time, (b) each and every phenomenon is shown to stem from and continue to carry on (in a condensed, abbreviated, particular form) the totality of all interconnections characteristic of a given totality.

Marx was clearly aware of contingencies inherent in the dialectical method and the implication that concepts at different levels interpenetrate and presuppose each other—in contrast with an analysis conducted in static (pre-given, ready-made) categories and concepts at whatever level of generality or concreteness. On the one hand, he seemingly downplays (in *German Ideology* co-authored with Engels) the role of abstract concepts for the dialectical method, stating that

> [t]he premises from which we begin are not arbitrary ones, not dogmas, but real premises from which abstraction can only be made in the imagination. They are the real individuals, their activity and their material conditions of their life, both those which they find already existing and those produced by their own activity. These premises can thus be verified in a purely empirical way. (Marx and Engels 1846/1978, p. 149)

Yet on the other hand, Marx accorded primary significance to the internal relations and interpenetrations among concepts of varying order as presupposing and positing each other. For example, illustrating the interdependence between the more and less developed concrete (equaling the interdependence of abstract and concrete concepts), he wrote,

> the simple categories are the expressions of relations within which the less developed concrete may have already realized itself before having posited the more many-sided connection or relation which is mentally expressed in the more [developed] concrete category; while the more developed concrete preserves the same category as a subordinate relation. (Marx 1978a, pp. 238–239, insertion added)

In my interpretation then, it is in the movement from the concrete to the abstract and back, in a spiral way, that a unit of analysis in a given investigation can be established—always representing both a product and a presupposition of an inquiry rather than a pre-given initial abstraction (yet also serving as a launching pad for subsequent stages) that purportedly can be imposed on the material at hand. The unit of analysis, therefore, has to be elaborated as a confluence of both abstract and concrete concepts in which the motion of phenomena and processes in the given field of inquiry become represented and embodied. The discovery and establishment of a unit of analysis is thus associated with an important additional requirement that marks the dialectical method—that phenomena are analyzed in their development through time, by tracing their historical roots and conditions of origination, including their internal relations with other phenomena as these relations develop and are transformed in history.

Applying such a circular dialectical procedure precludes two common errors. First, it helps to avoid the error of applying concepts as preconceived, ready-made categories taken as extrinsic principles that are only mechanically matched with the purportedly independently existing facts (even of the best units of analysis such as commodity in Marxism and meaning in Vygotsky's theory) and, second, the error of starting from empirical observations and facts as if they were independent of a particular conceptual apparatus and context of inquiry (including, most critically, its goals) that, in fact, represent a condition sin qua non for turning these facts and phenomena into categories of thinking amenable to inquiry in the first place.

Importantly, the dialectical method analyzes the phenomena in their different forms, while tracking down their inner connections and in the process breaking them into manageable parts and abstracting their various properties. Hence the value of analytical scrutiny and of analysis into discrete though interconnected moments and facets of one composite reality. Analysis can momentarily examine various parts (or dimensions) of phenomena and the relations through which these parts come together to constitute the totality of phenomena under examination. As these parts get abstracted in the process of inquiry, focusing on them as representing instantiations of one underlying totality or process is paramount so as to avoid reifying these parts into static, a-historical forms and thus essentializing their characteristics.

Last but not least, the true hallmark and condition sin qua non for the dialectical method is the notion that *practice* serves as the ultimate ground for advancing and verifying theories as well as for providing warrants for knowledge claims. Unlike the skepticism of social constructionism and other postmodernist approaches that acknowledge no grounds for falsifying theories or adjudicating among various theoretical standpoints and claims, the Marxist method provides warrants for such adjudication. These warrants have to do not with applying some abstract, fixed principles that lie outside knowledge claims but instead, are derived by discerning the (often implicit but always ineluctably present) ideological and ethical underpinnings and potentialities of a given theory as a form of practice.

Moreover, because theory and practice are not posited as separate and only extrinsically related endeavors but are viewed as two facets of one and the same process of humans engaging with their world, including through research and inquiry, practical considerations and goals are seen as immanent to theoretical inquiry and as inevitably imbuing theories and concepts with ideology—ethics, values, commitments, and politics. In one of his most famous statements (11th thesis on Feuerbach), Marx claimed that "[t]he philosophers have only *interpreted* the world, in various ways; the point, however, is to *change* it" (Marx 1978b, p. 145). There have been many suggestions as to how to understand this claim, such as that changing the world is an important addition to understanding it or, alternatively, that changing the world substitutes for and makes the process of knowing and interpreting unnecessary. On my reading, however, the goals of interpreting and knowing the world are neither seen as endeavors that are merely complementary to transformational activities, nor as in need of being eliminated by the all-out importance of changing the world; instead, the process of knowing and interpreting the world is posited as contained and subsumed (or dialectically superseded, that is, represented in a subordinate role within a more developed process rather than eliminated in it) within the ultimately always practical process of changing the world. Therefore, this position does not eschew knowledge; instead, it radically re-conceptualizes knowledge—as representing a practically relevant, ideologically saturated, and politically concerned, that is, agentive endeavor that partakes in and directly contributes (even if unbeknownst to its creators) to changing, and thus creating, the world. The contrast with the postmodernist notion about theory being a commentary on or extension of its own history, existing exclusively within the realm of discourse and not stepping outside it into the larger world of political-practical strife and struggles, could not be starker.

To summarize, the dialectical method entails the following principles:

- No pre-given set of principles or concepts completely exhausts the goals of a dialectical inquiry; these principles and concepts need to be developed each time a-new for the given task at hand, rather than taken and uncritically accepted ready-made (though some guiding rules, always contingent on the context of inquiry, are not thereby excluded).
- Both the general and the particular instantiations of phenomena and processes (the whole and its parts)—as grasped through abstract and concrete concepts—need to be scrutinized in a dialectical inquiry, with neither type being sufficient in itself; instead, they represent complementary, coevolving, and mutually constituting levels of processes and concepts; that is, the concrete is only grasped through the systemic whole to which it belongs yet the whole can and

needs to be understood through the analysis into developments and mutual (primarily antagonistic) relations among its parts as these relations are formed and transformed through time.

- It is through conducting inquiry that moves among and across levels of analysis and between abstract and concrete concepts that the dialectical analysis proceeds—with no element serving as an absolute zero starting point, nor representing a finalized endpoint of investigation; there is always some work behind any seemingly initial stage of investigation and always some new step to be made after analysis is completed so that its results and products are critically examined and further elaborated.
- Phenomena are analyzed in their development through time, by tracing their historical roots and conditions of origination, including their contradictory relations with other phenomena as these relations develop and are transformed in history.
- Practice—and therefore ideology and politics—is the ultimate grounding and the core linchpin for theories, providing warrants for knowledge claims and standpoints, with knowledge itself (including concepts and theories) representing ineluctably practical-political endeavor—stemming from practical tasks, embodying them through own conceptual and symbolic devices, and serving always ultimately practical-political goals.
- All the layers and dimensions in the cycle of praxis (practice-theory-practice), including conceptual knowledge and theorizing, dialectically interpenetrate so that each layer is present in all others and all others are present in each one—in a dialectical movement of mutual embedding (through the process of superseding and supplanting), interpenetration, and spiral expansion.

The Marxist outlook on reality is closely congruent with this methodology. Indeed, Marx devoted considerable time and effort to carefully examining both the empirically observable phenomena and to conceptualizing their relations as they evolve through time and come to form the basic realm of processes (i.e., the totality, the whole) underlying these phenomena. Based on achievements in a multitude of sciences, including in biology with its then newly developed Darwinian theory of evolution (which Marx valued very highly) that established ineluctable interconnections between seemingly disparate dimensions of nature (i.e., between contextual factors such as the geographical distribution of the species and internal factors such as the morphological structures of organisms) as well as in economy, politics, chemistry, geology, and astronomy, Marx continuously scrutinized the physical organization of individuals and their consequent relation to the rest of nature. At the same time, and taking ineluctable embedding of individuals in nature into account, Marx (together with Engels) came to formulating the core metaphysical premise about reality being a unitary—total—process that is constantly in motion (flux) and development. This basic dialectical premise (formulated in its incipient form already in Greek philosophy, which Marx studied in depth at the start of his career) replaced commonsense notion of things with notions of process, relations, and interconnections. According to this broad premise, all and any incarnations (or, more precisely, moments or dimensions) of reality are neither completely fixed and static nor exist in isolation, as self-sufficient entities, independently from other moments and dimensions of the totality. Instead, existing in the form of one moving matter, nature undergoes continuous development and change, with continuous (i.e., entailing no ontological gaps) transformations, transitions and transmutations of its various moments and dimensions (or facets) into each other. As Engels (1960) put it, "Motion in the most general sense, conceived as the mode of existence, the inherent attribute of matter, comprehends all changes and processes occurring in the universe, from mere change of place right up to thinking" (p. 85).

Notwithstanding all the importance of establishing the grounding realm and the foundational process—the flux of matter in which all phenomena are mutually related—the dialectical method does not end with this step and instead includes, as a next step, a procedure of delineating some interrelated, yet distinct, moments that constitute the basic contradictions in the grounding processes in a chosen area. The moments that create major contradictions and tensions within the unfolding and ongoing process of underlying reality are understood to constitute distinct—though never separately and independently existing—units or phenomena in the world that stem from the foundational process (and never completely break away from it) and can be explored and studied in more detail for purposes of solving particular research questions. This means that such phenomena, though themselves fluid and never completely static, representing but instantiation of the totality of the underlying basic process (movement), can nonetheless represent relatively durable and stable units within certain periods of time and when viewed from a certain vantage point. Moreover, given that any and all phenomena stem from basic underlying processes of ceaseless flux of motion (the primary mode of existence of matter) and never completely break away from this flux, these phenomena exist as contradictions in a unity where they interpenetrate, define, and presuppose each other while *co*-evolving in the processes of development. The emphasis on transitions from one form or dimensions of the totality into another, in various combinations of inner connections, from one series of connections into different ones is one of the staples of the dialectical method. The phenomena are thereby understood as forms, modes of existence, which should not be considered distinct and separate from one another but intrinsically linked in a dialectical unity, that is, unity in difference.

The Centrality of Meta-level Assumptions

What these methodological principles of dialectics entail for studying conceptual development and understanding is that these processes, and all other epistemic issues, cannot be approached in abstraction from theorizing questions of a very basic sort—about the way humans are, that is, about the fundamental character of their life and their Being as a totality and a grounding realm of processes within which knowing and understanding can be theorized.

Many philosophers have been clear about the all-out importance of broad theoretical ideas for developing conceptualizations of particular phenomena. In Hegel's interpretation, for example, no phenomenon can be defined prior to situating it in a theoretical context. Without such situating, "[a] preliminary attempt to make matters plain would only be un-philosophical and consist of a tissue of hypotheses, assertions, and inferences, that is, of dogmatism without cogency, as against which there would be an equal right or counter-dogmatism" (Hegel 2008/1931, p. 13). Extending Hegel's argument one step further, it can be claimed that no conceptualization is actually ever made outside of a broad meta-theory; the latter is always lurking behind even seemingly utmost atheoretical approaches and straightforward (e.g., empirically based or experientially derived) concepts. The broad assumptions about how the world works and how people come to understand it are powerfully implicated in all research activities, penetrating and affecting all of their layers, operating beneath the surface of even simple definitions and procedural decisions, whether we admit it or not—acting like the oceanic deep undercurrents that invisibly but powerfully affect the whole mass of water including its utmost surface levels. Even decisions about whether to study conceptual understanding in a laboratory setting through an experimental procedure, or alternatively, to observe it in everyday classroom situations, are made (whether explicitly or implicitly) from within a set of meta-level ideas about how humans are and how their being and knowing are to be understood.

In this light, it is virtually impossible, even for researchers working with apparently concrete and down-to-earth specific questions about conceptual understanding and development, to avoid allegiance with one or the other among the big frameworks that offer answers to broad worldview level questions. Unless a whole set of answers to such questions about how humans are and how they come to know the world is re-invented in each particular investigation (a hardly viable task), researchers inevitably find themselves, often unwittingly, being affiliated with one of the existing broad worldviews.

In practice, not many researchers explicitly claim their allegiance to one or the other broad theory; however doing so, in my view, is neither a mindless desire for a collective identity, nor a politicized strategic decision to follow with the existing fashion. Rather, it is an expression of the actual need (albeit often intuitive and insufficiently reflected upon) for grounding on a solid foundation comprised of core assumptions about key matters of human life and existence. Not realizing and not reflection upon one's answers to the foundational questions about human being and knowing (and thus, upon one's allegiance to one or the other among the foundational frameworks), puts researchers at risk of being on a thin ice of theorizing at the peril of falling through the shaky layer of fractionated conceptualizations into the pitfalls of faulty and outdated broad premises without, sometimes, even noticing the fall and lacking the means to reflect of how to get out of it.

In this light, although it is often tempting to work with a variety, a mélange of theories rather than stick to one meta-theoretical tradition—an approach apparently appealing to many researchers today—this strategy can be efficient, in my view, only if a careful analysis at all layers within each of the theories one attempts to bring together in a pursuit of a composite framework, including the foundational worldview-level premises, is carried out and these premises are tested for compatibility and cohesiveness or re-worked (a much more difficult task) into a new cohesive worldview-level foundation. Most certainly, this does not mean accepting assumptions of a chosen framework uncritically and mechanically. Instead, one's own reflective re-working, elaboration and contribution to the established premises is always needed—but not at the exclusion of a self-reflective historical continuity. What this type of theorizing reminds of is the well-known Newton's metaphor of scientists "standing on the shoulders of giants" (with its emphasis on historical continuity and the process of new discoveries always representing an elaboration on previous ideas—something that indeed cannot and should not be avoided, in my view). Yet this metaphor and this tenet can only be accepted with a realization that literally standing on someone's shoulders (and thus, continuing one's predecessors' ideas) is a very difficult and demanding, indeed agentive, balancing act (one only needs to try to stand on someone's shoulders in the real world to find out how much it takes to be successful at performing this act).

That the importance of broad foundational frameworks and meta-level worldviews has been neglected in recent theorizing is a regrettable outcome of a number of historical trends and developments. On the one hand, from its early years on, psychology aspired to define its identity by taking distance from any and all philosophical and meta-level matters, as expressed, for example, by Hugo Munsterberg who proudly stated that "the chief thing that [the modern psychologist] has added to the old psychology is that he has no philosophy" (cited in Connelly and Costall 2000, p. 148). American pragmatism has inherited and strengthened this skeptical view on philosophical foundations for psychology, developing an outlook that is both profoundly anti-intellectual and politically disempowering.

On the other hand, the abstention from broad issues has to do with later post-structuralist and postmodernist developments in social sciences. Although there are voices raised in favor of addressing big questions and foundational matters in way of building firm groundings for conceptualizing knowledge and knowing, this position is in a minority today. For example, Fraser and Nicholson (1990) argue that, for feminists, "a postmodern critique need forswear neither large historical narratives nor analyses of societal macrostructures … [as long as the theory is] explicitly historical, attuned to the cultural specificity of different societies and periods and that of different groups within societies and periods" (p. 34).

A much more common view, however, is that of social constructionism, which along with other contemporary theoretical currents embraced the demise of the empiricist view of knowledge and, quite understandably, welcomed emancipation from the stranglehold of traditional foundational meta-theory. In doing so, however, social constructionism fails to distinguish between two radically different premises. Namely, it is one thing to shift away from one particular form of meta-theory—the traditional one with its foundationalist view of human knowledge, its representationalism and its traditional demand for an inductive building of theory from facts—and it is a quite another thing to give up the task of developing, or at least reflecting upon, the foundational grounds (that do not have to be foundationalist) from which a psychological theory develops and which it must be in accord with. When, for example, Gergen (1991) states that "no longer is it essential to ensure a consistency between the psychologist's conception of the human subject and a foundationalist view of human knowledge" (p. 23) and offers instead the remedy of "creative theorizing … freed from the constraints of a priori foundations" (p. 23), he unwittingly invites researchers to relinquish the task of developing a viable conception of the human subject all together, compromising viability of inquiries into the realities of social world that can be of practical consequences for this world.

Today's "Big" Frameworks and Their Alternative Worldviews

Whether researchers working on epistemic problems know it or not, they de facto belong to one of the larger frameworks that provide answers to the big questions on the nature of knowledge underpinned by the overarching ideas about human nature and their Being (what can be termed the essence of humanness). Particular conceptualizations of knowing and conceptual understanding inescapably rest on these answers. With all the seeming variety of theories and frameworks being developed in today's research at the intersection of psychology and education, just few options exist in terms of broad meta-level foundational frameworks.

By far the most prominent framework, still dominating much research in psychology and neighboring disciplines and affecting even socioculturally oriented theories, is the traditional empiricist one according to which humans know the world through the input generated by the stimuli out in the world, with information passing from the environment into the brain via sensory organs. The mind is conceived as a computer-like device that detects signals from the environment and then processes information received through sensory organs, while representing the world in internal mental images including in conceptual representations. The human individual is set apart from the world and is viewed as a passive creature subjected to external influences that put its seal on the mind and give rise to knowledge in a unidirectional and linear manner. There has been much critique of this framework in recent scholarship, so there is no need to recapitulate the flaws of the mind-in-the-vat metaphor with its impasses in explaining how knowledge is possible, what warrants the truthfulness of knowledge and so on. It is enough to say that, when taken to its logical conclusion, this approach ends up in a position that, as one author adhering to it puts "[p]erception is somewhat like a guided *hallucination* based on sensory stimulation. Therefore the world we see around us is not the real world itself but merely a miniature virtual-reality replica of that world in an internal representation" (Lehar 2003, p. 25, emphasis added).

Another logically inevitable conclusion within this position is a strong eliminativism according to which knowledge of the brain is the ultimate solution to all ethical, psychological, and educational problems—because everything about human behavior is ultimately reducible to the underlying brain processes such as neuronal networks and neurotransmitters.

The concept of the learner based in this worldview and powerfully present in the minds of most lay persons including many teachers, educators, and psychologists entails that students record incoming information from their environment that gets imprinted in their brains to be processed and stored there for it to be later rehearsed and used upon demand. The educational strategy, accordingly, favors the practice of exposing students to a variety of stimuli and information that needs to be processed and memorized for future use.

The second big framework is most closely associated with the philosophical position articulated by Kant in his rationalist metaphysics. This framework posits that knowledge is generated through processes in which the human mind imposes its pre-existing structures on the sensorial input, rather than merely detects or records incoming external stimuli. In this framework, people are assumed to be equipped with some basic cognitive structures right from birth and development is viewed as the gradual unfolding and sophistication of these pre-given structures. Learning is thus understood as a largely endogenous process in which the pre-existent internal (mental) structures evolve on their own terms, though not completely independently from experiences of experimenting with an independent reality. Piaget can be credited with formulating the most well-known rationalist theory of cognitive development and today's educators are still powerfully swayed by the stage-based interpretations of this theory (often eschewing its deeper, and more relational, theoretical underpinnings). The educational practices based in this framework put emphasis on encouraging students to engage in self-directed experimentation with reality so that they can exercise their operational and cognitive structures (including through inducing imbalance in cognitive equilibrium) and thus facilitate their development. This results in the construction and reorganization of knowledge structures that start as and always remain internal to the learner. This approach, accordingly, favors engaging children's natural propensities to explore their environment and providing abundant opportunities for exploration and reflection without much direction from the teachers (e.g., as in guided discovery). There is an emphasis on active character of learning but as referring primarily and almost exclusively to the mental activity of exercising cognitive structures.

The important point to note here is that many among today's educational approaches, even those that go under the title of sociocultural theories, de facto uncritically adhere to one of these two frameworks (or, sometimes combine their elements), while merely adding emphasis on the role of social context, social interaction, cultural tools and other environmental aspects understood as outside factors influencing development and learning merely in an extraneous way.

The third framework—the sociocultural or socio-historical one, with composite roots in Hegelian and Marxist philosophy—is, for a number of reasons, much less widely adopted and known, remaining insufficiently theoretically articulated, explained, and implemented in educational practice (although it has gained in popularity in recent decades). Being the most recent, it is also the least consolidated one among the key frameworks, with its various currents presently competing for a leadership position. Several approaches within this framework ground themselves on the premise that cultural context and social interactions are the leading factors in human development; the mind and other cognitive structures are, accordingly, viewed as embedded or situated within and influenced by these sociocultural factors understood as external to human development. This type of approach, however, does not go far enough in contesting the propositions of traditional empiricist and rationalist worldviews. Other versions of sociocultural theories take the radical stance that eschews conceptualizing the mind and cognitive processes all together, thus leaving them under the aegis of individualist and mentalist approaches. Although laudable in their pursuit to dispel the longstanding and indeed harmful stereotypes about the individual as an essential and universal entity pre-existing collectivities and collaborative practices and about the mind as an internal mental theater withdrawn from the realities of human pursuits, these theories fall short in terms of offering explanations for many key aspects of human life especially in matters related to teaching and learning.

As a result, an alternative worldview and its implications that provide the grounding for sociocultural framework remain insufficiently articulated and researchers who adopt it often find themselves poorly equipped to counter alternative (and increasingly powerful) reductionist, eliminative approaches that are firmly grounded in a faulty and outdated but seemingly cohesive and attractively simple essentialist and mechanistic premises typical of the other frameworks. Especially urgent is the task of theorizing the individual person and the human subjectivity including psychological realities of self-determination, self-regulation, agency, and the whole experiential realm within this new socio-historical framework.

It is quite understandable, especially given the overwhelming power and the indeed disastrous implications of individualistic assumptions (and not just in science but also in economy and politics as exemplified by the present crisis in the US) prevailing science and everyday life that many of the socio-historical theories strive to move as far away from anything to do with the individual as possible. However, excluding processes traditionally associated with the individual level of functioning—such as thinking, reasoning, making decisions and choices, forming concepts and identities, committing to goals and so on is, ironically in my view, a remnant of the dualistic worldview where individual human beings are not fully integrated into the dialectical account of human life and development and not re-conceptualized anew on its grounds. How attempts to achieve such a full integration have been undertaken in Vygotsky's project integration—on the basis of the dialectical method and outlook on reality—and how this project can be further advanced in present day's context is discussed in the next section.

Vygotsky's Project as an Alternative Worldview and Its Implications for Theories of Conceptual Development

Vygotsky's project can be seen as one of the earliest and most articulate attempts (though not a fully fledged account) to address the issues of human development and learning within the dialectical worldview and while focusing on the organisms' continuous ongoing engagements (i.e., activities, practices) with the world as the core foundation for these processes. Explicitly grounded in Marxist philosophy (for political-historical reasons being among the first to be in affinity with its ideological underpinnings and to have access to relevant works) and profoundly saturated with the goals of radical social transformation, this theory stands out even today in terms of its conceptual breadth, its clear commitment to social justice, and its pursuit to provide an account of human development and learning on fully relational, dialectical premises while not excluding the phenomena at the individual level from this account. Moreover, Vygotsky's project can be said to pursue and implement key principles of the dialectical methodology and outlook on reality because, whereas many other theories within the sociocultural framework pursue descriptions at the level of the totality of social systems and activities (such as community practices),[5] Vygotsky's project also directly and centrally focuses on this level of analysis yet also breaks down this totality into interconnected derivative parts and tracks down their historical contradictions and connections, while never losing sight of their unity in difference.

Many assumptions and principles of Vygotsky's project have been exposed and explained in recent literature. However, less attention has been paid to the underlying core, worldview level premises of this theory. These premises need to be revealed and expansively re-worked today to reconstruct Vygotsky's project as a firm and viable alternative to empiricist and essentialist approaches.

In line with the dialectical outlook on reality discussed in previous sections, Vygotsky's project is grounded in the dialectical notion that all that exists is *one moving matter* taking various forms and shapes and existing at various levels and dimensions. These levels and dimensions always remain intricately connected with each other—as derivative products and expressions (or incarnations, moments) of one foundational reality that is ultimately unitary (i.e., existing as a totality). Within this broad notion of reality as one moving matter, furthermore, all living forms are understood as existing within processes of ever unfolding and continuous relations. That is, these living forms (organisms) are understood to only exist and come to be through and *as* relations with their surrounds including other living forms, rather than as pre-formed independent entities that develop from within some inner essence and can only come under (and can reciprocally exert) merely extraneous influences on other, also independently existing, entities and forms.

On the one hand, this worldview has been worked out by the members of Vygotsky's project by assimilating many ideas of dialectical outlook on reality and dialectical method—especially through assimilating ideas developed by Marx and Engels. On the one hand, the works within Vygotsky's project were also based on careful examination of developmental processes in ontogeny, phylogeny

5. As Altman and Rogoff (1987) explicitly state, within the transactional approach "one attempts to discern the nature of the whole without emphasis on antecedent and consequent relationships among variables, *without analysis of the whole into its elements*, and without identification of monolithic teleological or other mechanisms that inevitably govern the phenomenon" (p. 26, emphasis added).

and anthropogenesis and developed in line with the then cutting-edge discoveries in biology (i.e., Darwinian principles of evolution and origins of life creatively expanded by Kropotkin, Vernadsky, and Oparin), physiology (on the functioning of the living cell, the brain, and the central nervous system—works by Sechenov, Ukhtomsky, Anokhin, and Bernstein), as well as in anthropology, linguistics, semiotics, and other sciences. The core premise derived from these investigations was that from the first moment of life, all living organisms find themselves in an unbreakable, intricate connection with the world, and their existence takes the form of a constantly ongoing, open-ended and ever changing interactions and back-and-forth exchanges with the world—exchanges of energy, resources, forms, products, and so on. As explicitly stated in recent epigenetic accounts in evolutionary biology, behavioral and cognitive dispositions of organisms cannot be specified in advance of individual development and interaction with the world. Instead, all traits or characters (including behavioral and cognitive ones) are understood as in need of being constructed in individual development.

Furthermore, an explicitly dialectical relational worldview entails that, given the primacy of relations coupled with their process-like (i.e., non-mechanical, non-entity) nature, human Being needs to be understood as an indivisible and seamless, *unitary* (not composite) process of humans engaging with their world—the totality of life—that cannot be meaningfully broken into disconnected parts such as, for example, putatively self-sufficient endeavors of a conceptual understanding on the one hand, and of perceiving the world, memorizing facts about it, tackling moral dilemmas, or solving practical tasks and so on—on the other. Instead, all of these endeavors and acts need to be seen as forming one continuously unfolding stream, one whole seamless flow of life where various facets and moments mutually interpenetrate and define each other, are represented in each other, and thus are not reducible to a chain of single discrete episodes or disconnected levels and dimensions.

This idea is at the core of the notions of historicity and development (permeating Vygotsky's writings) with its central emphasis on continuity and cumulativeness of human Being. In my interpretation, this means that all happenings and events in life never end and can never be completely left behind; instead, life constantly evolves, moves forward without breaks so that past activities and associated experiences—both achievements and failures—are not completely eliminated but instead, are carried over into new forms and activities, becoming absorbed into them and transformed within the newly forming states of Being. In this sense, the past is powerfully present in what happens here and now, albeit not as dead and static remnants, but as constantly renewed and transformed resources for the presently existing structures and activities. New actions continue on the foundation of past actions, ensuing from these past actions (including achievements and practices of previous generations). However, the latter are never exactly copied within the new ones, instead undergoing continuous transformations as they are included into new actions and transformed in them in order to fit in with the changing realities of the world.

Perhaps due to its broad metaphorical character, this dialectical and relational worldview has been best expressed by literary critiques and writers. Thus, it did not escape Mikhail Bakhtin (1993) who wrote that one's entire life as a whole can be considered as a *single complex act* or deed. His central (and idiosyncratic) notion of "postuplenie" captured precisely this seamless and continuous, forward-moving path of becoming through one's answerable deeds—one's unique activities within the social world that are permeated by agency and full responsibility for each and every act. Or, as the novelist John Berger powerfully formulated, "Life," as a Russian proverb says, "is not a walk across an open field. Experience is *indivisible and continuous*, at least within a single lifetime and perhaps over many lifetimes. … [E]xperience folds back on itself, refers backwards and forwards to itself through the referents of hope and fear."

Moreover and most critically, Vygotsky's project provides its own original specification for the foundational ontological realm that represents the core grounding for human Being in the notion of collaborative transformative (i.e., goal-directed and purposeful) activity—or collective praxis. This activity continuously and cumulatively evolves through time while being enacted and carried out by human collectivities through unique contributions by individual participants in these collectivities acting as social subjects. The hallmark of these activities is that they do not narrowly conform to the existing reality and do not aim to fit in with it. Instead, their goal is to change the world and oneself along with the changing world that is instantaneously created by one's own activities. These practices, on the one hand, produce and engender social interactions (intersubjectivity), as well as psychological processes and agency (human subjectivity) which are also profoundly social, and on the other hand—at mature stages of development in history and in ontogeny—are themselves reciprocally produced by these very interactions and subjectivity.

The key point to make here is that collaborative transformative activities represent a unique—irreducible, indivisible, and non-additive—level of reality that constitutes the very fabric of human Being with all the phenomena of this Being originating from, being constituted by, existing within, and serving the purposes of such activities—as their derivative transformations in the form of various moments, or dimensions. These activities are viewed as the primary, core, and only reality—indeed the only world—that humans exist in, deal with, and come to know. Importantly, no ontological gaps are posited to separate phenomena within this one reality, with human mind and the self, knowledge and concepts also representing instantiations (or moments) of these collaborative transformative practices. The centrality of collaborative transformative practice for human Being and development can be seen on a par with the centrality of evolution in biological systems and therefore, it can be said that nothing in human sciences makes sense other than in light of human collaborative transformative practices as the foundation of their life and development.

In this sense, for example, the Popperian division of reality into three independent worlds, without a complementary specification of how these three worlds all also form unity and exist, at least at some level, as one process, and also how these three worlds issue or stem from this one unitary process, goes against the grain of Vygotsky's project. This project posits that there is only one world—the world that people create through their activities—in which human beings come to be and to develop as well as get to deal with and to know about. Dividing this world into self-sufficient (even if interdependent) levels is not viable from Vygotsky's project principles because there are no processes independent of the realm if collaborative transformative activities and practices. Therefore, knowledge and concepts (in whatever degree of generality and abstractness) do not exist as free-floating constructions, in some realm that is separate from what individual people do and enact—though always do so within collectivities and as social subjects.

This is the point where the duality between the social and the individual planes of activity needs to be addressed and contested with full force. From a transformative stance that posits the ontological primacy of social practice of collaboratively changing the world, as suggested herein, these activities do not exist other than through enactments by particular individuals who always act collaboratively, as social subjects even when performing seemingly solitary activities such as activities of theoretical reflection. Even in this latter form, activity is inevitably and profoundly social and collaborative through and through—being carried out with the help of collaboratively created cultural tools and artifacts (e.g., language, literacy, writing, technology, rules, norms, and patterns of acting and thinking), motivated by social contexts and circumstances of one's life (i.e., relational with other people) and directed at social goals. Yet each individual carries out these activities from a unique standpoint, with unique goals and as making an irreplaceable contribution to collaborative transformative practices. Though unique, these tools, standpoints, motives, goals, and other important constituents of activity, being individual, are not a-social either, representing an amalgamation of both—as a particular expression of social practice refracted through the prism of each human beings' inimitable positioning in history and context as well as his or her irreducible agency and responsibility.

That is, social knowledge and concepts do indeed represent a distinctive layer of reality but not a separate third world in the Popperian sense. Instead, they represent reifications, embodiments of communal social practices (as aptly shown by E.V. Ilyenkov and A.N. Leontiev) that come into being only when being again involved—further transformed and creatively developed—in activities carried out by concrete individuals through their unique contributions to social practices. For example, the most vivid creations of social practice (and of human subjectivity), such as language and art, appear as the products and carriers of practice, but only when reenacted (and reconstructed) in new rounds of ever expanding cycles of social practice by real people in their real life. It is in this sense that, for example, words and music are mute, and even dead, unless someone again and anew reenacts them, thus making them—and the history behind them—alive for oneself and for the others in the here and now. Importantly, even mere perception, memory and other seemingly mundane psychological processes are agentive and creative endeavors—that is, agentive deeds colored by and imbued with goals, purposes and commitments vis-à-vis some social matters and therefore, also always communal and participatory, that is, always conducted with other people, for other people and in view of other people and thus, contributing something new to social practice and history (even if in the zero form of pursuing some narrowly individualistic goals).

In this sense, the transformative ontology of social practice—strengthened by the notion of individual contributions to this practice as its carriers (as suggested herein)—can be seen as superseding the very distinction between collective and individual levels. What is offered instead is one unitary realm or process (perhaps in need of being described with a new term to convey the amalgamation of the social and the individual, such as "collectividual") of individuals always acting together in pursuits of their common goals and inescapably bound by communal bonds and filaments.

In this dialectical approach, there is no need to get rid of an individual because there is no such a thing as an individual—a solitary human being performing anything in disconnection from other people and outside of paramount social bonds, rules, means and obligations. Instead, an individual human being is an ensemble of social relations (as Marx famously stated), being first formed within and out of these relations and then coming to embody, carry out, and expand them through one's own life and deeds.

This is a deceptively simple point that often gets stated but without, I believe, a due appreciation of its implications and its deep meaning. To truly appreciate this point, one needs to resolutely break away from the dualism of the individual and the social and to be able to conceive of the individual human being, of each and everyone of us, as truly and deeply social—that is, as representing the totality of history and humanity (in all their vicissitudes), carrying them on and bearing responsibility for their future. To see history and society embodied and expressed in, or even created through the deeds of, one single person—regardless of how powerless and oppressed, seemingly insignificant and fragile this one person may appear to others or even to oneself—is a truly formidable task that the sociocultural scholars are only beginning to grapple with.

Finally, returning to the epistemic issues: In light of these points, the layer of individual knowledge and concepts need not be discarded but instead, can be re-conceptualized anew within the transformative relational stance. Some preliminary directions for this include the following. First, knowing needs to be understood as a dynamic interactive process of individuals relating to and actively engaging with their world—a process that is constantly enacted and reenacted (created anew) so that none of its aspects is ever completely fixed or frozen. In this sense, knowing is not something individuals have under their skin but something they do while interacting with their world (the point well understood by Piaget, Dewey, and Vygotsky alike, as well as by Gibson, Mead, and many other sociocultural scholars of the past).

Second, knowing is not merely a process of relating to the world through doing (the core of relational ontology) but part and parcel (or a particular dimension) of human purposeful collaborative activity through which people transform the world and thus transform—and essentially create and come to know—themselves. From this transformative activist stance, knowing is always an agentive and purposeful endeavor having to do with purposes, commitments, ideals, visions for the future and, ultimately, politics, that is, taking place within and in fact creating the world permeated by ideology.

Third, knowing is not a separate module or gadget that realizes separate and discrete goals disconnected from the wholeness of an individual unique life. Instead, it represents part of realizing the totality of life (or a life project)—as a stepping stone in carrying out a unitary and unique (though dynamical and constantly changing), seamless path of becoming a human being through making a difference in the world. As a part or dimension of carrying out one's life project, knowing, itself is a meaningful and answerable deed in the sense that it has to do with who we want to be and become. In this sense, the development of knowledge is also, and simultaneously, the development of identity and the self.

Last but not least, individual life projects and concepts involved in carrying out these projects are simultaneously profoundly social—concerned with finding one's place and role in the continuous historical practice of humanity. That individuals have concepts and develop conceptual understanding (including through conceptual change) is, then, not an impossible proposition from the point of view of Vygotsky's project as presented herein. It is just that all and each of the ingredients forming this proposition need to be re-conceptualized anew, in radically new ways suggested by the dialectical method and outlook on reality—starting from conceptualizing individuals as not really ever being individual and ending with conceptualizing concepts as active deeds—means of human being and becoming through contributing to collaboratively transforming the world.

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Chapter 7

A Sociological Response to Stetsenko

Regina Smardon*

At the start I should say that I tend to agree with Stetsenko that one must embrace the implications of a dialectical worldview and method in order to fully comprehend the Vygotskian project. I also have to agree that the Vygotskian project has been largely overlooked outside of the field of educational psychology, where Stetsenko argues it is still marginalized in comparison to other, more dominant theoretical models. Furthermore, Marxist psychology has never been a part of American sociology, a discipline that has instead focused on macrosociological Marxist models, including Immanuel Wallerstein's (1980) "world systems theory" or Theda Skocpol's (1980) "theory of revolutions." Thus, the Vygotskian project exists at the marginal nexus of both psychology and sociology.

Of course Marxism is a vital foundation for sociological theory. Marxist influences can be found in the Frankfurt School, led by Max Horkheimer and Theodor Adorno, as well as the neo-Marxist work of Herbert Marcuse, Antonio Gramsci, Louis Althusser, and Karl Mannheim, these theorists have in turn influenced sociology. Importantly, none developed a Marxist microsociological approach comparable to the lineage of the American Pragmatist tradition (including George H. Mead, John Dewey, and Charles S. Peirce) or the phenomenological tradition (including ethnomethodology, conversation analysis, and the work of Alfred Schutz), the rational choice/utilitarian tradition (including George Homans and James Coleman), and what we might call the Durkheimian microsociological tradition (as exemplified by Erving Goffman's conceptualization of interaction ritual).

More contemporary sociological accounts of the micro/macro divide draw from these dominant microinteractionist traditions. Jürgen Habermas's critical theory, which is certainly influenced by Marxism via the Frankfurt school, draws primarily from American pragmatism in his conception of communicative action. Similarly Anthony Giddens' theory of structuration draws on Erving Goffman's view of the

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social situation, as does Randall Collins' work on interaction ritual chains. The work of Pierre Bourdieu with his emphasis on practice and habitus is directly influenced, or at least responding to, Marxism. However, he intended his work to turn Marxism on its head and in truth his work is not microsociological nor does it draw from the Vygotsky project.

In short, I am intrigued by Stetsenko's insistence that traditional psychology has neglected the Vygotskian worldview and I tend to think that my own discipline of sociology has neglected the Vygotskian contribution to a Marxist microsociology. In fact, Stetsenko might say that Vygotsky holds the key to elaborating a sociology that bypasses the need to synthesize micro- and macro-models entirely, by suggesting a worldview and method that reinvent the unit of analysis afresh with each new investigation.

What Is Dialectical Materialism?

Dialectics is the method of reasoning which aims to understand things *concretely* in all their movement, change and interconnection, with their opposite and contradictory sides in unity. To summarize as briefly and concisely as possible, Stetsenko distinguishes a dialectical outlook on reality from the dialectical method of analysis. She goes on to argue that she perceives areas of commensurability between the dialectical outlook and method despite the numerous epistemological pitfalls of knowing about knowledge. According to Stetsenko, both the Marxist dialectical method and the Marxist dialectical worldview are based upon the assumption of infinite movement and interpenetration of any and all aspects of reality including activities of knowing and theorizing. As a materialist philosophy it also assumes the unity of reality. For Marx the base of the material world is constituted of social relations, especially class relations.

Stetsenko then goes on to explain that Vygotsky, and his intellectual circle during the 1920s and 1930s, represent the first attempt to apply the principles of Marxist dialectics to developing a theory of human development and learning. Stetsenko argues that Vygotskian scholars are not simply shifting their unit of analysis from society to the individual. In her words, this is just the "tip of the iceberg" with regards to understanding Vygotsky's larger theoretical project. She redirects our attention to the broader issue of how the dialectical method and outlook are addressed by the Vygotskian tradition and to fill in some of the gaps that exist along these lines with her own interpretations.

Whereas some might view circular reasoning, complexity or lack of closure as weaknesses, Stetsenko actually embraces the circular and multilayered nature of dialectical materialism arguing that this is its strength:

> [T]he dialectical method can be understood as a circular, recursive and self-critical procedure where, (a) observations and analysis of particular phenomena … are complimented and accompanied by (b) the efforts to discern their common origins and developmental transformations based in internal contradictions and inherent contradictions among these

> phenomena, which bi-directionally entails and leads to (c) theorizing these common origins and resulting features by means of concepts of higher (abstract) order … which in turn bi-directionally entails and leads to (d) a novel understanding and concrete conceptualizations of particular phenomena within a given domain of investigation in the form of now more theoretically rich (not to be confused with simple empirical) yet concrete concepts. From these latter conceptualizations, a new cycle begins where new abstract concepts of higher order capturing the totality of phenomena in a systematic way are developed, thus launching the next step in the ongoing (and strictly speaking, never ending) inquiry.

Thus the goal of the dialectical method is richness and dynamism rather than elegance or testability. However, Stetsenko does not view dialectical materialism as simply the reverse of positivism. She reserves this harsh judgment for post-modernism saying that the Vygotskian project can be contrasted with a post-modernist notion of theory being a, "commentary or an extension of its own history, existing exclusively within the realm of discourse." From a sociological perspective, this offhanded comment is actually a key theoretical move that distances the Marxist dialectic from the Hegelian dialectic associated with post-modern and poststructural thought. In Stetsenko's hands, the Marxist dialectic avoids drifting towards idealism while maintaining self-reflection and the flux and flow of cultural and social movement. The Vygotskian project, she tells us, is grounded in the material reality of political-practical strife and struggles. In Stetsenko's view, a Marxist dialectic entails *movement* across levels of analysis. It also entails *movement* across and among concepts; from abstract to concrete. In fact she takes great pains to explain the importance of abstract and concrete concepts. She sees abstract and concrete concepts as *complementary levels*. She tells us that, "The unit of analysis, therefore, has to be elaborated as a confluence of both abstract and concrete concepts in which the *motion* of phenomena and processes in a given field of inquiry become represented and embodied." Thus a researcher must track down the inner contradictions of a phenomenon by breaking it into manageable parts without losing sight of the interconnected unity of reality that a materialist stance presupposes. This compatibility between method and worldview prevents reifying or essentializing analytic abstractions into static, a-historical forms.

Stetsenko's Critique of Traditional Psychology

Stetsenko sets the stage for discussing the grounds of Vygotsky's intellectual project by taking psychology to task for neglecting the social. By social she appears to mean the importance of social interaction and cultural context. She cites two big frameworks as dominating psychology, and by extension educational psychology, both explicitly and implicitly—the computer model and the cognitive structure model (e.g., Piaget's model of cognitive development). Stetsenko sees these big frameworks—which she also refers to as meta-level foundational frameworks—as providing answers to questions about the nature of knowledge and overarching ideas about human nature.

She informs us that the computer model of the mind is an empiricist framework in which humans know the world through input generated by stimuli. Here information passes from the environment into the brain via sensory organs in a unidirectional, linear fashion. Thus thinking can be reduced to the functioning of neural networks and neurotransmitters. By contrast, the cognitive structures model is based in a rationalist metaphysics in which the mind imposes pre-existing mental structures on sensorial input. According to Stetsenko, “Piaget can be credited with formulating the most well-known rationalist theory of cognitive development and today’s educators are still powerfully swayed by the stage-based interpretations of his theory.” Educational practices based in this approach try to promote engaging children’s natural propensity for exploration. Like the computer model of learning, the cognitive structure model tends to view learning as an activity that transpires within the individual.

Stetsenko introduces sociocultural theory as a third framework for thinking about methodology and epistemology. This approach has its roots in Hegelian and Marxist philosophy and is much less widely adopted within psychology. She states that

> among today’s educational approaches even those that go under the title of sociocultural theories, de facto, uncritically adhere to one of these two frameworks (or, sometimes combine their elements), while merely adding emphasis on the role of social context, social interaction, cultural tools and other environmental aspects understood as outside factors influencing development and learning merely in an extraneous way.

Among the reasons proposed by Stetsenko to explain why the sociocultural framework remains marginal to psychology are: (a) the approach is insufficiently articulated and (b) various approaches within this camp are currently competing for a leadership position. Having criticized some psychologists for ignoring the social dimension, including attention to context, social interaction, and cultural tools, she then goes on to criticize some sociocultural theorists for going too far in rejecting the notion of the individual. This approach serves to weaken the sociocultural argument especially with regards to addressing concerns about teaching and learning. In Stetsenko’s view those who adopt this radical sociocultural approach often find themselves unable to refute the power of reductionist and eliminative approaches grounded in the computer model or the cognitive structure model. Therefore, she sees the task of theorizing the individual person and human subjectivity as especially urgent for the growth of the sociocultural or sociohistorical framework. Stetsenko then turns her attention to uncovering what she sees as the core worldview level premises of Vygotsky’s theoretical project. For Stetsenko, the path to a stronger sociocultural theory lies in returning to Vygotsky’s concern for providing an account of human development and learning on fully relational, dialectical premises, while not excluding the phenomena at the individual level from this account.

Marxist Microsociology

It is difficult to identify the big frameworks that dominate current sociology as Stetsenko has done for psychology, but such a task has been attempted by leading theorists nonetheless. Randall Collins (1994) divides sociology into four sociological traditions: the conflict tradition, the rational/utilitarian tradition, the Durkheimian or consensus tradition, and the microinteractionist tradition. These divisions reflect the dominant strains of sociological theory as Collins sees them within mainstream American sociology. He groups Karl Marx, Friedrich Engels, and Max Weber into the conflict tradition and he credits this tradition with a sophisticated view of the macrostructure of society. Collins includes pragmatism, symbolic interactionism, phenomenology, ethnomethodology, and the work of Erving Goffman in the microinteractionist tradition. Within Collins' four traditions Vygotsky's legacy might fit best somewhere between the conflict tradition and the microinteractionist tradition because Vygotsky could be interpreted as Marxist microsociologist.

Michael Burawoy and Eric Olin Wright (2002) describe periods in American sociology when Marxism has been completely marginalized. In fact, until the era of the Cold War American sociology almost completely ignored Marxism. Briefly during the 1960s sociologists who wanted to reject the status quo in American society as well as Communist totalitarianism rejuvenated Marxism. Burawoy and Olin Wright argue that there is a renewed effort on the part of some sociologists to bury Marxism today by discounting the importance of class analysis because they believe the category of social class is no longer relevant in contemporary society. Conversely, there are a small number of sociologists who continue to argue that class is at the core of capitalist reproduction. For example Annette Lareau and Dalton Conley (2008) recently assembled a group of sociologists around the topic of class analysis. For their part, Burawoy and Wright see many possibilities for building sociological Marxism without embracing Marxism as an ideology. Although they do believe that Marxist sociology entails a commitment to social change and social justice.

Rather than simply mining Marxism for inspiring ideas Burawoy and Wright want to build the theoretical possibilities of Marxism. Many sociological analyses of labor processes and social reproduction and change borrow conceptually from Marxism without being self-consciously Marxist. One prominent example not cited by Burawoy and Wright is Arlie Hochschild's (1983) *The Managed Heart*. This book elaborates a theory of emotional labor that borrows directly from Marxism but does not aim to contribute to the theoretical project of Marxism so much as it aims to describe and explain a particular phenomenon. Interestingly, Burawoy and Wright do not devote sustained attention to dialectical materialism as a worldview or a method in their discussion of what they view as the core ideas of Marxism. Not surprisingly, Vygotsky is not mentioned.

For a variety of reasons the Vygotsky tradition is so marginal in American sociology that it cannot be said that it constitutes a framework at all even among sociologists who are committed to Marxist class analysis. Within the sociological subfield of social psychology—not to be confused with the psychological subfield of social psychology—Vygotsky is rarely mentioned. Although sociological social psychology has borrowed from psychology on occasion it lays claim to a long, if uncertain, history of its own. Stolte and colleagues (2001) trace the history of social psychology within sociology to a textbook written in 1908 by sociologist Edward A. Ross. According to Stolte and colleagues, psychological social psychology ultimately embraced the laboratory experiment and sought to explain individual behaviors and attitudes as a function of an external reality. In contrast, sociological social psychology has been more diverse in its methodological and theoretical approach. Stolte and colleagues suggest that its primary contribution can be called sociological miniaturism. Sociological miniaturism is not a methodology or a theory but rather a way of interpreting social processes and institutions; specifically, the examination of large-scale social issues through small-scale social situations. In fact, Stolte and colleagues actually prefer the term micro-sociology rather than social psychology.

Within Stetsenko's interpretation of Vygotsky the distinction between micro- and macro-levels exist purely as analytic constructions. She insists that the Marxist dialectic assumes the unity of reality and that the dialectical method does not privilege the micro- or the macro-scale of analysis for explaining one another. Thus it makes little sense in her view to talk about a small-scale social situation leading to insight about large-scale social issues because the entire activity system must be taken as a unity within which contradictions must be uncovered. Still, the notion of miniaturism captures the importance of the small-scale social situation within the dialectical method. Although the micro-scale in this tradition might be called praxis—by which I refer to social action constrained by time. As Roth and Lee (2007) point out, praxis in the Vygotskian tradition refers to the moment of real human activity whereas practices are patterns that characterize actions that can be reflected upon outside of the time demands of praxis.

Stetsenko's Interpretation of Vygotsky's Project

Two central concepts are often cited that distinguish Vygotsky's (1978) perspective on learning: (a) The notion of a zone of proximal development that conceptually draws a line around the dynamic relationship between learning and development and (b) the genetic law of cultural development that conceives the natural course of the development of culture in the individual as leading from the social to the psychological level, that is, it exists first between people as an intermental category and then within the child as an intramental category. In my own work I have argued that Valentin Voloshinov (e.g., 1973) further develops the sociocultural model using the concept of "inner speech," to explain how individuals negotiate contradictory cultural codes that have been internalized (Smardon 2004). (See also the points the editor makes in the introductory text to this Part A.) I see this as the primary strength of the sociocultural model of the mind. Unlike American interactionism, it does not assume internalizing norms to be adaptive and unlike Freudianism it holds the power of explaining intramental conflict as an outgrowth of intermental conflict, not the inherent structure of the personality. Most importantly, the sociocultural model of the mind allows for the resolution of inner conflicts as a potential source of creativity and change.

Stetsenko finds it necessary to rework and reconstruct Vygotsky's project with an eye for highlighting the underlying worldview premises of this theory. Her thoughts on this topic can be better understood when viewed as building upon her ongoing interest in constructing a noncanonical activity theory (Sawchuck and Stetsenko 2008). Stetsenko believes that the generational approach to activity theory does not fully capture shifts in the foundational grounds of cultural-historical activity theory. Ultimately, she sees canonical activity theory as having lost its focus on transformational change and social justice. In previous work she has developed her ideas about the relationship between the individual and collective plane of activity (Stetsenko 2005) and reviewed sociological understandings of conduct for inspiration to further this project. In her contribution to this book, Stetsenko is focused on implications of Vygotsky's project for conceptual development. However, she begins by explaining how individual contributions to collective practice work.

Stetsenko's emphasis on the emergence and unfolding of continuous relations within Vygotsky's worldview has a vague kinship with actor network theory. Stetsenko sounds like Bruno Latour (2005) when she insists that living forms (organisms) are understood to, "exist and come to be through and *as* relations with their surrounds including other living forms, rather than as pre-formed independent entities that develop from within some inner essence and can only come under (and can reciprocally exert) merely extraneous influences on other, also independently existing entities and forms." However, I suspect that Stetsenko would take issue with the way that Latour conceives of agency and distributes it evenly among objects and humans. This view would seem incompatible with Stetsenko's focus on the role of human subjectivity in transformational change. Unlike Latour, Stetsenko remains focused on how goal-directed and purposeful activity leads to new practices emerging,

> [n]ew actions continue on the foundations of past actions, ensuing from these past actions (including achievements and practices of previous generations). However, the latter are never exactly copied within the new ones, instead undergoing continuous transformations as they are included into new actions and transformed in them in order to fit in with the changing realities of the world.

Thus, transformational change is made possible in part through human improvisation that takes place within the constraints of real time with previously existing practices serving as resources, albeit sometimes limited resources. More importantly, this type of change occurs in the context of collective praxis, which I interpret to mean groups of people acting within the constraints and affordances of real time with access to a repertoire of previous practices. The notion of collaborative transformative practices is the backbone of Stetsenko's interpretation of Vygotsky's project. This focus on collective practice does not erase the importance of individual subjectivity. Rather, each person carries out his or her activities from a unique standpoint and contributes to collective transformation uniquely. Here we can see that the distinction between the individual and collective level is purely analytic because all social action transpires within a social context: with people, for other people, in view of other people and contributing to social practice and history. As Stetsenko points out, even the most narrowly self-interested goals are social in nature. This reasoning would seem circular were it not for the materialist presupposition that all reality is unitary and interpenetrating.

Individual conceptual knowledge in Stetsenko's view becomes reconceptualized as a dynamic process that is a product of collective transformational change. Knowing is something individuals do while interacting with the world rather than something contained within them. It is also always wedded to the project of producing an identity. In Stetsenko's words, "the development of knowledge is also, and simultaneously, the development of the identity and the self." As individuals we are constrained by history but we are also enabled by it. This radical activist stance has been lost to American sociology.

Reuniting the Psychological and the Sociological Perspectives

Due to the marginalization of Vygotsky's project in American psychology and in American sociology—which are, in turn, due to a variety of factors, delayed translation to English being perhaps the most obvious—very little work has been done that integrates Vygotsky's thought with other dominant perspectives. I see the possibility of developing a Marxist micro-sociology that is in dialogue with educational psychology and contributes meaningfully to Marxist debates within American sociology, such as the debate surrounding class analysis. (On this point, see also the discussion in the epilogue concerning the use of the ethnomethodological micro-sociology with Marxist structural analyses.) However, given the marginality of Vygotsky's work in both psychology and sociology much work remains to establish its relevance to the dominant questions addressing each discipline. Stetsenko has begun the work of challenging dominant psychological perspectives. The first step for introducing Vygotsky's project into sociological thought is to develop a Marxist micro-sociology that challenges the dominant microinteractionist traditions within American sociology. Psychologists such as Stetsenko are also beginning an interdisciplinary dialog with sociologists that will strengthen sociocultural theory.

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Chapter 8

Turbulence, Risk, and Radical Listening A Context for Teaching and Learning Science

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One of the most engaging aspects of science education is the ways in which the spectra of related human endeavors (e.g., sociology, psychology and neurobiology) provide foundational approaches fundamental to the continuing development of the discipline. There is always an urge and tension to push the boundaries of science education in new and exciting ways even though what have often stabilized this area (and other areas) of study are its established traditions, language, methodologies, policies, institutions, schooling mechanisms, myths, and trailblazers. Although there is still much contestation and turbulence in the acceptance and enactment of these fixtures and approaches (e.g., see *Cultural Studies of Science Education* Volume 3, Issue 2 dedicated to conceptual change theory) I find that the logic, language, and referents used to engage in these issues must also reflect the complexities, risks, and at times settled nature of what has been produced and is currently being produced as science education.

During the 1990s and early part of this decade when I worked with many others to organize inner city out-of-school science youth programs in New York City (NYC), I thought about many approaches to articulate and practice this work with colleagues and institutions in ways that seemed uniquely positioned to form durable collaborative relationships. In thinking about these approaches it is extremely important to recognize what other science educators have done before and the knowledge that the area of study contains. When thinking about standing on the shoulders of trailblazers, like Melvin Webb—currently at Clark Atlanta University—who established one of the first successful elementary to doctorate science education pipelines using out-of-school and summer programs as points of entry, what came to mind was my own life's project. The project I helped to cultivate combined a central thinking and approach that had at its core an understanding that building

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functional relationships would help to frame successful collaborations around teaching and learning science. I also brought to this project a lot of enthusiasm and problem-solving approaches that often overlooked the instrumental nature of how I understood the effectiveness and ripple effects of the collaborations that were produced with others. In other words, it is not only important to fashion functionality with colleagues and institutions but to also recognize and co-create culture that produces unique and valuable ways of teaching and learning science with urban youths and their families.

Perhaps not unexpectedly, there is an active challenge to address contexts that are connected and intertwined with the way that science education is thought about and valued. The contextual nature of what we value as knowledge and how we go about obtaining this knowledge has generated much conflict within and among science educators. This is particularly noticeable when epistemological demands are confronted and terms of responses to the challenges are debated. The most significant challenge not only involves critiques of what constitutes knowledge in general, but also specifically points to the sociocultural experiences of different contextual conditions that knowledge claims about teaching and learning science produce. The representation that knowledge is a fixed reality promotes an epistemological and ontological outlook that asserts that there is a common tendency in all moments: differences therefore, are to be explained away. The challenge to this notion is to suggest that to conceive knowledge as operating in isolation separate from all other situations provides overly deterministic viewpoints and neglects the complex context and continuity of social life. As such, within the dynamics of producing knowledge about teaching and learning science, sensibilities need to emerge that pay particular attention to the context and configurations of social life. Asserted in the context and configurations are ongoing mutations and inversions of difference and sameness, as well as the individual and collective that naturally persist simultaneously and as one.

Engaging Narrative Moments and Plans for the Chapter

This chapter emerged as an outcome of my participation in dialogues at the 2008 Springer Forum: *Cultural Studies and Conceptions/Conceptual Change: Reuniting Psychological and Sociological Perspectives.* Whereas this chapter adds to the ongoing conversation that took place at the forum and in this book as a whole, it also exists more intimately as a narrative in this section of the book where Anna Stetsenko contributes a lead chapter. In this chapter I do not attempt to deconstruct Stetsenko's conceptual frameworks; instead I provide a narrative that swings the pendulum in the direction of science education.

Narratives provide a sampling of historical moments that can present constant interpenetration and re/negotiation with current moral standing and other types of schema. Whether having polyphonic qualities or a single voice, narrative consciousness illustrates observations in recollections that are positioned in textual knowledge

(Connelly and Clandinin 1990). Accordingly, I proceed by first conceptualizing a moral solidarity across difference. Building on these ideas and on the educative merits of recalling and re/discovering past experiences, I render a vignette containing a debate between a colleague and me at an international science education conference. The narrative attempts to recall the context of this encounter, albeit from my vantage point, that connects and excavates an innovative level of engagement with epistemologies about knowing, learning and teaching science. I also use the vignette to illustrate the need to seize opportunities that combine exchange of ideas with *radical listening* among science educators in both formal and informal venues. Despite there being a constant presence of both difference and similarities illustrated in this encounter, there is a continuous and complex re/negotiation across being, belonging and building moral solidarity across professional standpoints. I then offer concluding thoughts that affirm the right and necessity of all stakeholders (e.g., students and parents) to participate in examining and building theory and practice to improve teaching and learning science.

Doing the Right Thing at the Right Place and the Right Time

Differences in individuals and social location are inherent aspects of social life. As individuals experience sameness, they also experience and confront differences. These differences create social and cultural boundaries that arise from cultural enactments that are produced, reproduced, and transformed in a dialectical relationship. The concept of difference is also formative in that it can give rise to a matrix of boundaries formed by sociocultural and political enactment. For example, students in a science classroom can live in the same neighborhood, admire the same musical and sports heroes, and share classroom experiences, yet experience difference in age and ethnicity between their classmates and teacher, and how education policy is implemented. Above I highlight my professional experience working with out-of-school science programs throughout NYC before becoming a university level science educator in the Bronx. Throughout these two phases of my career there have been many unique opportunities to listen to and learn a significant amount about different journeys that are part of the narrative of science education in NYC. Through my numerous encounters, I have worked with many students and other science educators who have been positioned differently in social spaces. The populations of urban centers, such as the Bronx, are increasingly becoming diverse. New and diverse streams of immigrants alongside long-term residents create dynamic modes of difference that are dialectically connected with modes of sameness. The emergent modes are often reflected in science classrooms. Although past and current attempts to overcome differences are often accompanied by control-over and conformity, similar interests, such as interest in science, create the need and opportunities to build interstitial culture to create successful encounters to meet goals and motives. Interstitial forms of culture are created as individuals and communities are brought together in new and unique ways. As such, when science classes are scheduled in school buildings, students and teacher(s) are brought together and form unique circumstances to teach and learn science. Teaching and learning science in classrooms can afford the emergence of shared culture and solidarity that can be used for successful encounters across boundaries of difference. Interstitial culture (Bhabha 2006) emerges not just from the co-presence of different and similar cultural forms; it takes traction by doing the right thing at the right place at the right times in expanded ways. For example, when teachers and students coteach successful science lessons together they enact interstitial culture in fluent ways that are timely, appropriate, and anticipatory.

Building Moral Solidarity Across Difference

In *Orientalism*, Edward Said (1978) characterizes the concept of "power moral" expressed in sociopolitical intentions to control and manipulate images that manifest "the other" as different. Said, writing from the viewpoint of a post colonial critic, outlines dispositions and the ways of knowing the Third World as the other that serves the interests of the West and Europe. Embedded in the concept of the power moral is the development of deficit perspectives that challenge the sensibilities and competencies that might have been tacitly (and/or explicitly) celebrated as achievement but then become newly cast in the context of a deep level of dysfunction which is deserving of intervention and control. Thus focusing on the other, power moral asserts the ideas that "we do what they cannot do or understand as we do" (p. 12). Similarly, deficit perspectives in the context of schooling can be defined as "a person-centered explanation of school failure among individuals as linked to a group membership (typically, the combination of racial/ethnic minority status and economic disadvantage)" (Valencia 1997, p. 9). In a quite persistent manner, this type of hegemony devalues subjectivity and choice that generates different views from dominant mainstream views of knowing and understanding. The crisis of deficit perspectives ruptures the potential for productive social relationships and denies the legitimacy of the other to speak his or her own special cultural Truth without being isolated, marginalized, and retaliated against.

One of the most serious shortcomings of the power moral is seen in the context of science classroom experiences and in university and associated professional learning communities. For example, inner-city urban students are often viewed of as lacking in the ability to develop and choose ways to understand science that best suit their interests in the short- and long-term. This is often projected in the language of closing the achievement gap in science and other academic and structural measures (e.g., Norman et al. 2001). The contingency of choice extends to the practice and affiliation we enact, both within and outside the classroom, with students and colleagues. Cognizant of the complexity of social life, the intersections, inscriptions, and the politics of class, racial, ethnic, gender, and other social markers have rendered the production of culture, including identity and agency, fluid and tentative. For example, Michael Omi and Howard Winant (1994) conceive race as, "a concept which signifies and symbolizes conflicts and interests by referring to different types of human bodies (phenotypes)" (p. 55). In this manner race can activate passivity (being inscribed by others without conscious awareness) in the classroom. A Black male student participating in a classroom might act in ways that he feels as affording learning and cooperation, but unknowingly he is inscribed, by other classroom participants, as unlikely to earn high grades. In this way he might find it very hard to build social networks with classmates and the teacher to improve his chances of success. As such, it is important not to perceive others and ourselves as helpless, but in fact recognize that science teachers and students experience passivity and simultaneously act agentially to negotiate and renegotiate how science education is conducted locally and in expanded ways.

Difference does not have to imply a hostile state and the necessity to assert control over the other. The emphasis instead is to look beyond dominant modes to build moral solidarity across difference. Solidarity is an affiliation and a sense of belonging together that produces synchrony (coherence in practice) and shared schema among participants in a field. It is the coming together of multiple ontologies. There are collective and individual responsibilities that are associated with the affiliation. Salient to the affiliation is a feeling that, "I will look out for you," or "I share culture with these people," and there are collective responsibilities and obligations that shape encounters between them. As such, solidarity requires the acceptance of others' culture that binds the collective together, embodied in modes that create synchrony and fluency. The evidence for synchrony might include coordinated eye contact, head movement, gestures, prosody, body orientation, overlapping speech and enactment of rituals. In this manner, rituals (or practices) such as humor, smiles, high-fives, and sharing anecdotal metaphors can aggregate and resemble an ensemble of solidarity. Accordingly, solidarity is an emergent resource created within the dialectic of the individual and collective. It is produced by the simultaneous aggregation and fluent expression of widespread positive emotional energy and synchronous ways of being, becoming, and belonging.

A moral solidarity can also be built around culture that encompasses sameness or difference. Cultural dispositions that are socially acquired in fields outside school, and are shared to a high degree by students can create the type of sustained interest, physical, and emotional entrainment that is critical in the development of solidarity. For example, difference can be characterized by expressive individualism. An individual can express his or her individuality and yet still belong to a collective. As such, individuals experience difference simultaneously with sameness. As described earlier difference is in a dialectical relationship with sameness. To build a moral solidarity that gives students the right to be present in the science classroom and participate, students must have the ability to identify with a group that they like and identify with the subject matter produced as a form of cultural. In addition, students must identify with success and build resources, such as accessing social networks, with what they learn to improve the quality of their lives. Often successful science lessons are not the result of a well-written curriculum or expert teacher (although both are important), but rather the product of a successful cooperation and coordination involving teachers and students. As such, a moral solidarity is important in order to build science identities and create successful encounters in science classrooms across differences. Sharing successes and failures have enabled an ongoing examination for the implication of synthesis-of-choice in addressing the emerging context of being science educators and students, particularly in the urban context. In other words, building moral solidarity increases the potential to afford new roles and responsibilities to catalyze positive change across familiar and different circumstances for teaching and learning science.

Looking Ahead

In the next section, I share critical recollections of a debate that I participated in during a meeting at the 2009 National Association for Research in Science Teaching (NARST) international conference. I offer a brief narrative of some of my own constructions as memories of the debate are brought to consciousness and educative value is attached to these memories. Whereas my participation in the debate emerged precipitously, I was glad to participate in what was at different moments filled with varying repertoires of positive and negative emotions, ferment and friendly agreements. For instance, there were three other colleagues who did not participate much verbally, but showed emotional solidarity that initially indicated tuning in with interest to the emerging debate. Whereas at other moments, they became annoyed that the debate was not timely and took up the greater part of a 1-h open planning meeting; and they tuned out as a result. I focus on general and some specific ideas I tuned into during the debate.

Critique, Debate, and Opportunities for Radical Listening

At a strand meeting at the 2009 National Association for Research in Science Teaching (NARST), a fellow science educator and I got involved in a very vigorous debate over what I would characterize as what it means for teachers to teach and students to learn science in a controlled classroom environment. Although I felt that the entry point for this debate was somewhat awkward for me because my stance is that both teachers and students often negotiate classroom roles and learning how to teach and learn together by being in and with the other, I felt it was very important to take a risk and to enter the debate. Too often university science educators who do not share similar paradigmatic or epistemological outlooks on teaching and learning science do not get to talk to each other (or talk past each other) to find out if there is common ground across differences. Productive engagement enables us to help move the profession along in trajectories that can ultimately help teachers and students. As such, while listening to my colleague, I anticipated my main point would be to assert the salience of culture in understanding teaching and learning science and in thinking about new ways to engage and assess teacher and students.

During my first turn at talk, I asserted my viewpoint that teaching and learning science are forms of cultural enactment and participants in a science classroom experience and appropriate cultural resources to teach and learn science. Immediately there was an effort by my colleague to shut this viewpoint down by requesting that I do not go into the witchcraft of definitions. From my vantage point definitions are important and necessary for science educators to explore and discuss; to talk with each other. Even more important, are surrounding words with meaning and elaborating with examples to create cogent levels of analytical distinctions. This does not mean that definitions are taken as static. In fact definitions are often historically and contextually driven. My main argument here is that definitions exist in the political and power dynamic where the pressure of convention is used to position oneself against the worth and relevance of what others are doing. For example, there have been calls by many in science education, and in other adjacent areas of study, to develop a unifying definition of culture in order to create more systematic analyses of social life. When we refer to culture do "we" mean customs, types of human development, attitudes, behavior, institutions, and social groups (Young 1995)? In my work I view culture as a dynamic interaction of schema and associated practices. Consequently, I also view teaching and learning science as a form of cultural enactment. As such, success in teaching and learning are recognized as gaining fluency by acting in ways that are timely, appropriate, and anticipatory to help meet goals and motives. Culture is both an individual and collective resource that can be simultaneously appropriated, produced, reproduced and transformed with family resemblances and in unique ways. I do not contend that working with other perspectives about culture is methodologically wrong. Beyond states of correspondence and dissonance there needs to be a considerable degree of nuance and elaboration of context that provides an understanding that culture is continuously being produced. Culture is not static. For instance, a new inclusion science teacher entering the classroom immediately experiences the culture (and other structures) being produced in the classroom. The longer he stays in the classroom, the more likely he will appropriate and enact culture in ways that are familiar and fluent in the context of the classroom. At the same time, he co-creates culture with other participants (e.g., new ways of being in and with the other to teach and learn science). Accordingly, culture cannot be approached and defined by single sets of reified concepts.

It was evident from the debate, so far, that both of us faced the polemic of how to link our frameworks to a more productive understanding of science education without descending into slippages of dualisms. Accordingly, it is always important to remember when arguing from certain standpoints of analyses that these standpoints are always constituents of other networks of understanding. For my colleague, it was important that I understood that what ever type of culture was being enacted in science classrooms it was very insignificant compared to setting clear goals and roles for teachers and students to perform. He continued to stress that it was important to give the process rigorous structure, including time, to meet these learning goals and associated objectives. Inherent in this conceptualization is that there exists a straight line between the students (and teachers) as subject and knowledge to be mastered as objects. I took this argument as wanting to move towards a type of pedagogy that, while not totally disregarding context, emphasizes individualism and repetition. Although I do agree that structure, including human, material, time, instruction and policy, are important resources to use to teach and learn science, they do exist dialectically with human agency. The dialectical relationship between the individual and the collective enactment of teaching and learning was missing from his epistemological standpoint. In debating my colleague, I found these moments of departure promoted difference. However, the challenge was not what I would characterize as theoretical difficulty, it was to find ways to continue to engage an emergent perspective that was, relatively speaking, not applicable to move my trajectory of analysis forward.

After several vigorous exchanges the conversation took another turn debating whether it was important for educators to pay attention to how uniquely science teacher and science student identities are constructed. My colleague, used himself as an example, and asserted that it was not terribly important because the identity he constructed as a successful university level science educator could survive without a collective. We both agreed that this was a solipsistic point of view. What would it mean to become a university professor without the university? Why seek to sustain membership in NARST if it did not help to construct social capital that comes along with being part of a prestigious science education research organization? I do not want to set up my colleague as a straw man to beat up on—quite the contrary. There were certainly points of overlap that we promised to pursue. For instance, we agreed that there needed to be a move towards more innovative research that has greater impact on policy as well as innovations in what we may call radical listening. (On such forms of listening in feminist research see chapter 12 by Scantlebury and Martin.) Often there exists a constant reluctance among science educators to embrace radical listening standpoints. Perhaps this is due to both explicit and implicit disregard for the perspective and modes of the analysis of others. Radical listening provides a means for transcending conditions of alienation and alternatively precipitates exchanges that articulate how to learn with others what they already know. At the same time, radical listening calls for critical encounters that construct understanding that respects and extends to the other before imposing questions from countervailing perspectives. Any productive theory and associated practice takes into account competing approaches and responds to particular aspects while deconstructing and appropriating others. Of prime significance is the fact that radical listening provides opportunities to think reflectively about our teaching practices, our peaks and troughs, and challenge us to continue to work toward improving ourselves as responsible citizens and critical science educators.

Although there were moments of levity during the debate, the seriousness of the discussion can be seen from a critical perspective that incorporated aspects of my reflexivity and detachment from the experience. On the one hand, my detachment from the experience allowed me to embrace the possibilities of differences without commensurability. Sidestepping the attachment from moments associated with the debate attempted to provide a third person perspective to interrogate and critique my rational convictions. From this perspective the main critique of my interactions is perhaps my generalizations around teaching and learning as cultural enactment. Although generalizations are continuities of particularizations (and visa versa), they involve particular questions associated with nuanced answers that make theory and practice worthwhile. In accordance, learning, development, and instruction related to science education from my standpoint are articulated and observed as culture that is emergent and gaining fluency (i.e., changing and ready to go). As such, I observe culture and theorize schema embodied in related practices as human development.

From the perspective of my reflexivity (incorporating unconscious and rational convictions), I thought about how the robustness of my standpoint, such as teaching and learning science as cultural enactment, epistemologically operated before and after the debate. Although I saw many theoretical difficulties in my colleague's standpoint, my reaction produced forms of culture that allowed me to be persistent in my standpoint. In this debate, we presented multiple perspectives that were robust and were truly essential in helping us to learn more about each other. However, it also allowed us the opportunity to engage in a way that many science educators may fail to engage. Despite being newly introduced colleagues, we communicated, connected and challenged each other on an insightful level. Of prime significance, is the fact that the debate provided us with a chance to think reflectively about our teaching practices, our peaks and troughs, and challenged us to continue to work toward improving ourselves as responsible citizens firstly and as critical science educators. I realize that the future of science education depends on critical analysis of culture and associated solidarity as drivers of social positioning. In this respect, it is important to work and continue to conceptualize our goals and roles and translate what we know into professional practice. As a science educator, I have become aware of theoretical frames that can be used to describe our practices in recursive relationships to our schema. However, as Tobin (2006) notes, reflective and conceptual objects are no guarantee that a curriculum can be reformed in the ways that teacher and students envision. Science educators must also acknowledge that students are important stakeholders in determining what happens in the classroom, as should all those involved in their education, including parents. However, the creation of moral solidarity in the science classroom is of prime significance in the effort to afford successful teaching and learning experiences. With this comes the anticipation that science educators embrace a renewed responsibility to produce change, become agential within the structures they experience and belong to, and likewise provide numerous opportunities for student empowerment.

Theory and Tension in Classroom Instruction

In a range of different ways, science education has been constructed through the providence and qualification that contain arguments for contemporary and historical resemblances. For example, teaching and learning science understood as cultural enactment is continuous and, as such, immediacy unfolds in singular moments that also generate multiple possibilities for future moments. As such culture is both past and future facing in the moment of production. As culture is enacted it is not just practices (or empirical events) there are also schema that are articulated in the moments of consensus that confront narratives of unfolding science education and science educators. Margaret Eisenhart (2001) noted when conducting (science) education ethnographies and using strategies and text that are commensurate with telling a story about knowledge working in a particular place and time and through ripple effects, the difficult question to consider is: How is knowledge and being constructed? For example, how do science students know with others to start counting drops at the right time or to slowly add more indicator solution in the process of conducting a titration during a chemistry experiment? The arguments about these are often construed at a juncture where theoretical and empirical foundational reference points become possible and begin to cohere. Yet there are always moments of awkwardness and other subjective concerns where complementary approaches in a framework fail to sufficiently orient new syntheses. Here the tenacity of the approach must reassess the origin of the patterns and the transformation of difference in associated contradictions. As such, the opportunities for creating new understandings can encompass new empirical and narrative discoveries and associated theoretical conceptualizations. There are also instances where science educators talk to each other, as exemplified in the vignette presented in the previous section, and find it difficult to overcome incommensurability. In other moments, interacting across boundaries of different methodological positions can provide reconsideration of constitutive constraints and produce productive encounters.

Anna Stetsenko isolates two key ideas involving epistemology, namely the necessity for synergies between methods and associated conceptualization within an epistemic system of inquiry and that “knowing is a meaningful and answerable deed in the sense that it has to do with who we are and who we want to be and become.” The first is developed on the shoulder of Vygotsky’s project where Stetsenko agues for a continuous dialectical process of inquiry that finds renewable and intrinsic self-reflection and establishes commensurability between outcome of epistemic inquiry and associated methods. With this Stetsenko maintains that a Vygotskian core principle is to a dialectic generating constant movement. With this core principle change, and historicity—through commensurability and interconnected moments—intersect and merge with conceptions about the phenomena of social totality and its processes. As such, a dialectical totality—where each part of the whole expresses the other and makes the other and the whole possible—is always in flux. In this manner, the continuous totality of social flux, as expressed in the immediacy of singular moments, provides the continuity of human capacity to enact who we want to be and become (i.e., culture).

One of Vygotsky’s most significant contributions was to problematize over deterministic ways of knowing that separated human beings from history, social networks, and cultural flux. He found activity to be a methodology of how human beings organize (known) and develop human capacity, indivisible and irreducible from the totality of life. As such, being involves one's coming into being in activity. The individual and the collective dialectically constitute this process. However, even with such essential commensurability present experiencing contradictions in the dialectical process is a characteristic that exists as we consider the existence and unity of the whole. There is constant tension in the conception of the whole. Perhaps epistemologically, the significance of the presence of contradiction in dialectic reasoning indicates that patterns of thin coherence in social life are always realized continuously with new and old direction for the whole.

As mentioned previously, I view teaching and learning science as the cultural enactment where human development as both simultaneously being and becoming more fluent. This conceptually poses a paradox: How can you be something that you are not yet? Lois Holzman (2009) also makes this point and argues that the production of the learning environment and knowing as a dialectical process where individuals relate "to who they are and who they are not (who they want to become)" (p. 18). In this conceptualization of knowing the acquisition of what is to be known is not mediated by tools such as language, modes of classroom instructions, and other resources. It is important to understand that tools that mediate knowing do not exist separate from subjective experience and are positioned to connect individuals to the world. Tools are part of the totality of consciousness and enactment constituting the subject-object totality. The process of knowing and the emergence of new ways of being always are co-created as a dialectical whole. For example, goals and motives do not serve as connective links between being and becoming. Being and becoming are simultaneously created in the process of enacting culture. Stetsenko also criticizes well-established frameworks used to theorize knowing as a process where what is to be known exists externally to the individual. For instance, conceptual change theory of knowing explains knowing and learning in terms of an internal process triggered by newly acquired and updated knowledge in conflict with preexisting knowledge. Although more recent models of conceptual change acknowledge the influence of social context, knowing and learning still remain internal processes (e.g., conceptual change occur as an individual's ontology to a body of knowledge changes). Stetsenko also criticizes sociocultural frameworks (e.g., social constructivism) that overemphasizes the collective and ignores the individual inevitably producing a dualism between the individual and collective. Moving beyond these ideas requires thinking about how they resemble and become practice during science classroom instruction.

Science classrooms provide an important space for those who seek the opportunity to learn forms of science that are central to their lives and gain the social mobility they seek. Thinking about how the discussion presented so far in this chapter relates to the context of teaching and learning science in the classroom, there are many dilemmas and opportunities faced by students and teachers who genuinely seek ways to improve experiences in the classroom. Understandably many university level science educators, teachers and students struggle to find ways to improve understanding and instruction in the classroom. It is not purely by coincidence that the system(s) of education, particularly in the United States, confronts teachers and students differently. For example, well-established practices—such as direct teaching from the front of the room or even constructivist oriented project-based learning—still create learning environments that are not mutually constitutive. When students are invited to create learning through project investigation, in the context of a classroom community, learning and development (i.e., gaining fluency) are often seen as being accomplished sequentially within individual participants that report what they come to know to other classroom participants (the community). The term often used is share what you know at the end of the project investigation. As Stetsenko notes, "while merely adding emphasis on the role of social context, social interaction, cultural tools, and other environmental aspects understood as outside factors influence(s) development and learning merely in extraneous way(s)." In this example the tool is the instructive intervention of project-based learning. Invited back into this type of instruction should be an effort to theorize how learning and development occur simultaneously in the construction of the individual and collective dialectic. In this manner, instruction is a resource that is concomitantly created with and is a part of a constitutive environment. As such it is not only a resource but also a source with being and becoming in and with the other. Instruction is neither created nor is it only constitutive of the teachers or policies prescribing curricula.

Continuing the Conversation While Experiencing Difference

A narrative assuming to contain more knowledge about how social life occurred than what was actually created in the moment will often fail to put to use the dialectical tensions and at the same time will fail to nuance generalities and particularities of the story. The idea of generating a narrative to illustrate theory and practice confronts a formidable task to enrich and nuance the text with personal experiences and testimony in the emergence of theoretical understanding. Despite differences in sources of knowing and knowledge there is an urgent need to provide a similar but yet informed manipulation of narrative voices and the subject matter. Accordingly, several important concluding thoughts provide mechanisms to continue the conversation with others.

As an urban science educator, what has truly afforded me some of the positive encounters with students, teachers, other university level educators and stakeholders is a willingness to develop moral solidarity and radical listening to work alongside and with others as colleagues. In the process, we are always recreating our identities by being with and incorporating others in becoming who we are not yet. Although I belong to a university system in NYC, I also belong to NARST and several other organizations dedicated to researching teaching and learning science. This, of course, afforded me the opportunity to participate in the debate described earlier with my colleague. This debate was fortuitous although at times filled with tension and turbulence. Creating a narrative about this experience allowed me to replay, interrogate, and share in text emotions and educative concepts associated with teaching and learning science. What continues to echo in this experience is the right for me and other colleagues to be present and interact across boundaries of difference. Even as I asserted my stance—viewing teaching and learning as a form of cultural production—I came to appreciate the stance of my colleague who viewed learning as objective reality to be appropriated by the knower. Although we do not agree on what all the problems, solutions or even who all our heroes are in science education, how we come to know, learn and become fluent in our actions are still key questions. As such, students, teachers, parents, university educators and other stakeholders must always be invited in to re/explore the constant tension between theory and practice to improve science education. Even as we stand on the shoulders of giants and trailblazers, it is a risk not to do so.

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Chapter 9

Thinking and Speaking A Dynamic Approach

Wolff-Michael Roth*

Much of the work in science education today presupposes some stable entities (factors, variables), including conceptions, identities, opinions, views, attitudes, motivations, or emotions that are thought to be the origin of students' observable behavior. In this chapter, I provide a careful, social psychological reading of concrete episodes from a course in thermodynamics in their historical context. The reading will show that—consistent with the ideas that Lev Vygotsky (1986) articulated in Thought and Language on thinking, speaking, and the relation between the two—actually observed behavior is incompatible with theories that hypothesize conceptions, views, attitudes, motivations as fixed structures that undergo (developmental) change as an individual develops. Vygotsky takes an absolutely dynamical perspective that is inconsistent with much of the work done on knowing and learning to the present day. He suggests that: "The connection between thought and word, however, is neither preformed nor constant. It emerges in the course of development, and itself evolves" (p. 255). In this, he is joined by others, including Bakhtine (1977), who holds that living speech undergoes continuous evolution and to really understand, we need to "understand the word in its particular sense, that is, to capture the orientation that is given to the word by a context and a precise situation, an orientation towards evolution and not immobility" (p. 101, my translation).

In my analyses I show that the thought language relation needs to be thought dynamically, as the product of a dialectical relation, inherently non-deterministic, but once it emerges, it evolves. Thought, language, and the thought-language relationship are dynamic processes that change at three time scales: moment-to-moment (microgenetic) scales experienced in continuously unfolding situations; ontogenetic, individual-developmental (mesolevel); and at historical scales (macro-, phylogenetic levels). As a result, a model is proposed in which thinking is a generative process that changes in and because of speaking so that structure ought

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to be sought not in the thinking itself but in "deeper" processes that generate ever-changing thinking, the consistent patterns of which are as much to be sought in the situationally and contingently available social, societal, and material resources in the setting.

Already in the early 1930s Vygotsky (1986) wrote that

> [t]he relationship of thought to word is not a thing but a process, a continual movement back and forth from thought to word and from word to thought. In that process, the relation of thought to word undergoes changes that themselves may be regarded as development in the functional sense. Thought is not merely expressed in words; it comes into existence through them. (p. 218)

When I first read these sentences, I thought that most science educators probably have not read them, for they would have had to react because of the way in which they fly into the face of pretty well everything that is being done in the field today. First, the relationship between thought and word is not held constant, which means that a word at the beginning of a lesson or at the beginning of an interview no longer expresses the same thought as it does in the middle of these events or at the end. Yet every analysis that I am familiar with takes for granted that the words invariably index pre-existing and specific thought structures. More so, the quote shows that Vygotsky (as Bakhtine) held thought to come into existence through words, which means that we cannot even speak about words as denoting structures of thought, because the thought only comes into existence through the articulation of words. Thus, "the structure of speech does not simply mirror the structure of thought; that is why words cannot be put on by thought like a ready-made garment" (p. 219). Thought is not ex-pressed in words, pressed out of a brain case that contains them and the thought structures they are said to denote, but rather, as Vygotsky noted, thought comes into existence, into being, through words. Thought *is not* before the word.

The changes, even those in the mature mind, as thought realizes and develops itself in speaking are not merely momentary but, as Vygotsky states, "may be regarded as development in the functional sense." This would imply then that when we conduct interviews about conceptions the thought has to be considered as unfolding and changing in the process of the interview itself rather than as the result of a constant structure that is more or less directly made available, ex-pressed or, better, ex-pelled (from Lat. *ex*, out, + *pellēre*, to drive, thrust) by means of words. This is so even when we consider "mature minds," such as those of veteran professors giving lectures to undergraduate students on some introductory topic. Unless the person is reading from a paper or reproducing a memorized text, there are developmental aspects to thought, which therefore has to be considered as an emergent property of the situation rather than as the result of a fixed underlying structure. Vygotsky complained that, "no matter how they were interpreted, the relations between thought and word were always considered constant, established forever" (p. 254). He continues by suggesting that his own "investigation has shown that they are, on the contrary, delicate, *changeable relations between processes*, which arise during the development of verbal thought" (p. 254, emphasis added). And he concludes that all existing theories at his day had in common "their antihistorical bias," studying thought and (living) speech "without any reference to their developmental history" (p. 255). This is also the main complaint of Bakhtine. Accordingly, language has to continuously evolve within situation to be able to evolve on ontogenetic and cultural-historical scales.

In this chapter, I bring together and intertwine two readings, one concerning the video and associated transcript of an excerpt of a lecture in a third-year university physics course on thermodynamics, the other of *Thought and Language*, the leading text on the relationship between language and thought from a social psychological perspective. That is, my reading brings together sociology and psychology; but it is incompatible with the kinds of readings we get in much of the current literature of science education, especially that which focuses on conceptions, views or attitudes on a variety of topics, or motivations. My reading/hearing of the lecture is intended to be no more but also no less certain than that of any of the students in the lecture hall. Readings/hearings are not constructed, but are concrete realizations of the same cultural possibilities of reading/hearing that are also available to others.

A Brief Episode from a Physics Lecture

> Thought undergoes many changes as it turns into speech. It does not merely find expression in speech; it finds its reality and form. (Vygotsky 1986, p. 219)

The entire episode analyzed here lasts less than 2 min and starts when the lecturing professor remarks that he is giving students something about adiabatic demagnetization. It was completed when he noted that there is something wrong about what he has uttered but that they could figure out some time later what if anything was wrong, whereupon he announced moving onto the next topic of the lecture. That is, the professor demarcated the episode as such, as a lecture segment devoted to a particular issue. The following analysis shows that in the course of the lecture episode, the professor communicated in and through the diagram that emerges, which itself is the result and outcome of a developmental process. The data and analyses bring out the fact that the entire episode is marked by mumbles, stumbles, ticks, and conversationally long pauses during which the professor frequently is staring toward the floor or at the emerging diagram on the chalkboard. The analysis reveals little evidence that the speech simply reads out a predetermined text and thought; rather, the thought itself appears to be unfolding, initially evidenced only in and by the naming of the topic to come.

The Set Up

The professor begins by announcing the topic, adiabatic demagnetization, and he also tells students that he has talked about it somewhat ("a little") before (turn 01). He continues by articulating that he already suggested "one possible way of looking" at this process (turn 02), but then stops for a long pause. In the process, he has been drawing two lines that intersect on the bottom left in such a way that they are recognizable by members of the culture as the axes of a coordinate system. The pause is long given that speakers normally pause less than 1 s; research in the late 1970s and early 1980s has shown that most teachers leave less than 1 s time for students to respond when they have asked a question. Therefore, the present pause of over 2 s becomes significant in the sense that most teachers do not leave this amount of time for students to think. There is therefore another possible reason to account for a pause of this length. (For the transcription conventions see the Appendix to this chapter.)

```
Fragment 1
1   i gave you a little bit about adiabatic demagnetization
    (0.22) but
2   i said that [one:: (0.21) ↑POSSible↓ way](0.43) of (.)
    ↑`looking at it
                [((draws ordinate, abscissa]
3   [(2.04)
```

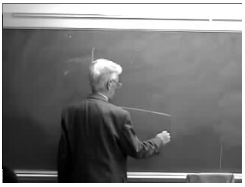
[

The video offprint—a composite of two separate, superposed and blended images—shows how the professor from staring toward the chalkboard changes his gaze and directs it toward the floor. It is as if he is gathering himself up and toward speaking about the way that one can look at adiabatic demagnetization. Despite the announcement of what the forthcoming talk is to be about, this talk itself is not yet produced. One might think that if the topic existed in thought or if the concept of adiabatic demagnetization existed in terms of a pre-given framework, the professor could and would simply read it off. But this does not appear to be the case. The topic, though named, appears to be in undeveloped, sketchy, dim form that seeks to realize it in and through formulation, which, at this point, is not yet forthcoming.

When he begins to speak again, the professor draws out each syllable of "since we are," and then produces another pause of nearly 2 s. During the pause, he gazes toward the end of the horizontal line and his right arm/hand slightly raised and in holding position, as if waiting for the contents of whatever it is to be written. (People wait like this when they know someone else is going to instruct them to write, or we are in such a holding position when we know we want to write something but do not yet know what it will be, waiting for the inspiration.) He then utters "doing an" before briefly pausing again. Then, just as he begins to utter "isothermal" he writes the letter "T" next to its end (turn 04).

Fragment 2

```
4   S::INCE:: WE=ARE:: [(1.95) doing an (0.34) [^iso:^thermal
    (0.90)
                       [[((gazes toward the end of abscissa
```

[

```
                                               [((writes "T"
5   process (0.30) f:ollowed by an [adiabatic isentropic |1
                                   [((writes "S" to ordinate))
6   (0.70)
7   [u::m:::|2 (0.60) ↑DE:↓=process|3 (0.49) u:m:
    [((walks to right of classroom, Fig. 9.1
8   we could get some; (0.36) ↑IN↓sight|4 (0.25) into=it by
9   (1.15)
10  uh on on uh: on an entropy|5 temperature diagram,
11  [(1.50)
    [((walks back toward graph
```

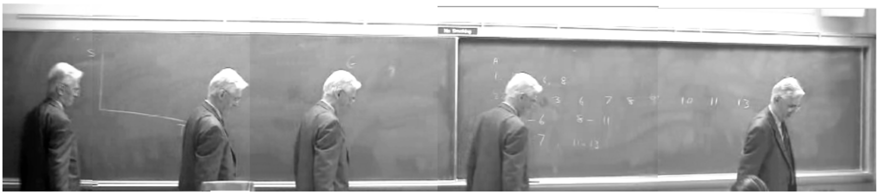


Figure 9.1. While producing utterances in a hesitating manner, the professor walks across the entirety of the front part of the lecture room. (Coincidence with talk is marked in transcript.)

Almost 5 s have passed since the professor has announced the topic that they have talked about before, adiabatic demagnetization, and that he has already talked about a particular way of looking at this process. Vygotsky suggests that "[b]ecause a direct transition from thought to word is impossible … new paths from thought to word leading through new word meanings must be cut" (p. 251). It therefore would and should not surprise that we observe delays such as the ones observed here. Only after the time has passed does the professor introduce two processes involved, an "isothermal process followed by an adiabatic isentropic 'de' process" (turns 04–07). Again, we note the pauses (0.90, 0.30, 0.70, and 0.60 s) that separate the production of the utterances. In addition, succeeding the 0.70-s pause there is a long, drawn-out filler sound "um" (0.83 s) followed by another 0.60-s pause, so that in essence the pause is extended to over 2 s. More so, the concept word then produced is not one that we find in textbooks on this or on other topics, but an invented way of denoting processes where something negative ("de-") is happening. That is, rather than naming the specific process involved, which we later come to learn as being a *de*magnetization, he generically points to a kind of process, a *de*-process. But at this point in time there is no reason to collect a series of processes of the same kind into the same, more abstract category. It is as if the specific term or concept was unavailable and therefore denoted in an undeveloped, generalized form to be realized in a concrete way afterward. That there is time to come can be seen from the fact that the diagram is itself in embryonic state, existing at the moment only in its most generic state, the sketch of coordinate axes.

As before, the professor writes a letter “S” to the ordinate at the same moment that he begins to utter the first of two adjectives, “adiabatic isentropic,” where the connection between the letter and the second word is given in the common century-old convention of denoting entropy by the letter *S*.

After and interrupted by further pauses and fillers, the professor suggests that they “could get some insight into it by/on an entropy temperature diagram” (turn 10). Since announcing the first part of the process (turn 05), the professor has walked across the entire front part of the classroom to its right end (Figure 9.1, turn 10) before turning about and slowly pacing his way back to the diagram. All the time, his gaze was oriented at the floor, in a manner that we might see when someone is looking for his topic and words.

The entire production from turns 03 through 07 is introduced by the term “since,” until the phrase “we could get some insight to it” appears to be picking up again on the idea of “one possible way of looking at it” (turn 02). In this case, the intervening production is an extended clause, in which the premise is articulated and elaborated for the proposed way of looking at the process. In fact, premises usually are stated before the development of an argument. In the present instance, the professor begins with the logical development that follows the premise only to return to the premise once he realizes that it has not been enunciated.

After writing “S” next to the ordinate axis, the professor begins to walk to the right front end of the classroom (seen from the students’ perspective) and returns to produce the first curve 20 s later. In walking away from the diagram, he actually and physically disconnects the talk from the graph itself. In walking away, he directs attention away from the diagram. During the time of the “long march,” he reiterates and elaborates the topic on a meta-level by saying that some insight could be gained into the process on an entropy-temperature diagram. Here, the relation of the thought concerning the purpose for the present situation is physically embodied in the distance to the graph, which is the actual topic to be developed. We see the two levels of the thought enacted and the difference between them enacted in the bodily movement away from the graph and back toward it.

How can we understand this course of events? One way of looking at it is by thinking that the thought to be unfolded only exists in some embryonic form. Here, it might be glossed as “modeling magnetocaloric effect in graphical form,” though even in this form the actual nature thought might have been over-articulated, over-specified, and over-determined. At this point it may not exist other than in some vague idea of using a graph. But there is nothing we have available to test these hypotheses other than that there have been long pauses and hesitating during the production of utterances, which appear to indicate that the thought is unfinished and only in its beginning stages, coming to be realized in the process of talking and writing/drawing.

By this time (turn 10), the professor has set up the axis and has stated the premises for looking at—gaining insight into—a process denoted as "adiabatic demagnetization" (turn 01). He now produces the remainder of the ground against which the process of interest can be modeled. He begins by articulating that there is some schematic, which involves a variation of entropy with temperature (turn 14). He announces that it is "something like that" while draws a curve, to which he then, after a 2.11-s pause, adds the equation "$B = 0$" at the precise time of uttering "no field."

He does not simply draw the curve, but the beginning is itself a drawn out process during which he first places the chalk at some point on the ordinate (turn 14), then gazes toward the lower right in direction of the "*T*," then returns his gaze to the present point moves the hand slightly up and down as if making sure that the starting point is at the right place, and then draws the curve, his eyes apparently closely following the chalk/hand combination until he reaches what comes to be the endpoint of the curve (turn 16).

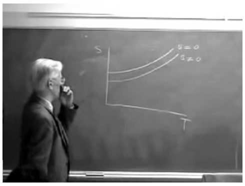
```
Fragment 3
11  [(1.50)
    [((walks back toward graph
12  an=i said the schematic is supposedly;
13  (2.18)
14  entropy varied with temp[erature;
                                 [
```


```
15  (1.74)
16  [something like that,[
    [((draws curve))      [
```


```
17  (2.11)
18  when there is [no field,
                  [((writes "B = 0"))
19  (2.95)
20  and uh:::; (0.39) [<<p>as the curve varied something like
    that;>](.)
                       [((draws a second, lower curve   ]
21  [when; (0.97) there is a field,
```

[

[((writes "B≠0"))
22 (2.48)
[((steps back to look at diagram))

[

Another rather lengthy 2.95-s pause ensues during which he completes the writing of "= 0" before, with some delay, he returns to the ordinate to draw another curve below the first one. This represents whatever is under consideration "when there is a field" (turn 21), which he completes while writing "$B \neq 0$." He then steps back and gazes in the direction of the diagram without talking for 2.48 s. Yet he moves rather quickly and directly from writing the "0" to a specific point below the existing curve to produce a second one, which he equally follows with his gaze as it comes to be realized on the chalkboard. This part of the episode ends with the professor stepping back, as if attempting to see the diagram as a whole, and moving his left hand up to the side of his mouth.

In the transcript, there are repeated indications that the professor has talked about the topic before ("I said [gave]" [turns 01, 02, 12]). And yet, there are long pauses, gazes toward the diagram and toward the floor, and a long walk from the chalkboard to the right end of the classroom and back. The production of this, what comes to be the first part of the episode, its set up so to speak, is far from fluent. This might be surprising if we consider his experience of having lectured for over 30 years and having spent more than 40 years doing research following his PhD. From a conceptions and conceptual change perspective, we might expect him to have a mental structure, which, in case he had forgotten it, should have been reactivated during the previous lesson when he, as articulated, already talks about the phenomenon and gaining insight into it by means of graphical modeling.

As soon as something has been produced, it is a resource for subsequent inspection, which we clearly see in turn 04, where the professor lengthily gazes at the diagram before writing "*T*" and producing the sound that we hear as "isothermal." Similarly, he gazes for a while at the diagram prior to writing "*S*" and uttering the associated adjective "isentropic." He also gazes at both axes, shifts his chalk, then draws the curve, as if locating the new action in the framework provided by abscissa and ordinate. He obviously positions himself, and yet there has to be some prospective orientation to the possible outcome of the talk even though there is indication that it is not yet prefigured. There therefore is an interesting tension in that he orients to what is prospectively the frame of what will be the case after he completes the action, even though what the action precisely will be cannot be known until after it has been produced.

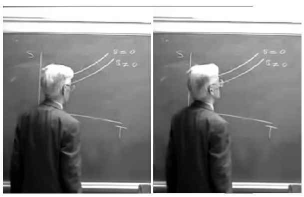
There is therefore little evidence to support that he simply was reading off a conception, opinion, or view on something, for example, from or based on a framework, which he was ex-pressing and externalizing using speech, gesture, and drawing. Rather, there are lots of indicators for the thought as forming itself in and through the verbal (sound), gestural, and graphical production of material resources.

A First Adiabatic Lowering of the Temperature

As announced, the topic of this part of the lesson has to do with "adiabatic demagnetization" (turn 01). After preparing the ground, the professor now announces that he is addressing some first process (turn 23). In fact, the ground can be seen as having been established in and through the announcement that something else is forthcoming, namely a first process. What has happened before, if a member of the audience has not attended to it, is denoted as not being part of the issue at hand because only now does the professor begin to talk about process. He has already articulated that the real issue of this part are two processes, an "isothermal process followed by an adiabatic isentropic … de-process" (turns 04–07). Whatever has been said and done before was nothing but a preparation for what is announced here as forthcoming, a look at the first process. This is said against the ground of the diagram that has been prepared, which we already understand as the ground against which the "one way of looking" at the process can yield some insight.

Although he has announced that the topic is going to be a specific ("the") first process, there are pauses (turns 24, 26, 27), including an especially long one at 3.75 s, before the professor actually begins to draw something onto the diagram (turn 28). He then steps back slightly and looks at the diagram as a whole.

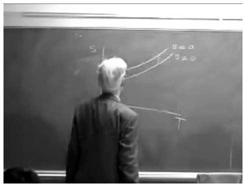
```
Fragment 4
23  when (.) the ‘first process
24  (1.41)
25  when you,
26  (3.75)
    [((stares at diagram, looks from down to up
```

[

```
27  when you; (0.30) PUT the material in a magnetic fie:ld at a
28  constant temperature (0.47) [its just] like ‘that
                                [((draws downward line))
```

[

29 [(1.79)



[

After the long pauses, the professor finally utters what physicists call a phenomenological description, here that of putting some (unspecified) material into a magnetic field at constant temperature (turns 27–28). After a brief pause, he then announces that, "it's just like that" while simultaneously drawing a line straight downward from a point on the line labeled "$B = 0$" to the one labeled "$B \neq 0$." To understand what he is saying, we have to backtrack for a moment. This part of the episode begins with the announcement of a first process, which itself is part of a presentation that is to gain insight into "adiabatic demagnetization" by looking at it in some unspecified way, which may be the graphical way he is in the process of developing. (Which we do not know with certitude.) The first part of the process is being described phenomenologically, so that we can hear that whatever has been described "is like that" where the indexical term "that" refers to the line. This line, therefore, may be part of what has been announced as a possible way of looking at the process as a whole.

Once this "first process" has been described and represented in the graph, the professor steps back and looks at the graph as a whole, as if contemplating what is there available on the chalkboard. What is going to be the next step? And how does it relate to what has been said and represented? The lengthy pause is indicative of the time required for preparing the next process, which is a function of what has happened so far. Again, this is not evidence that the professor simply "spills the beans" or "empties his mind" relative to this introductory topic of thermodynamics—after all, such graphs have been in the physics literature since the beginning of the twentieth century—but that the thought itself is developing. It is not just developing by concentrating on itself, but, as the gaze and inspection of the present graph suggests, uses previous realizations of thought as the material for thought to move on and further develop the current idea. If this is taken momentarily as a hypothesis, we can then find confirmatory evidence in the immediately following events. Readers are encouraged to note the hesitating production, which is evident both in the verbal as gestural and graphing modalities (Figure 9.2).

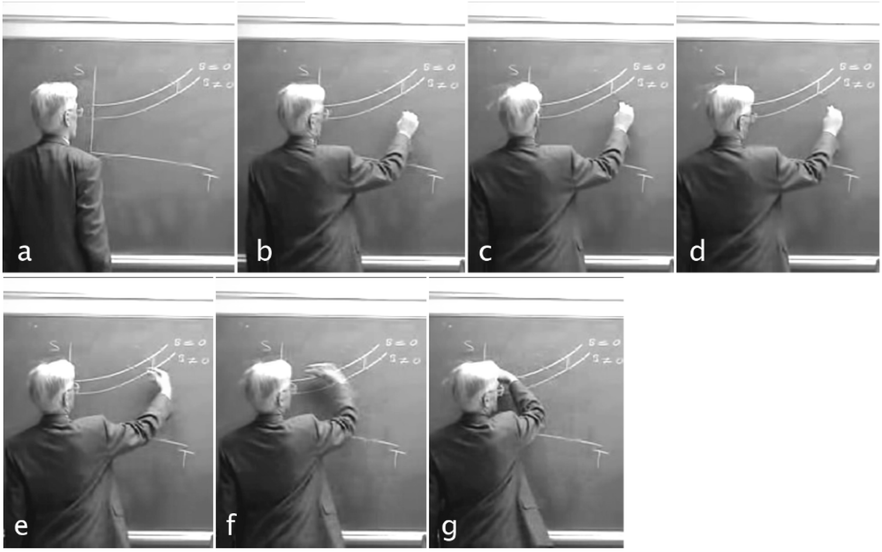


Figure 9.2. Video offprints corresponding to transcript lines 29–31.

With pauses, repetitions, drawn-out syllables, and filler sounds, the professor than announces the second part of the phenomenon: an adiabatic demagnetization (turns 31–32) followed by a repetition of an earlier utterance "it's that" during which he draws a horizontal line from the intersection of the vertical with the $B \neq 0$ curve toward the left (turn 33). Prior to actually drawing the line, we can observe the professor shifting his gaze across the graphic as a whole, his hand rests on the board, moves away and then engages in a gesture, prior to the actual drawing of the line with the chalk. Here, the gesture anticipates what is to come. The gesture is the developing idea in progress, and once it is realized, it is then transcribed into the line. (There is other evidence that the idea emerges together with such gestures rather than preceding them.) The gesture is actually a form of epistemic action, thinking as occurring in and as of the hand movement, rather than as happening in some region of the brain, though some brain activity is indeed involved in making the hand move. But the possibility of the epistemic action itself exists at the same time that it is realized concretely, for otherwise it could not be recognized as such.

```
Fragment 5
30  a:nd when you; (0.95) uh:::
31  that when you when you then uh a:dia:^batical[ly::] (0.53)
                                                 [((gesture
    horizontal))
32  demagnetize it, (0.44) it uh::::
33  (0.30) [y its 'that]
           [((draws line horizontal
34  [and so] its temperature is lowered.
    [((horizontal gesture
```

Here again, we observe a lot of hesitation. The gesture that the professor produces prior to drawing some iconically resembling line prefigures what is to come. Here, an idea appears to emerge in the very moment that it is being configured. Rather than immediately drawing the line, which one might expect if the idea had already existed, the hand movement appears to stand for the thinking itself. It is only once the gesture and the line have been drawn that the professor utters the second part of the phenomenological description, “and so its temperature is lowered.” This articulation is actually preceded by another gesture that traces out an ephemeral path iconically related to the line now present, itself iconically related to the epistemic action (gesture) that not only announced its forthcoming but also produced the very possibility of this future event.

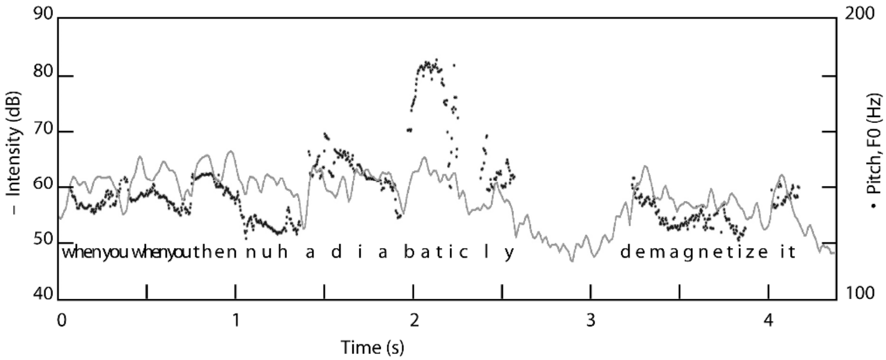


Figure 9.3. The pitch and intensity contours for a stretch of speech point to the psychological subject, which here is an adjective rather than the verb (“demagnetize”) or the grammatical subject (“you”).

In this context, we also note the role prosody plays in pointing to the psychological subject of the utterance. To Vygotsky (1986), the lack of “accord between syntactical and psychological organization” (p. 221) is a cornerstone in the argument for the separate developmental trajectories of thinking and speaking. Using the statement “The clock fell,” Vygotsky shows that depending on the situation and setting, either the clock or the falling may be the subject (content) of the message independent of the grammatical organization. Grammatically, however, the clock always is the subject and the falling the predicate, independent of situation and setting. Speakers use prosody, without being conscious of this fact, to point to and make salient what listeners ought to attend to as the content (subject) of their utterances. In Figure 9.3, I present the utterances from turns 31–32, “when you, when you uh adiabatically demagnetize it.” The PRAAT produced temporal analysis of pitch and intensity shows that the adjective “adiabatic” stands out both in terms of the pitch and speech intensity (volume) from the remaining talk and therefore comes to be emphasized so that it can be heard as a the topic (subject) of the present utterance.

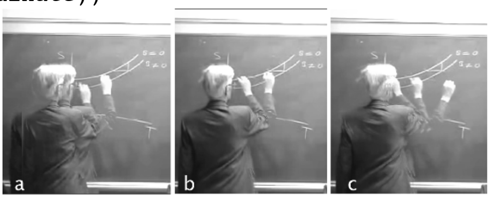
The filler (interjection) “uh” is at lower mean pitch (126.6 Hz) and intensity (60.47 dB) than the preceding talk representing a restart (137.1 Hz, 62.37 dB).

The first part of the utterance “adiabatically” has means of 145.6 Hz (pitch) and 61.37 dB (intensity), whereas these values rise to the central part of the utterance, 173.8 Hz and 62.04 dB, respectively. In the last part of the utterance (“demagnetize it”), the mean pitch and intensity drop to 130.2 Hz and 58.03 dB. Phenomenologically, we hear the word adiabatically stand out, the “batic” more so than the remainder of the word, itself standing out from the surrounding talk. Thus, although the grammatical subject is “you” and the predicate is “demagnetize it,” it is the adverb “adiabatically” that stands out and thereby becomes the true, psychological subject of the sentence. The listeners are called to direct their attention to the fact that what is happening, the demagnetization, is occurring in an adiabatic manner. It is this the core of the physical phenomenon, without which the demagnetization would not produce the decrease in the temperature and therefore not the phenomenon of the magnetocaloric effect required for cooling substances close to the absolute zero temperature.

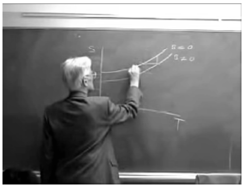
Going All the Way to There (Zero)

After the first set of processes, which constitute the phenomenon of interest as announced in turns 04–05, there is a period of long pauses and repeated hand gestures from right to left (see off prints in transcription turn 37). As in the previous subsection, the gestures appear to be testing and laying the ground for what is to come, a thought realizing itself not internally but right there in front of our eyes. It is as if the professor did not know what to do next, and the repeated gestures produce ephemeral test traces. It is only with the third such gesture that the professor then draws an actual chalk line but very slight, as if sketching out the ground to be able to place the actual lines (turn 37).

```
Fragment 6
35  (1.63)
36  a:nd uh: (0.44) kh:m
37  (2.31)
    [((gesture left, right))
    [((another gesture to ordinate, back to below first line))
    [((at end of third gesture, he makes a weak line parallel to
    abscissa at the height of the intersection of the B = 0 graph
    with the ordinate))
```

[


```
38  and then i<<acc, dim>i said [it by the ^time you get to>
    ↑`HE:re
```

[

```
39  (2.27)
    [((looks at graph at length))
40  <<all,dim>when you put it in [a magnetic field and that we=re
    kind o
                                       [((hand below end of previous
    line, Fig. 9.4
41  [and by the time you get> to here when you put it in the
    mag[netic]
    [((places hand to the left end of horizontal line))

    [((draws downward line))
42  field it goes like> ↑the:re
43  (1.73)
44  and then when you demag[netize it, (0.55)  <<p, dim>it go]es
    all the way there;>
                                 [((draws line right to left))]
```

[

He then moves his hand around the diagram vertically from the intersection of the first horizontal line with B = 0 to a point below, to another point again suggesting that he has already told the students about it (“I said” [turn 38]). He looks at the graph again during a longish pause in talking and then places the chalk on the $B \neq 0$ line just below the intersection of the horizontal chalk line with the $B = 0$ graph. He then moves the hand upward and places the chalk at the intersection and, in the process of describing the phenomenon of putting the substance in the magnetic field, draws a downward line (Figure 9.4). In the course of the utterances (turn 40–41) his voice is fading away, as if he were not sure of what he is saying to become almost inaudible. Another pause follows before the professor continues the phenomenological description, “and then when you demagnetize it … it goes all the way to here” (turn 44). Simultaneously with the latter part of the utterance he draws a line from the intersection of the second vertical with the $B \neq 0$ graph parallel to the abscissa until he gets to the point where the $B = 0$ graph intersects with the ordinate. Again, his voice completely fades away as if he were not convinced with what he is in the process of producing, verbally and in drawing.

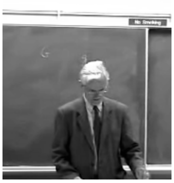
Figure 9.4. The hand and chalk move to different places, as if uncertain about where to put the next line.

In this situation, the hesitations in the delivery of the speech, the repeated fading away of the voice, the repeated gestures preceding the actual drawing, and the movement of the chalk to different places on the diagram before actually finding the place from which the next line is to be drawn all are indications that the accompanying thought is not finished. Rather, it is that thought is finding itself in the production of the outward signs, which are always productions for the students in the class attending this lecture.

Assessing the Thought as (Possibly) Wrong

The final part of the episode prior to announcing the movement to a new (sub) topic consists of the assessment that was has happened in the previous 2 min is wrong. More so, the professor indicates that he has already “said before that there was something wrong with that picture.” At least, he might have said it (“I think I said”). He therefore has produced the “picture” of a process that he had done once before, and he announces that he already had denoted it then as being wrong. Hesitatingly he has arrived at producing the “picture” in a way that he now recognizes as the same as the one he previously produced, and he now, as then, is uncertain about its correctness. He walks toward the desk where his notes are placed and begins to turn the page, clearly staring at the first and the second one, without finding an answer to the question about the correctness.

```
Fragment 7
45  (0.35)
46  we=ell i ↑think I ↓said there [was something::: (0.23)
                                  [((questioning  grimace,  walks
    toward his notes))
47  wrong with that picture
48  [(0.87)                                ]
    [((grabs page in his note, looks at them))]
49  [a:n:d uh:::   ] (0.79) wel=well:: uh: we=ll maybe see:: (.)
    [((turns page))] [((continues to stare at page))
```



[

50 a little later=on:: wha <<dim>what if anything is wrong with it.>
51 (0.62)
52 in the ^MEAN:time i want to talk about nernsts heat theorem

He does not actually know "what if anything is wrong with it" (turn 50) and announces his hope ("we'll maybe see") to see some time later on what is wrong. That is, the professor not only produced a series of utterances constituting one of the topics of his lecture, but also, in the end, declares being uncertain about whether what he has said and done is correct. Any theory of cognition that presupposes cognitive frameworks as the source of what people say, during lectures, laboratory exercises, discussions, or interviews, might well wrestle with situations such as this: from such perspective, this episode may well be an intractable problem. Granted, the professor could have forgotten what the topic is about since the previous year or previous time that he lectured on it. But surely he admitted to having talked about the topic to this class before. That is, he would have already have engaged in the effort of remembering. He also announces that he had indicated doubts about this before. There is also considerable evidence that he does not produce this lecture segment from memory, but that it is produced in real time and that the associated thought develops as the professor articulates himself in speech, writing/drawing, and gesture.

Developments at Longer Time Scales

In *Thought and Language*, Vygotsky (1986) intimates that the relation of thought and language evolves and changes over three different time scales, the microgenesis of thought in the moment, a longer timescale that corresponds to learning and development, and a historical time scale. Vygotsky conceives of thought as a process that moves "from primitive generalizations," the germ cells of thought, "to the most abstract concepts" (p. 213). Such development can be observed on three characteristically and distinct time scales: cultural-historical (phylogeny), individual developmental (ontogeny), and situational (moment-to-moment unfolding). Correspondingly, both the content of words changes at these three time-scales and "the way in which reality is generalized and reflected in a word" (p. 213). This also implies that word meanings are not constant but rather develop, an implication that Vygotsky himself considered to be "the major result of [his] study" (p. 212). In other words, he is concerned with the development of meanings "from the first dim stirring of a thought to its formulation" (p. 217).

Individual Development

In the context of the present lecture, there is evidence of development at time-scales exceeding the moment-to-moment unfolding of communicative production. We already have heard the professor indicating that he has talked about the topic and graph during a previous lesson. He returns to the topic again for a third time some 20 min later. In the intervening time, the professor has produced a number of additional mathematical inscriptions. Among these is an equation that he denotes as the Gibbs-Helmholtz relationship.

$$\Delta H = \Delta G - T\left(\frac{\partial \Delta G}{\partial T}\right)_p \tag{9.1}$$

The professor first suggests—incorrectly so, as it turns out—that one term of the equation, $(\partial G/\partial T)_p$. would be zero when the temperature reaches zero. After staring for a while at the equation, he then writes "$T \rightarrow 0$" and "$G \rightarrow H$," pointing out that when the temperature of a sample approached absolute zero (0 Kelvin), the *G* (i.e., Gibbs free energy) and *H* (i.e., enthalpy) become equal. He moves on to suggest that this "has a number of consequences," the first one being "$S = 0$ as $T = 0$."[6] He then goes on for a couple of minutes elaborating on the fact that $S = 0$, sketches partially several equations because, as he says, he does not remember them in their entirety, and then announces, while turning toward the chalkboard and pointing toward the graph, "another consequence is that." He stops talking, stares at the graph for a while, then walks the 2.5 m in front of the graph to his notes on the desk and turns around. He then announces, "this is wrong," walks to and erases the graph in silence, and then produces the set of axes again and a pair of curves that—this time—intersect each other at the origin as required by classical thermodynamics.

In this situation, therefore, the professor first produces the graphical representation of the magnetocaloric cooling during one lesson. He reproduces it a second time in the episode analyzed here, again in a manner that he is uncertain about its correctness. Finally he produces another version and this time it is to his satisfaction and in a manner that other physicists would accept as representing the canon. This graphical representation, however, and the particular way in which the professor approaches the teaching of the concepts of entropy and adiabatic cooling processes, cannot be understood outside of their historical contexts.

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6. In Walter Nernst's formulation of the third law of thermodynamics, the entropy is at a minimum value when $T = 0$. The actual value of this minimum is an arbitrary constant and has been fixed to be zero ($S = 0$) when $T = 0$. In this chapter, I am not concerned with the errors in the physics content that the professor produced while lecturing but focus on the communicative processes during lectures.

A Brief History of the Entropy Concept

Historically, we have to understand the lecture in the context of the evolving field of physics, and *this* lecture would have been impossible, for example, in the nineteenth century when the concept of entropy was first invented and developed. Moreover, the lecture deals with the magnetocaloric effect, which itself, though initially discovered in 1881, was independently proposed in 1926 as a means of reaching very low temperatures close to absolute zero. That is, some topic cannot be taught until it comes into existence. Generally the concepts are at the cutting edge of the culture and therefore inaccessible to novices. However, over time they are transformed and become so much part of the canon of the field that even undergraduate students will eventually be able to understand it so that the topic becomes part of textbooks.

In the eighteenth century, when James Watt was working on the steam engine, the concept of entropy did not exist. James Watt had described the various states of his engine but the scientists and engineers—many of whom were self-taught—of the day were not interested in attempting to understand its working. The effort to do so really got under way when the French engineer Sadi Carnot picked up on the work and described the steam engine in terms of the processes known today. The German physicist Rudolf Clausius noted that during adiabatic compression and adiabatic expansion cycles in the Carnot cycle, there was some constant quantity, the relation of heat to temperature at the beginning and end states of the process, that is, Q/T. To produce a close association with the term energy, he chose the term entropy for this new quantity. The chemist Walther Nernst subsequently formulated a theorem about heat, now known as the third law of thermodynamics, which may be stated in this form: In an isothermal process involving pure solids and liquids, the change in entropy approaches zero as the temperature approaches absolute zero. Max Planck later restated the principle in a more general form: The entropy of every actual substance in the pure state is zero at the absolute zero of temperature.

Lectures on the topic of entropy likely changed already during the nineteenth century with the work of the Austrian physicist Ludwig Boltzmann. Whereas earlier approaches to the question of entropy were based on the phenomenological meanings, that is, as encountered in the laboratory—the heat engine—and observable quantities, Boltzmann expressed entropy in terms of the statistical properties of a system: a system is going to move to that state which is most probable and the entropy S can be expressed as the natural logarithm of the number of natural states Ω available to a system and some constant k, which has come to be called the Boltzmann constant ($S = k \ln \Omega$). Entropy now has come to be understood in a radically different way, which further changed when information theorists derived the same equation for the informational content of a message. At the beginning of the twentieth century (around 1917–1919), chemists were interested in the concept and determined the entropy for various pure substances as a function of temperature. The first entropy–temperature diagrams for substances other than H_2O (ice, water, steam), including the ones our professor used, emerged in the literature in the 1920s, when Willard Gibbs pointed out that such diagrams graphically illustrate not only the work involved in a reversible cycle but also the heat. At the time, the discourse about entropy was being developed and certainly not yet suitable to be taught in undergraduate courses. But though thought to be suitable and insightful, my survey of about ten university texts shows that these graphs are not being taken up in undergraduate teaching, such as the temperature entropy diagram used in the lectures analyzed here, which appear only in very few textbooks in chapters on the second law of thermodynamics and entropy.

Ideas and presentations of entropy changed again with the discovery and development of the magnetocaloric effect. Forty-five years after its initial detection by the German physicist Emil Warburg (1881), Peter Debye and William Giauque independently proposed in 1926 refrigeration using the magnetocaloric effect to reach low temperatures. Physics textbooks written in the 1960s would include the effect as one of the ways in which temperatures near absolute zero could be reached. It is this effect that is the subject of the lecture episode featured in this chapter.

Which topics and conceptualizations are taken up and become topics in undergraduate courses requires a cultural-historical study. Sometimes, new conceptualizations rapidly enter the pedagogical canon whereas other suitable conceptualizations do not. Thus, although there changes in conceptualization are proposed and although these conceptualizations are suitable for teaching, they are not taken up in general classroom discourses. For example, a radically different way of conceptualizing thermodynamics was proposed by Constantin Carathéodory, who developed and presented in 1909 his "Untersuchungen über die Grundlagen der Thermodynamik" (Investigations of the Foundations of Thermodynamics) an axiomatic approach in which the phenomenology of substances completely disappeared. Based on the principle that for any state of some unspecified substance, describable by some set of variables, there are states in its neighborhood that cannot be attained by adiabatic paths. But its presentation was so complex that even experienced physicists and chemists did not easily take it up. The original formulation was quite difficult to understand, but repeated expositions and elaborations allowed the eventual articulation of the theory to make it suitable for inclusion in undergraduate textbooks by the mid-1960s. The ground for this development was laid in a 1949 article by Hans Buchdahl that appeared in the American Journal of Physics, which suggested a presentation that could be "understood by undergraduates in their second or third year of physics." Yet despite these developments, the axiomatic approach has not been taken up to any noticeable extent in the teaching of thermodynamics at the undergraduate level.

Emotion

Already in the 1930s, Vygotsky (1986) complained about the "weakness of traditional psychology," which derives from its separating intellect and affect. This separation "makes the thought process appear as an autonomous flow of 'thoughts thinking themselves,' segregated from the fullness of life, from the personal needs and interests, the inclinations and impulses, of the thinker" (p. 10). This absence of emotion as a constitutive moment of thought continues to this day. Bakhtine (1977) had the same complaint and points out that the affective-volitional aspect of thought reveals itself in speech itself, in the form of intonational (i.e., prosodic) variations. Emotional qualities are available also in the lecture episode under study.

When the professor launches into his lecture about the adiabatic cooling process, we can observe him gathering up and then launching into a process that he has not yet thought about. There is an intention that drives the entire event, but the intention cannot be more than some general frame that allows freedom to realize it. But with this gathering up, there is also a particular anticipation that what is coming is to be for some end, and once achieved, there is a satisfaction with having achieved whatever it turns out to be. In the end, however, the goal has not been met; the thought that has been developed before the audience in and through the articulations across various expressive modalities (speech, gesture, writing/drawing), has not achieved the insight announced. Such non-achievement of goals generally is associated with a negative valence. This negative valence expresses itself in the production of the reflection on what has happened, as thought turns upon the product of its own immediately preceding labor.

In the present instance, the professor has wanted (as declared) to explain something only to find himself in a situation where he does not know whether he has achieved what he wanted to achieve. He articulates the great likelihood that he is wrong, though he is not certain about it. When considering the relationship between thought and language, we must not forget other aspects of mind, most importantly the role of affect and its relation to thinking. Using a voice analysis software package (PRAAT) we can evaluate some "objective" parameters and changes therein (Scherer 1989). Such parameters are linked to the emotions and emotional changes. In the present, the professor begins with the declared intent to lecture on the topic of "adiabatic demagnetization" and the associated decrease in the temperature of a substance to, as the unfolding lecture shows, absolute zero temperature. But in the end, he concludes that something appears to be wrong with what he has been saying, though he is not quite sure.

When we compare the voice toward the beginning of the lecture segment with the voice toward the end of the lecture segment, we notice marked decreases in pitch (F0) (between 160 and 190Hz to below 130 Hz), pitch variability (from 121–210 Hz to 88–153 Hz), and pitch contour (constant to downward). The speech intensity decreases considerably (around 65 dB to below 59 dB). The speech noise to harmonics increases. The speech rate has decreased from a normal 5.9 syllables per second to around 4.7 syllables per second and even slower rates. The voice repeatedly fades away into very low intensity. All of these changes are objective indicators of sadness/dejection (Scherer 1989), which we can actually hear in his voice at the mesolevel (ethnographic) analysis of the videotapes. A low level of pleasantness, high relevance, discrepant expectations, obstruction, and low urgency to resolution characterizes this emotion. Control levels are low to non-existent, and the level for adjustment is medium. We see the professor leaf through his notes as if looking for an answer to the present situation, but when there is none, moving on to the next topic.

Thought is not some epiphenomenon; nor is the behavior of human beings something determined by internal or external structures. Rather, the thought is inhabited from the inside by the intent to provide an articulation of the adiabatic cooling process, and it is towards the realization and completion of this intent that everything that happens is oriented toward. In the present situation, we can observe the integral nature of thought and emotion, as the professor publicly articulates for his students not only concerns about the correctness of the accomplished thought shared and developed in and through his articulations, but also the emotions that cannot be dissociated from the very articulations that realize thought, here, concerning the evaluation of thought itself.

Current (psychological, sociological, social-psychological, anthropological) theories of knowing and learning generally do not explicitly deal with emotions; and certainly not as a core aspect of thought. If they are included at all, then emotions are considered as factors of a separate, affective system that somehow diminishes thought from the outside. In Vygotsky's thinking, however, emotions are the very source and origin of thought. Thus, if we do not include the study of emotion at the core of the study of intellect then we have no means of understanding the reverse mediation: of thought on affect and volition. It is not surprising that we find in subsequent elaborations of cultural-historical activity theory emotions and their associated valences—motives, motivations—integral moments of all human collective motive-oriented activities and individual goal-oriented actions that realize the activities.

Semantic, Pragmatic, and Syntactic Issues

Word Meaning: A Developmental Process

A confusing aspect of the scholarly literature is the term meaning. Generally it is treated as something that somehow is attached to words, such as when students are said to "make [construct] meaning," which then comes to be a property of the word. For Vygotsky, meaning is something different. Thus,

> [t]here is every reason to suppose that the qualitative distinction between sensation and thought is the presence in the latter of a *generalized* reflection of reality, which is also the essence of word meaning; and consequently that meaning is an act of thought in the full sense of the term. (p. 6)

Here, the essence of word meaning comes to be found in "a *generalized* reflection of reality." The generalized reflection arises from the fact that words do not refer to single objects but to groups and classes of objects. Even in a simple utterance "This is a tree," we see the generalization at work, as whatever singular, definite thing (picture, photo, actual) the person indexes ("this") with or without pointing is predicated to be something of a kind, as indicated in the indefinite article "a." Seeing is (the result of) a sensation; seeing something (specific) *as* something (class) constitutes a qualitative difference, is in fact a dialectical leap: "not only between total absence of consciousness (in inanimate matter) and sensation but also between sensation and thought" (p. 6). Because the essence of word meaning is the generalized reflection of reality, a form of consciousness (knowing together), meaning comes to be an "act of thought," a process rather than an attribute of a word. Thinking is singular, verbal thinking is not, because in making use of language, verbal thinking is already oriented toward the generalized other, from whom the language has come to the speaker, and to whom it returns.

Words and the utterances they make are recipient-designed; if they were not, it would make no sense to speak. Vygotsky locates word meaning at the intersection of private thought and public language so that we cannot detach anything like word meaning from the particular situation in which the word is uttered, and therefore, from the audience that it is uttered for. The analysis of word meaning, language, and the reflection of reality (thought, consciousness) requires the cultural-historical analysis of the situation as a whole. A lecture on the topic of adiabatic cooling would have been different some 50 or 100 years ago, and it is likely to differ from a lecture on the topic some 50 years hence.

Vygotsky decried that all psychological schools of his days studied "word and meaning without any reference to development" (p. 217). Yet this continues to be the case when, for example, science educators of all sorts of brand analyze classroom and interview transcriptions as if the words at the beginning, middle, and end had the same meaning and reflected the same thought. "Thought and language are not connected by a primary bond" (p. 210). "It would be wrong, however, to regard thought and speech as two unrelated processes, either parallel or crossing at certain points and mechanically influencing each other" (p. 211). The analysis of the lecture in this chapter shows that we require a different approach, one that takes thought, speech, and word meaning as developmental processes rather than fixed structures. Thought finds in its own articulations resources for development, making it both contingent and passive at the same time that it is actively pursuing development and expression.

"If word meanings change in their inner nature, then the relation between thought and word also changes" (p. 217). This change not only observable during ontogeny, the development of individual minds, but also is a characteristic of "the relation between thought and word in the mature mind" (p. 217) at the moment it emerges, makes itself present in and through communicative productions. Vygotsky was equally concerned with changes during development, over long periods of time, as he was with the development of meanings in "the way they function in the live process of verbal thought" (p. 217). In their conceptualization of the cultural-historical changes language undergoes, Bakhtine points out that only if change is inherent in every single production of speech do we get to a dynamic perspective on language that is consistent with the dynamic changes we can observe languages to undergo even in our lifetimes.

In the traditional literature on meaning, it is something learners "construct" in the process of engaging with the topic of their science courses. This literature presents the situation as if students make something that comes to be attached to words and languages they use. But from a phenomenological perspective, meaning is not something that accrues to words; rather, it is the other way around that words accrue to meaning, which can be thought of as a network of living relations of significance that characterize each moment of lived praxis. This phenomenological formulation, however, does not help us much further unless we clarify the usage of the term meaning in the two situations. For Vygotsky, word-meaning lies somewhere between the singularity of inarticulate and unarticulated thought and shared language. In language, according to Vygotsky, words have their places, as there are different ways in which they can be employed, that is, there are specific senses that a word can take. This sense changes from situation to situation and from application to application. The sense or senses a word can take is specified within the sociocultural and cultural-historical context. The senses of a word represent different forms of generalities. Individual thought at its very beginning, before it becomes verbal thought, is utterly singular. But the moment it realizes itself on an internal plane, as verbal thought, it comes to inhabit a space that is both singular and general: the word references inarticulate and indeterminate, singular thought and relates to one or the other publicly shared forms of sense. It is precisely at this intersection of the utterly singular and commonly shared that I shall locate meaning.

"Every thought tends to connect something with something else, to establish a relation between things. Every thought moves, grows and develops, fulfills a function, solves a problem" (p. 218). In the present lecture, the goal of the thought to be evolved is to present a way of looking at the topic that provides a new and different insight. The insight comes from the fact that there are new relations that are (to be) established, which then give a different perspective on something known in a different way. Thought thereby fulfills a specific function, namely, the elaboration of a situation that gives rise to the announced insight and therefore to the further development of thought. The problem to be solved is that of coming up with a way of presenting adiabatic demagnetization so that it gives rise to a new insight.

On Syntactic, Pragmatic, and Psychological Subjects

Grammar (syntax) is an achievement rather than the cause of the utterances (Roth in press). It is therefore not legitimate to use formal grammar as a tool in making logical inferences from the spoken word about the topic of the thought. Any research inferences need to take into account the differences between syntactic, pragmatic (who is speaking), and psychological subjects (topic) of an utterance, differences that are relevant and have to be worked out in the concrete details of the situation. Take the following utterance from the lecture in which the psychological and the grammatical subject are different.

```
1   i gave you a little bit about adiabatic demagnetization
    (0.22) but
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Vygotsky makes a distinction between the psychological subject, the topic, and the grammatical subject of the sentence, which is completed by the predicate. Here, the "I" is the grammatical that indexes the pragmatic subject followed by the predicate gave and the remainder of the complement. Psychologically, however, the topic is not the professor or that he has said something but the adiabatic demagnetization that is the topic of this lecture sequence. "Accord between syntactical organization and psychological organization is not as prevalent as we tend to assume—rather, it is a requirement that is seldom met" (p. 221).

"Not only subject and predicate but grammatical gender, number, case, tense, degree, etc., have their psychological doubles" (p. 219). This psychological subject, the core of the thought that expresses and develops itself in plain sight, can only be disclosed in the consideration of the situation as a whole. For example, when the professor walks away from the diagram, the audience may legitimately take him to talk about something else than that which is expressed and to be developed in the diagram. Prosodic changes, changes in the body orientation away from the diagram and to other discernable moments of the setting also provide resources for understanding just what is being communicated at this moment in time. For Vygotsky, "the simplest utterance, far from reflecting a constant, rigid correspondence between sound and meaning, is really a process" (p. 222). The present, close analysis of a lecture intimates that we need to go beyond the mere word but to other aspects of the sound (prosody) and other expressive means that are part of the communicative whole.

We can take the entire episode as one where the unfolding thought concerns the announcement of a possible way of looking at a graph that the students have seen before and that from this perspective insights are to be gained. But as the thought attempts to articulate itself, it realizes that something is missing and so effort is devoted to articulating the premise to the thought of gaining insight. But by the time the entire graph has been reproduced, doubt emerges about the correctness of the graph and the possibility of gaining insight. Vygotsky thought that, "the flow of thought is not accompanied by a simultaneous unfolding of speech. The two processes are not identical, and there is no rigid correspondence between the units of thought and speech" (p. 249). In part this may be because he never considered communication other than speech and the relation of thought to language, disregarding in his analyses the other changes in the setting that are part of the communicative production and that audiences can talk to make sense of what is going on. So we can understand when there are changes in the nature of thought, for example, when it is directed at aspects of itself or some of its earlier productions whenever the professor takes a "reflexive stance," which, for the audience to understand, is/has to be indicated in some fashion. The thought concerning the magnetocaloric effect that the professor denotes by the term "adiabatic demagnetization" and the metalevel thought about gaining insight from the representation that is to be available some time down the road in this lecture have different content (psychological subjects); and these differences are available in the bodily orientation that the professor (pragmatic subject) takes with respect to the diagram that is itself developing.

"Experience teaches us that thought does not express itself in words, but rather realizes itself in them" (p. 251). The brunt of this sentence could easily be lost in a quick reading, and we ought to take a closer look. How can it be that thought realizes but not expresses itself in words? Is not the expression in words a realization of thought? Of course, the problem arises within a particular ontology that has thought preceding and being the cause of words. A very different perspective arises if we consider thought and word as mutually constitutive and mutually presupposing phenomena. The words we hear are sounds, and as such pertain to the world of material objects, that which we can sense. Thoughts are part of the ideal. In speaking, ideal thought realizes itself such that reality now is expanded, and this expansion is reflected in an expansion of thought, an aspect of consciousness, which is a reflection of reality on the plane of ideality. The reality in the case of the situation is a lecture by the professor for the students for the purposes of assisting them in acquiring course credit and degree. Reality and ideality stand in a dialectical relationship, leading Vygotsky "to study experimentally the dialectics of transition from perception to thinking" (pp. 255–256) with the result that he could "show that a generalized reflection of reality is the basic characteristic of words" (p. 256). As a consequence, words (which are but material sounds) cannot be thought independently from thought but the two stand in a dialectical relationship: "thought is born through words. A word devoid of thought is a dead thing" (p. 255). Each of the two terms presupposes the other. The word, for Vygotsky, is a Being animated by thought; and this Being, that is, the word, is absolutely essential for thought to exist.

In the process whereby thought becomes word and word becomes thought, "thought is not the superior authority" (p. 252). It cannot be thus if the relationship between thought and word is a dialectical one, where each of the two partners presupposes the other, each contributing to the constitution of the other. Thought is not begotten by thought but "engendered by motivation, that is, by our desires and needs, our interests and emotions" (p. 252). It is not thought that engenders the emergent thought of the professor. Rather, thought emerges as part of the realization of the motive of the activity: teaching third-year students of physics the fundamentals of thermodynamics. "Behind every thought there is an affective-volitional tendency, which holds the last 'why' in the analysis of thinking" (p. 252).

Thought has to become its own subject (content), objectify itself, which requires that it externalizes and thereby estranges itself: this it does in and through the production of the word by way of word meaning. The intent that we see realized in the lecture is the lecturing of a particular topic, here adiabatic cooling. But although this is the intent and although the professor has all the (teaching) experiences to articulate in speech a form of physics consistent with the canon, it does not happen here in this instance.

"A true and full understanding of another's thought is possible only when we understand its affective-volitional basis" (p. 252). But we have no access to the affective-volitional basis of the thought other than through what the Other makes available to us with the resources at hand. "To understand another's speech, it is not sufficient to understand his words—we must understand his thought" (p. 253). But we cannot understand another's thought unless we take an external perspective on our own thought. Knowing that a particular expression is that of a specific emotion requires us to take an external perspective on ourselves. And this perspective on ourselves we can only take when our Selves have been constituted by the Other. This interlacing of Self and Other makes a pure representation impossible, each auto-representation of my body to myself is interconnected with a re-presentation, which in turn requires it to be a presentation of the Self. To understand thought, we need to understand the motive of the activity. For Vygotsky, therefore, verbal thought takes its course "from the motive that engenders a thought to the shaping of the thought, first in inner speech, then in meanings of words, and finally in words" (p. 253). Each of these levels constitutes a plan that cannot be derived directly from the other, each standing in a constitutive relation to and with the next plane, each being on its own trajectory.

Units of Analysis

Traditional psychological analysis decomposes the phenomenon into elements thought to be the building stones of the phenomenon as a whole. Vygotsky (1986) on the other hand thought that analysis in terms of elements provides "no adequate basis for the study of the multiform concrete relations between thought and language that arise in the course of the development and functioning of verbal thought in its various aspects" (p. 5). He proposes "analysis into units" as an alternative. In the following, I first describe Vygotsky's position on the analysis into units and then propose an extension of the units that he had described so that these account for the features that my analysis brings forth. (On the point of unit analysis and unit of analysis see also the epilogue).

Towards the Analysis of Units

Vygotsky proposes the use *unit analysis* in place of an analysis in terms of elements. Unit analysis takes into account the social reality toward which thinking is oriented and for which language is produced in the way it is and can be anticipated to be intelligible, reasonable, and fruitful. "The primary function of speech is communication, social intercourse" (p. 6), which requires us to study the dual function of speech: being for the speaker and the audience, realizing intellectual (development of thought) and interactional purposes (sharing of thought). Unit analysis is of interest, because "units are capable of retaining and expressing the essence of that whole being analyzed" (p. 211), which, in the case of the lecture excerpt presented here, is the historical situation of culture generally, physics more specifically, and this university and its undergraduate student population, and the level of the course being delivered concretely and singularly.

In the present instance, therefore, we cannot separate the professor's thought from how it occurs and how it realizes itself. The lecture is *for* the specific audience assembled, students in a third-year university physics course on the topic of thermodynamics, and is presupposed to be intelligible to them. This audience does not consist of colleagues, postdoctoral fellows, or graduate students; nor does it consist of some general public that walks off the street in the evening to attend a public lecture on some specific topic of general interest. The talk therefore realizes "a practical consciousness-for-others" (p. 256), here the *specific* audience but also realizes, consequently, consciousness for the pragmatic subject (the professor) himself. There is a particular lecture hall, and in the process of the lecture, the chalkboard comes to be filled with semiotic resources that can be subsequently used to further develop thought and lecture. This is evident in the way the lecturer looks at the unfolding graphical representation before adding to it. He tentatively gestures repeatedly prior to actually adding a new feature. He does so not in the context of telling students what he will be doing but in the attempt to find the appropriate place where to place the next line. Even more blatantly evident is the role of the previous production in subsequent developments of the lecture when he looks at one of the equations he produced, suggests that there are implications and, while staring at the diagram produced in the present episode, says "another [implication] is that this is wrong." That is, a subsequent production becomes a resource in realizing where the error lay in his previous production, about which he had voiced concern without being able to locate where the error lay or without being able to say whether anything is wrong with the display he had produced. That is, unit analysis also has to take into account the emotional-volitional moment driving the event, because "[e]very idea contains a transmuted affective attitude toward the bit of reality toward which it refers" (p. 10).

Unit analysis allows us "to trace a path from a person's needs and impulses to the specific direction taken by his thoughts, and the reverse path from his thoughts to his behavior and activity" (pp. 10–11). In the case study presented here, I trace and exhibit the emerging thought as apparent in the relation to the language (speech). The approach taken here to the question of thought and its articulation and expression allows for the reverse process, the influence of thought on affect and volition. The realization that the intended results of the developing thought have not been achieved mediates the emotional tenor of the moment. The non-achievement having a negative valence thereby comes to decrease the emotion at the heart of the generation of thought; and this decrease in the emotional state also is made available to the audience (including the analyst watching the videotape) in and by the prosody with which speech is delivered and in the body orientations and positions by means of which the audience comes to be "contaminated" (p. 7) with the doubt.

Extending Vygotsky's Unit

In *Thought and Language*, Vygotsky (1986) is primarily interested in developing a theory about the relation between the two. He hints at the integral role emotions play in thought as the driving forces and relates language to consciousness, the shared access and reflection of the world in the mind. Vygotsky notes that, "there is a vast area of thought that has no direct relation to speech. The thinking manifested in the use of tools belongs in this area, as does practical intellect in general" (p. 88). In communication, however, practical intellect expresses itself and is expressed in modes other than speech. I hold it as a legitimate extension of Vygotsky's work to include other communicative forms as integral to the articulation and expression of thought and practical intellect. For me as Vygotsky, "language is a practical consciousness-for-others and, consequently, consciousness-for-myself" (p. 256). But the word, as a thing in consciousness, "that is absolutely impossible for one person, but that becomes a reality for two" (p. 256). Moreover, the word is also a "direct expression of the historical nature of human consciousness" (p. 256). As the lecture unfolds, we see how prosody, for example, makes available the true psychological subject, whereas the grammatical subject and the verb—according to Vygotsky often becoming the psychological subject because it is related to the process character of thought, which is essentially predicative—but to an adverb that modifies the grammatical verb.

Gestures figure in many ways, both in terms of occurring over and about existing lines and thereby highlighting them as forms of thinking in which possible configurations of subsequent lines come to be articulated and tested prior to actually placing a chalk line into the diagram. Positioning the hand, finger, or chalk in the diagram prior to drawing also constitutes a form of resource for thought to articulate and evaluate itself and thereby create new resources for its auto-development. This auto-development is not as presented in constructivist theory, where there would be an intention in and to the development, but rather, there is an essential passive component whereby thought externalizes itself to see what comes of it, and therefore what comes of itself. Thought has not yet figured out what it means but evaluates what some production means in, through, and after realizing itself in various material forms.

We also have to figure into the unit of analysis physical locations, artifacts, and relative position of human subjects with respect to their setting. Thus, we observe in the analysis how the professor, in walking away from the diagram to be developed and the true subject of the present presentation (it is through the graphical presentation that the audience is to gain insights), denotes that the current talk has a different psychological subject. To be discovered by the audience, the new subject is that of the gaining insight.

I maintain with Vygotsky—and with Bakhtine/Volochinov and other cultural-historical psychologists and philosophers—that thought specifically and consciousness generally each constitutes a (non-mirror-like) reflection of the social and material reality in which the acting subject is embedded. My proposal for extending Vygotsky is this: All of these other resources, in the same way as language, stand in constantly changing and developing relations to thought, each representing thought, but each in the one-sided and oblique ways that language does. Communication is understandable because of the interplay of all these productions and resources, the collective sense and personal meanings of which arise from the transactional interplay of all of these resources collected together into a unit of the Vygotskian type. Thus, none of these resources constitute elements because communication is a higher order unit that cannot be decomposed into language, gesture, body position, body orientation, prosody, and so on each of which is to be analyzed. In some instances, we may see a stirring thought in the repeated "testing" movement of a gesture over and about a diagram, which subsequently comes to be "fixed" in some form by a chalk line that resembles it. It is not just language that constitutes consciousness-for-the-other but thought in its entire breadth, including all the other modes in which it articulates, expresses, and ex-scribes itself. Not only speech together with thought "constitutes the key to the nature of human consciousness" but also communication as a whole with all its dialectical moments to which it cannot be reduced has to be considered together with thought as holding the key to consciousness. Together, the expressive modes constitute the generalized and communicable reflection of reality.

Reflexive Comments

In this chapter, I develop and intertwine two readings, one having as its text the selected sections of Lev Semenovich Vygotsky's *Thought and Language* and the other one being that of one lecture in an undergraduate physics course. The unfinished, undeveloped, and underdeveloped stirring of a thought began in January 2006 when an idea developed within me of taking Western scholars to task about their readings of Vygotsky's text and to extend his work to incorporate subsequent developments of his work done by his student Aleksei Nikolayevich Leont'ev and his son Aleksei Alekseevich Leont'ev, who built a psycholinguistic theory of language, speaking, and speech activity. Subsequent theoretical developments of the theory emerged with the work of Felix Mikhailov in Russia and Ferrucio Rossi-Landi in Italy. My undeveloped sense also was that Vygotsky's work has been taken further but that educators have not attended to the further development of this work on language and language development.

This chapter is a first attempt to better understand *Thought and Language*. But it constitutes only a first step in the development of thought concerning language, language development, speaking, and speech activity. The chapter therefore constitutes a moment in the development of thought concerning the topic of thought, language, speech, and their relation to collectively motivated societal activity. Some aspects of the work of Vygotsky may remain the same, whereas others may change. But even if everything were to change, the ultimate product of my thinking about language, thought, speaking, and speech activity cannot be dissociated from its cultural-historical roots. Disconnecting it would constitute an antihistorical bias.

The present analysis shows how the communication unfolds in time and is an entirely historical product. Any one moment of the thought as available to the audience cannot be understood independently of the three historical time scales from which I have considered the events in this lecture. Thought, as speech and language, is not constant but continuously develops. This perspective is not compatible with a view whereby interviews or classroom episodes are analyzed as fixed structures that—in a process resembling the spilling of beans—are poured out of the inaccessible mind to the audience. Such a view embodies an antihistorical bias. Rather, there is only dynamic development at different historical scales This development occurs in the moment-to-moment articulation of thought, from distinguishable episode to distinguishable episode at a meso-level, and from period to period at the cultural historical level.

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Appendix: Transcription Conventions

In this chapter, I draw on transcription conventions common to conversation analysis enhanced by transcription features specific for researchers interested in marking prosody. I added specific features for transcriptions that include video offprints. The transcription is neither grammatical—see punctuation—nor consistent with spelling rules but attempts to exhibit the sounds as produced.

Feature in context	*Explication*
(0.25)	Time in hundreds of seconds
(.)	Pause less than 0.10 s
((draws line))	Double brackets surround transcriber comments.
hh, uh	Outbreath, each “h” corresponding to 0.1 s.
survi:ve	Colon indicates lengthening of phoneme, each colon corresponding to 0.1 s.
r=one	Equal sign means “run-in” of the phonemes or “latching” of different speakers, meaning no pause between phonemes.
084 <<p>point [he:re] 085 [than with]	Square brackets in consecutive turns indicate extent of overlapping speech, features.
;.,?	Punctuation marks indicate movement of pitch toward end of utterance segment, down, strongly down, up, and strongly up, respectively
<<p>point>	Triangular brackets mark prosodic features, here “piano,” that is, lower than normal intensity.
<<pp>point>	“Pianissimo,” much lower than normal speech intensity, next to inaudible intensity.
<<dim>point>	“Diminuendo,” decreasing speech intensity.
<<all>first>	“Allegro,” fast.
<<h>that’s>	Higher than normal pitch register.
[, [$_2$	The bracket marks the coincidence of an offprint (part thereof) with the transcription of words.
↑↓`b ‘clear	Arrows and diacritics indicate movement of pitch: upward and downward jump, downward and upward contour of phonemes that follow.
OR	Capital letters indicate louder than normal speech.

Chapter 10

Thinking and Speaking On Units of Analysis and Its Role in Meaning Making

Eduardo F. Mortimer*

The chapter of Wolff-Michael Roth, *Thinking and Speaking: A Dynamic Approach*, offers a fundamental contribution to the analysis of the relation between thought and word. Based mainly on Vygotsky's *Thinking and Speech*[7] (1934/1987), particularly on the final chapter *Thought and Word*, Roth analyses a physics lecture given by an experienced professor and discusses some of the main theoretical themes emerging from Vygotsky's work. The basic assumption of the paper, which I share with the author, is given in this quotation from Vygotsky:

> The relationship of thought to word is not a thing but a process, a movement from thought to word and from word to thought. Psychological analysis indicates that this relationship in a developing process which changes as it passes through a series of stages. Of course, this is not an age related development, but a functional development. The movement of thinking from thought to word is a developmental process. Thought is not expressed but completed in the word. (Vygotsky 1934/1987, p. 250)

According to Roth, this is so even when we consider mature minds, such as those of a professor of physics given lectures to undergraduate students. Normally there are developmental aspects of thought that have to be considered as an emergent property of the situation rather than as the result of a fixed underlying structure. The author argues against analysis in the field of science education that "takes from granted that the words invariably index pre-existing and specific thought structures." In his view this should be replaced by a dialectical approach that considers thinking, speaking and the thinking-speaking relationship as dynamic processes that change at three time scales—microgenetic, ontogenetic and historic-cultural scales.

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7. I worked with a different version of this book, normally known as *Thought and Language*. This explains why quotes from the same passage look different.

W.-M. Roth (ed.), *Re/Structuring Science Education: ReUniting Sociological and Psychological Perspectives*, Cultural Studies of Science Education 2,
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In my comments I address some theoretical aspects that emerged in Roth's paper. I consider how the units of analysis proposed by Vygotsky can be worked in similar ways from a different author (McNeill 2005); and how these units can be expanded in ways which are different from those considered by Roth but which are consistent with his analysis.

Thinking and Speaking

The episode presented by Roth shows an experienced professor of physics lecturing an introductory thermodynamics course. The episode shows a lot of mumbles, stumbles, ticks, and conversationally long pauses during which the professor is staring toward the floor or at the emerging diagram on the chalkboard. The thoughts of this professor appear to be unfolding with the speech he is producing. One important feature of the episode is the quantity of long pauses produced during the professor's speech, which signal that he is in a process of thinking during the time he is lecturing. His discourse, sometimes, looks like inner speech. It has all the predicates but not all the subjects in each of the sentences. Vygotsky (1934/1987) says that inner speech has a syntactic form of pure and absolute predicativity. Of course the professor is in front of an audience of students, but the mumbles and long pauses he does during his talk, together with the fading away of his voice in some parts of the episode, indicate that in most of this talk he was struggling for meaning, thinking before articulating his thought in words.

As Roth notes, there is considerable evidence that this lecture segment was produced in real time and that the associated thought develops as the professor articulates himself in speech, writing/drawing, and gesture. Of course there is memory involved in the production of speech. We need memory to formulate our thoughts. What is in needed here is a multifunctional unit of consciousness, one that involves perception, attention, memory and thinking, altogether. According to Vygotsky, the fate of each functional part of the consciousness depends on changes in the whole.

> Remembering presupposes the activity of attention, perception, and the attribution of meaning. Perception requires attention, recognition (or memory), and understanding. In both traditional and contemporary psychology, however, this concept of the functional unity of consciousness—of the insoluble connections among the various aspects of its activity—has consistently remained on the periphery. (Vygotsky 1934/1987, p. 188)

What seems to be absent in the professor's consciousness is memory of what he is trying to teach. It is as if he has never looked at his notes before this lesson took place. It is probably because of this lack of memory that he mumbles and gives long pauses, and his voice sometimes faded away, as if he was passing from overt speech to inner speech. This raises the question of which unit we are searching for here. Is it the complex multifunctional microcosm of consciousness, which must be capable of reflecting all the complex relationships that characterize human consciousness and must also be amenable to objective investigation? How could a unit like word meaning fit this complexity? Would not tool-mediated action be this unit, as it preserves the characteristic of the whole consciousness activity? These are important questions that, from my point of view, remain untouched in Roth's chapter and which I do not address in my comments. Nevertheless, I think is important to have this broader picture of consciousness in mind to treat some less complicated issues, as the question of unit of analysis in the way it was discussed by Roth.

Units of Analysis

This theme emerges in chapter 7 of Vygotsky's *Thinking and Speech* and concerns the relationship between thought and word. Vygotsky uses units of analysis in the place of elements of analysis. Units, unlike elements, do not lose the characteristics inherent to the whole. According to Vygotsky,

> We found the unit that reflects the unity of thinking and speech in the *meaning* of the word. As we have tried to show, word meaning is a unity of both processes that cannot be further decomposed. That is, we cannot say that word meaning is a phenomenon of either speech or thinking. The word without meaning is not a word but an empty sound. Meaning is a necessary, constituting feature of the word itself. It is the word viewed from the inside. This justifies the view that word meaning is a phenomenon of speech. In psychological terms, however, word meaning is nothing other than a generalization, that is, a concept. In essence, generalization and word meaning are synonyms. Any generalization—any formation of concept—is unquestionably a specific and true act of thought. Thus, word meaning is also a phenomenon of thinking … It is a unity of word and thought. (Vygotsky 1934/1987, p. 244)

Roth also proposes extending this unity in incorporating the other modes of communication. According to him, communication is understandable because of the "interplay of all these resources collected together into a unit of the Vygotskian type." Communication is a higher-order unit that cannot be decomposed into language, gesture, body position, body orientation and prosody.

> In is not just language that constitutes consciousness-for-the-other but thought in its entire breath, including all the other modes in which it articulates, expresses, and ex-scribes itself. Not only speech together with thought, "constitutes the key to the nature of human consciousness" but also communication as a whole with all its dialectical moments to which it cannot be reduced has to be considered together with thought as holding the key to consciousness. Together, the expressive modes constitute the generalized and communicable reflection of reality.

I consider two aspects in the extension of Vygotsky's unit of analysis. First, I comment on the extension proposed by McNeil (2005), which expands language beyond its verbal aspects and has important aspects that relate to Roth's extension. Second, I add another dimension to this expansion, not just in terms of the modes of communication but in relation to the works of Bakhtin and his circle, who propose utterances and not words as the unit in their analytical tools.

Language and Gesture Unit

McNeill (2005) also proposes an extension of Vygotsky's unit of analysis in a dialectical manner, in a way I think is significant to Roth's chapter. He advances the concept of growth point as a minimal unit of an imagery–language dialectic. McNeill believes that for studying gesture and language, forming a unit of analysis, we should consider both the static and the dynamic dimension of language. First, he calls attention to the fact that gesticulation accompanying speech is non-conventionalized, is global and synthetic in mode of expression, and lacks language-like properties of its own. The speech, with which the gesticulation occurs, in contrast, is conventionalized, segmented, and analytic and has linguistic properties. Thus, although occurring together, they reflect different modes of thinking.

McNeill (2005) presents the static dimension of language basically as the achievement of Ferdinand de Saussure in the early twentieth century. He argues that much of modern linguistics remains Saussurian. Saussure considered that human language has two aspects: langue, which accounts for everything that is systematic in human language; and parole, which accounts for the aspects of language that do not pertain to the system of language, such as discourse. For Saussure langue is a social fact, which means that it is a socially constituted norm and a sociocultural institution. A sign, for Saussure, has two parts: the signifier, or sound image, and the signified, or the concept it conveys. Their bond is radically arbitrary. This arbitrariness requires that language should be a social convention. And in language, difference is everything. The system of language consists of elements that define each other by differing from one another. Each sign is thus opposed to other signs. The oppositions take place along two axes simultaneously: the syntagmatic and the paradigmatic. The syntagmatic oppositions are between signs in the same syntagm, a sequence of signs producing some syntagmatic value. For example, a sentence is a kind of syntagm that attributes value to subject and predicate. Being a subject or predicate is not a property of any word, but it is a product of entering into a certain syntagmatic opposition.

According to McNeill (2005), a dialectical relation implies: (a) a conflict or opposition of some kind and (b) a resolution of the conflict through change. Because changes seek repose, dialectic also creates a systematic role for the static dimension of language. A grammatically complete sentence is a state of repose, a natural stopping point; it is static and reachable from instability. It is what McNeill called intuitions. These intuitions are not a violation of good grammatical form and must exhibit the speaker's sense of well-formedness.

The dynamic dimension of language is based on Vygotsky's *Thinking and Speech*. The basic idea is that the relationship between thought and word is a process and not a thing and that the meaning of the word is a process that belongs to thought and language at the same time. This fusion of thought and speech generates verbal thought, which McNeill's dialectic takes as its scope. This implies in recognizing that there is an overlapping region of thought and speech, which corresponds to verbal thought and excludes thought without speech and speech without thought.

Gesture and speech are material carriers of meanings. In a gesture, for example, the actual motion of the gesture itself is a dimension of meaning. This is possible because the gesture is the very image, not an expression or representation of it. Gesture is an image in its most developed and most materially, naturally embodied form. As Vygotsky (1934/1987) stated, speech is also a material carrier of meaning because a word without meaning is not a word but an empty sound. As material carries meanings, gesture and speech provide an alternative to representation. In McNeill's dialectic, the dynamic and static dimensions of language intersect, with the static dimension experienced via linguistic intuitions.

Growth point is then proposed by McNeill as the minimal unit of an imagery–language dialectic. A growth point has both linguistic and imagistic components, but is an irreducible unit. It is, in this sense, a Vygotskian unit, the smallest package that retains the property of a whole. In the case of growth points, the imagery–language role is seen in synchronized combinations of co-expressive speech and gesture. The growth point is a dynamic, not a static unity. Dynamic implies change and this change arises from the instability of simultaneously conceptualizing the same idea in opposite semiotic modes—gesture and speech—and from the shaping of the growth point by context. This brings us back to the Vygotskian psychological predicate, as introduced by Roth.

The psychological predicate marks a significant departure in the immediate context and implies this context as a background. Regarding the growth point as a psychological predicate suggests a mechanism of growth point formation in which differentiation of a focus from a background plays an essential part. This differentiation, according to McNeill, is validated by the very close temporal connection of gesture strokes with the peaks of acoustic output in speech.

Thus, we can look for an example of a growth point in one of the combination of gesture and speech in the Roth's episode. When the professor, on turn 31, utters the sentence "when you when you then uh adiabatically demagnetize it," the analysis of pitch and intensity made by PRAAT indicates that the values of pitch and intensity rise to the maximum of 173.8 Hz and 62.04 dB just in the "batic" of the word adiabatically (see Figure 9.3 in Roth). Accordingly, the word adiabatically stands out in the sentence and becomes the psychological subject of the sentence, what is marked against the immediate context, which is left in the background. Together with this peak of acoustic output in the speech occurs a gesture, represented in the Figure 9.2, which precedes the drawing of the horizontal line that represents the adiabatic demagnetization but occurs immediately before it, without drawing the line. The gesture coincides with the peak of acoustic output. The two together constitute what McNeill calls a growth point, a Vygotskian unit of gesture and speech.

I consider that McNeill offers a good example on how to expand the unit of analysis proposed by Vygotsky, as he is able to show how this new unit encompasses the entire phenomenon of speech and gesture. His growth point has the characteristics of the whole he is searching for: it depends on speech and gesture produced together in a way that marks their departure from the context, which is a characteristic of the Vygotskian psychological predicate. And he demonstrates how he encounters these growth points in data, which I translate to Roth's data. I think this is more productive than calling "communication as a whole" a high order unit, but without demonstrating what specific parts of the communication retain the characteristics of the whole, which is how the unit of analysis is defined by Vygotsky. I agree that we need to expand Vygotsky's units of analysis, but we should be able to do this by putting together different modes of communication, like speech and gesture or speech and diagrams/drawings, and by demonstrating how they can constitute the smallest package that retains the property of a whole.

Beyond Word as Unit of Analysis?

In my view we should try to extend Vygotsky's unit of analysis not only in incorporating other modes of communication to his framework but also by extending the unit from word meaning to utterance meaning. Vygotsky's focuses on word meaning as units that can be treated in isolation from their role in a sentence prevent him from recognizing important aspects of the issue. According to Wertsch (1985), because of his focus in isolated words, Vygotsky's account of meaning development rested only on sign-object relationships. For Vygotsky, the fact that adults and children can agree on reference but fail to agree in meaning was considered the main impetus for development, at least up to the point where scientific concepts begin to be used. The fact that Vygotsky did not consider the way in which a word generally occurs in a sentence—the privileges of occurrence as defined by grammar—prevent him from recognizing important aspects related to the meaning of the words that children master. When children begin to use a word they can recognize not just its relation to nonlinguistic objects; they also recognize its propositional role. Lexical content and propositional role are related in many ways. Nouns with certain lexical contents, for example animate or human, make good natural agents. Names with other lexical content (e.g., inanimate) make good natural patients. Each language has its own way of dealing with this distribution of roles in the sentences. For example, in Brazilian indigenous language there are many more things that have human agency than just humans, which makes the choice of natural agents and patients quite different. When children are struggling to master the meanings of words, both their relations to nonlinguistic objects and their role in a sentence make the difference.

For Bakhtin (1956/1986), nevertheless, it is not the sentence that should be considered as the real unity of speech communication, but the utterance. The concept of utterance assumes a central position in his philosophy of language, and it is articulated with several other central concepts like interaction, dialogism, speech genre, and polyphony. The Bakhtinian conception of utterance results from the apprehension of a language in its semiotic and ideological nature. For Bakhtin, the true substance of a language is not constituted by an abstract system of linguistic forms but by the utterances that emerged in the social interaction (Voloshinov 1929/1973). The utterance acquires a social nature and the understanding of it should consider the interaction in which it occurs. "Any utterance—the finished, written utterance not excepted—makes response to something and is calculated to be responded to in turn. It is but one link in a continuous chain of speech performances" (p. 72).

Considering the utterance as the link in verbal communication, Bakhtin and his circle distinguish it from the sentence—a language unit—and insert it in a universe of relations that is entirely different from pure linguistic relations, emphasizing its historic, social and cultural nature. According to this approach, all utterances have two aspects to be considered: the linguistic—its meaning—which is reproducible and self-identical in all instances of repetition; and the contextual—its theme—which is individual, not reproducible, and gives the utterance its definite and unitary meaning. This contextual aspect is, therefore, the expression of the concrete, historical situation that engendered the utterance. Three different but related aspects constitutes the context: the spatial horizon that is shared by the speakers; the knowledge and comprehension of the situation by the speakers; and the common evaluation they have of the situation. It is by this three-dimensional model that someone is able to understand what is presumed in an utterance, what remains not said (Bakhtin 1935/1981). Accordingly, the understanding of an utterance transcends its mere decoding. Understanding implies the reciprocal relation between the speaker and the listener and a relation between what is said and what is presumed. In this sense, the utterances are capable of mobilizing an active responsive attitude, an answer, meanwhile the sentence, object of a language, does not mobilize it.

The concept of utterance is capable of reconstructing the role of the other in communication. For Bakhtin, a listener always has an active responsive attitude although this is always subject to variation. A speaker presupposes this responsive attitude. She does not expect that the listener has only understood what she has said. She does not want to duplicate her thought in the thought of the other. What she expects is an answer, an agreement or disagreement (completely or partially) that can take the form of an action, an adhesion, an objection, or a complement. Bakhtin does not determine the length of an utterance that can vary from a short rejoinder in everyday dialogue, like a single word, to the large novel or scientific treatise. Nevertheless, he always compares utterance, as real units of verbal communication, with sentences, units in decontextualized language. The kind of relation that exists between utterances—relations between question and answer, assertion and objection or agreement, order and execution—are not possible among sentences taken in isolation as units of language. Thus, we can consider sentences, words, or pauses with gesture, as utterances, which in a dialogue can take the form of a rejoinder. This converts the utterance in something that can be recognized and in this way operationalized. When someone nods in agreement to what you have just said, you can take this gesture as meaning "I agree" what makes this gesture an utterance.

If we consider this kind of sentence—including solely words or gesture without words but with the same value of a sentence—within its social, historical and cultural aspects we are in condition of expanding the Vygotsky units in another sense. In his analysis Roth does not take the words in isolation. He always analyzes sentences within their social, historical and cultural contexts—in a word, he always analyzes utterances. The way he presented the data reflects a way of segmenting the talk in which he made evident the pauses and sentences. Each number he uses to segment the data contains, normally, an entire sentence or a pause. These sentences, nevertheless, are not taken as decontextualized sentences but as utterances, which have a historical, cultural and social context that shapes what the professor is saying and doing. When Roth uses the three time scales in his analysis he is framing the utterances in an adequate context. Microgenetic corresponds to moment-to-moment scales experienced in continuously unfolding situations; ontogenetic, to the individual development; and historical, to broader scales where the changes in the thermodynamic discipline give the frame to which the professor is attached in the lessons.

Final Comments

Wolff-Michael Roth raises important questions concerning the development of a theory of thinking and speaking. Roth offers appealing evidence that a professor, in teaching an introductory thermodynamic lesson, is not just simply reading out a predetermined text and thoughts. Rather, his thought itself appears to be unfolding during the lesson, as the entire episode is marked by mumbles and conversationally long pauses from the professor. From the analysis of this episode Roth is able to discuss a series of issues, some of which I addressed in this chapter. Although I agree with the need to expand the unit of analysis proposed by Vygotsky, I think this expansion should begin by treating the utterance, and not the word, as the minimal unit to ascribe meaning. We also need to demonstrate how this new unit of analysis can be the smallest package that retains the property of a whole. In this way, it is valid to expand this unit to incorporate other modes of communication, but we always need to think which of these modes can operate together to function as a unit. I think that prosody is a good instrument to study speech in its natural occurrence, like a lecture. Prosody itself, nevertheless, does not constitute another mode of communication. Gesture is another mode of communication and its use together with speech makes a good unit of analysis. The diagram/drawing sketched by the teacher is another mode of communication that functions differently from gesture and also works together with speech. The body position and the orientation of gaze also mean a mode of communication that works together with speech. Thus, what we need in this expansion of Vygotskian units of analysis is to work in each of these pairs trying to discover how they function together as a unit. We should, nevertheless, always remember that they acquire their meanings inside utterances, and not words.

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Chapter 11

Thinking Dialogically About Thought and Language

Pei-Ling Hsu*

In educational studies, it is not uncommon for researchers to take the relationship of thought and language as "what people said is equal to what they thought" or, more specifically, "thought is speech minus sound." However, drawing on genetic methods such as ontogenetic and phylogenetic investigations, Vygotsky concludes that thought and language are not in a fixed or parallel relationship but dynamically interact with each other. Roth, in his chapter "Thinking and Speaking," draws on Vygotsky's social psychology to closely examine in a sociological manner the relationship between thinking and speaking during a professor's physics lecture. During the episode, which lasts less than 2 min, the professor reintroduces the concept of adiabatic demagnetization to his class. Although it is not the first time the professor teaches this topic, many of his modalities, such as pauses, mumbles, and stumbles, indicate that he does not just spill out words from his "existing and stable conceptual framework" but that his ideas continuously emerge while he is lecturing. Roth, informed by Vygotsky, also provides us three different timescales of investigation (moment-to-moment, individual development, cultural-historical) concerning the professor's lecture that allow us to understand the situation in a holistic manner. Beyond Vygotsky's advice on using a unit analysis that retains a dynamic system of word meaning with its affective and intellectual consideration, Roth extends the analysis unit to recruit resources such as gestures, body movements, intonations, prosody, positions, artifacts, or physical locations to enhance the credibility of analyzing the-person-in-the-setting as a whole. Roth's chapter asks us to pay extra attention to the relationship between thought, language, and other resources in settings as they continuously interact in an oblique way. Importantly, human language is a fundamental ground for conducting all kinds of social science research. If we make an assumption that goes against the nature of language, then our research is likely to be in vain.

During the process of reading Roth's chapter, however, a question keeps coming to my mind. Although Vygotsky asserts that a dynamic relationship exists

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between thought and language, I have not yet seen him provide evidence or explanations of how language actually influences thoughts. That is, the "dynamic" nature of their relationship is unclear to me. Perhaps due to the difficulty of finding evidence about how people think in an experimental manner, Vygotsky did not explicitly inform us how word meaning develops and how thought and language influence each other. Thus in Roth's paper, although we can sense that the professor's thoughts continuously emerge during the lecture rather than being fixed, the relationship between thought and language is unclear. This question occupies my mind and urges me to search for an explanation and evidence. During my search, I found that the concept of dialogism developed by the Bakhtin circle (i.e., Mikhail Bakhtin, Valentin Vološinov, Pavel Medvedev) may serve as a plausible and fruitful framework to explain the relationship between thought and language. Although Bakhtin was not a psychologist, his insights into literature and the nature of human existence inspire me to look at the world with new eyes. In this chapter, I apply Bakhtin's ideas and claim that the relationship between thought and language is dialogical, with evidential support provided in Roth's paper. This proposal then provides us a possibility to enrich our thinking on Vygotsky's unit of analysis for the dynamic relationship between thought and language. In the following sections, I first introduce Bakhtin's dialogism; then, I demonstrate my proposal of the dialogical relationship between thought and language with the empirical information from Roth's chapter; finally, I suggest enriching Vygotsky's unit of analysis by combining it with Bakhtin's dialogical analysis. (In the chapter, I use the same turn numbers used in Roth's chapter to indicate the empirical information of the professor's lecture.)

Dialogism

> The very being of man is the deepest communication. To be means to communicate. Absolute death is the state of being unheard, unrecognized, unremembered. To be means to be for another, and through the other, for oneself. A person has no internal sovereign territory, he is wholly and always on the boundary. (Bakhtin 1984, p. 287)

Like Vygotsky, instead of taking language as a closed, abstract, fixed system of normative form, Bakhtin views language as a dynamic, concrete, and continuously developing resource that are closely tied to their social and historical contexts. The idea of dialogue, a concept depicting people's natural form of communication, not only serves as a core concept for Bakhtin to analyze literature but also becomes a philosophical ground from which to look at human existence. To be means to communicate, to dialogue with the other. Only through the other, our words make sense and we can learn who we are. For Bakhtin, every utterance is a response to a previous utterance and is directed toward an anticipated answer at the same time. Thus, utterances are never one's own but always from the other, for the other, and contextualized in particular contexts. The simultaneity of self and other then becomes the very nature of utterances. Here, one might ask, if every word is always from the other, then how do we explain human beings' creativity? Here, I cannot help but think of a well-known sentence from one of the most creative men, Albert Einstein—"the secret to creativity is knowing how to hide your sources"—a sentence that vividly portrays the simultaneous existence of self and the other in human creativity.

Due to the dialogical nature of utterance, we can always hear different voices within utterances. This is what Bakhtin called polyphony—a term borrowed from the art of music—which he described as a key feature engendering novelty in novels (especially Dostoevsky's work). Instead of using the traditional unit of language—the sentence—a unit that has no capacity to determine directly the responsive position of the other speaker, Bakhtin asserts that an utterance is a unit of speech communication that shifts between different speakers. An utterance's beginning is preceded by the other's utterance and its end is followed by another responsive utterance. Thus, the utterance is "a real unit, clearly delimited by the change of speaking subjects, which ends by relinquishing the floor to the other" (Bakhtin 1986, pp. 71–72). Utterances can be not only in oral form but also in written form. For instance, an utterance could be as short as an interjection, a sentence, a 2-min talk, like the episode demonstrated in Roth's chapter, or even a whole novel. As Bakhtin suggests, "the utterance is filled with dialogic overtones, and they must be taken into account in order to understand fully the style of the utterance" (p. 92). Thus, it is important to address the dialogic overtones in utterances because the fundamental function of language is to communicate.

The professor's lecture in Roth's chapter obviously is recipient-designed for students in that university class. If we take the professor's 2-min talk as an utterance (because no other's utterance appears in the transcribed episode), we can hear explicitly that the professor's utterance is directed toward his audience (i.e., students; "I gave *you* … [turn 01]", "*we* could … [turn 08]", "when *you* … [turns 25, 27, 30, 31, 41, 44]"). However, we should keep in mind that it is not only these words that are directed toward to the audience, it is every single word in the discourse. Namely, "word is a two-sided act. It is determined equally by whose word it is and for whom it is meant. As word, it is precisely the product of the reciprocal relationship between speaker and listener, addresser and addressee" (Vološinov 1973, p. 86). In other words, a word is always shared with interlocutors in the discourse and never is one's own. Importantly, a word is never finalized because it always anticipates a response even when it is in an inner speech form. Thus, the non-finalizability of words allows language to be alive and continuously developing.

Sensing the Voice of Language (Inscription)

People might assume that a dialogical relationship only happens between speakers in discourse. However, "dialogic relationships can permeate inside the utterance, even inside the individual word, as long as two voices collide within it dialogically

… [dialogic relationships] are also possible among different intelligent phenomena, provided that these phenomena are expressed in some semiotic material" (Bakhtin 1984, pp. 184–185). This insight provides us new directions to see other possible dialogical relationships in the professor's lecture. In this section, in addition to his audience of students, I claim that there is another audience—the inscription on the chalkboard that constitutes another dialogical relationship with the professor—with the support of three relevant pieces of evidence provided in Roth's chapter, as below.

First, informed by dialogism, interlocutors are all subjects of address because an utterance is always directed to its audience—addressivity in utterances. In conversational contexts, it is known that the gaze of a speaker is an available indicator for showing the address of one's utterance (Goodwin 1979). That is, the speaker's gaze is usually located on the address of his utterance. In the case of the professor, we can see that he spends most of the time in this episode gazing at the diagram he drew on the chalkboard (e.g., Figure 11.1 [turn 22], turns 3, 4, 14, 16, 21, 26, 28, 29–31, 37, 38, 44). These gazes at the inscription on the chalkboard all indicate that the professor has a close conversational relationship with the inscription, as if the inscription is another audience in the classroom.

```
22   (2.48)
     [((steps back to look at diagram))
```

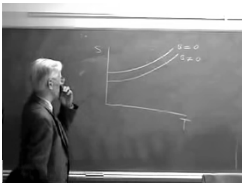
[

Figure 11.1. The professor looks at the inscription on the chalkboard for most of the time in the 2-min lecture, as if he is addressing the inscription.

Second, from the professor's gestures and words, we can tell that the voice of the inscription appears in his utterance. As we know, the inscription on the chalkboard is a coordinate system with two curves and notes. In the transcripts, we notice that the being (shape) of the inscription is not only formulated by words (e.g., "diagram [turn 10]," "as the curve varied something like that [turn 20]") but also in the professor's gazes and gestures (e.g., "gazes toward the end of abscissa [turn 4]," "stares at diagram, looks from down to up [Figure 11.2, turn 26]," "horizontal gesture [turn 34]"). That is, solely from the professor's being (words and gestures), we actually can sense another being in his discourse (besides the students)—the co-being of the inscription in the professor's utterance.

Third, a dialogic relationship is possible within utterances "if we somehow detach ourselves from them, speak with an inner reservation, if we observe a certain distance from them, as if limiting our own authorship or dividing it in two" (Bakhtin 1984, p. 184). In the professor's case, he shows this distance and detachment to the diagram on the chalkboard in several instances. For example, he makes certain spatial and temporal distance (e.g., "steps back to look at diagram [turn 22, Figure 11.1],” “looks at graph at length [turn 39]”), and he walks away from the diagram to the very right end of the classroom (e.g., turn 7). In particular, in fragment 7, he says “something wrong with that picture (turn 46–47)” while moving away from the picture and approaching his notes. Here, he does not say *my* picture but *that* picture, as if the picture is another being apart from his authorship. These instances indicate that the professor not only physically keeps a distance from the diagram, but also alienates his authorship of it, as if the inscription is another being in the lecture discourse.

```
26   (3.75)
     [((stares at diagram, looks from down to up))
```

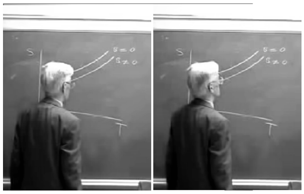
[


Figure 11.2. The professor’s gaze is following the shape of the curve of the inscription, indicating that he interacts with the messages from the inscription carefully.

These three orientations of the professor’s words, gazes, gaze trajectories, gestures, body movements, and spatial distance from the diagram all indicate that another voice co-exists in the professor’s utterance. It is as if the professor, together *with* and *for* the students, interacts with another being in the classroom—the inscription on the chalkboard.

Hidden Dialogue with Language (Inscription)

Having identified another audience (i.e., the inscription) in the professor’s discourse, in this section I suggest that the professor has a hidden dialogue with the inscription. As Bakhtin observed, Dostoevsky’s novels are full of double voices for dialogically addressing characters as “only in communion, in the interaction of one person with another, can the *man in man* be revealed” (Bakhtin 1984, p. 252, original emphasis). It is the unique feature of dialogical interaction that brings Dostoevsky’s characters to life. For Bakhtin, man’s consciousness can also be better understood by depicting his internal dialogue, such as glancing sideward while making an utterance. Imagine a dialogue of two persons and the second speaker’s statements are omitted. Although the second speaker is invisible, his words can be traced in the words of the first person’s statements—they are sideward glanced. That is, although only one person’s utterances are available, we can sense a conversation between two persons. One example of this hidden dialogue in Dostoevsky’s work is in *Underground Man’s Notes*:

> Well, are you not imaging, gentlemen, that I am repenting for something now, that I am asking your forgiveness for something? I am sure you are imagining that. However, I assure you it does not matter to me if you are. (p. 228)

This excerpt shows that the character (underground man) in Dostoevsky's work depicts what others would "imagine" about him. Although there is only one person's utterance in this excerpt, two voices are actually enacted. One voice is from the underground man himself and one is from the other (gentlemen). More specifically, one is I-for-myself and the other is I-for-another. In this excerpt, the other is invisible, but we can hear the other's voice in the underground man's internal dialogue. That is, the underground man's words about himself are structured by the continuous influence of someone else's words about him. It is a similar situation with the professor's discourse in Roth's chapter. As I articulated in the previous section, an inscription, an intelligent phenomenon, can also become an influence in the lecture discourse. Moreover, we also can hear two voices coinciding in the professor's utterances—one is from the professor himself and the other is from the inscription. Examples are illustrated below.

After drawing two curves indicating the field conditions ($B = 0$, $B \neq 0$) on the entropy temperature diagram, the professor looks at the diagram and says "when you put the material in a magnetic field at a constant temperature" (turns 27–28, Figure 11.3). Then, with a drawing action (i.e., "[draws downward line]" [turn 28]), the professor says "it's just like that" (turn 28). Here, we can see that the professor sets up a "constant temperature" condition and self-responds to this condition with a drawing action. It is as if he initiates a question and then gets a response from the diagram to add a downward line fitting the semantic relationship of the diagram on the chalkboard. This is more evident in the next few turns.

After a long pause (turn 29), the professor again sets up a condition "when you then adiabatically demagnetize it" (turn 30–32). This time, however, before he physically draws a horizontal line (turn 33), he makes a horizontal gesture first (turn 31) on the middle section of the diagram (between two curves), as if the inscription has already given feedback to his question through his horizontal gesture. Here, an important message is shown to us—the initiation ("when you then adiabatically demagnetize it") and response (horizontal gesture) happen simultaneously, just like the simultaneity of self and other in an utterance. That is, although the voice of the inscription is invisible, through the professor's words and gesture of waving at the inscription, we sense a conversation going on between him and the inscription.

This is especially salient when the professor is in an uncertain situation. From turns 38–44, as Roth describes, the professor seems to be uncertain about where to put his next line on the chalkboard. He has long pauses in his utterance (turns 39 & 43), his voice is fading away (turns 40–41), and his hand moves to different parts of the diagram as if he cannot decide where to draw his next line (Figure 11.4). This example indicates that the professor seems to have a dialogue, or even an argument, with the inscription. Although we do not know what the inscription says to him, from the professor's various modalities we can sense that he struggles with the inscription as if he is arguing back and forth with it (Figure 11.4).

```
27   when you; (0.30) PUT the material in a magnetic fie:ld at a
28   constant temperature (0.47)   [its just] like ‘that
                                  [((draws downward line))
29   (1.79)
30   a:nd when you; (0.95) uh:::
31   that when you when you then uh a:dia^batical[ly::] (0.53)
                                                 [((gesture
     horizontal))
32   demagnetize it, (0.44) it uh::::
33   (0.30) [y its ‘that]
            [((draws line horizontal
```

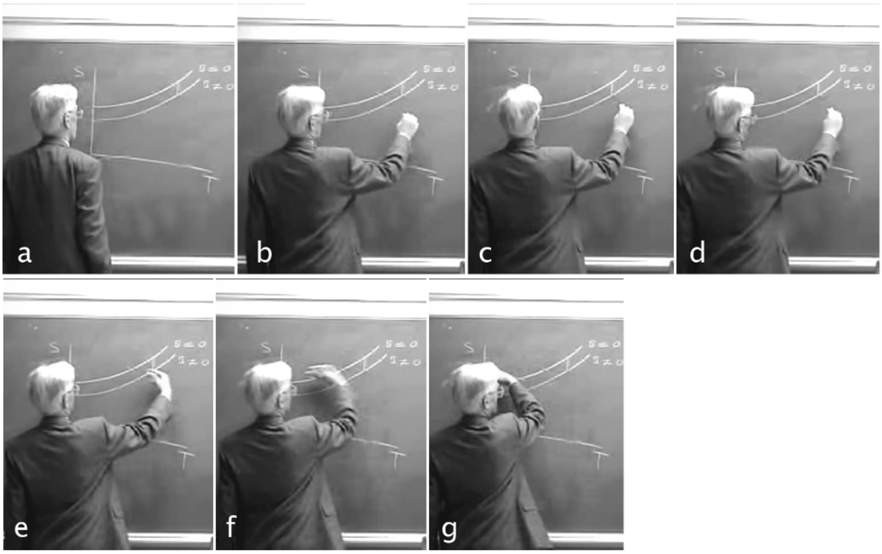


Figure 11.3. In turns 29–31, the professor uses the words “when you then adiabatically demagnetize it” and gestures “gesture horizontal” simultaneously. It is as if the voice of the inscription simultaneously responds to the question (condition) and its answer is delivered through the professor’s gesture.

Moreover, it is noticed that the dialogue develops together with the development of the inscription. For instance, when there is only a sketch of coordinate axes in the embryonic state of the diagram, the professor uses the generic term deprocess (turn 07) in his discourse. Whereas when the diagram is further developed into a complex inscription, the professor then uses the more specific term demagnetize (turns 32, 44) to describe that process. It is as if the complexity of the inscription is closely associated with the complexity of language use. That is, when the inscription changes, the use of words also changes.

The examples above show that the professor interacts closely with the inscription as if he has a dialogical relationship with it. That is, the professor’s drawing and words seem not to spill out from an existing conceptual framework in his head but are engendered through a continuous dialogue with the inscription. In other words, the words and next line of the semiotic inscription are produced between two interlocutors as “truth is not born nor is it to be found inside the head of an individual person, it is born *between people* collectively searching for truth, in the process of their dialogic interaction" (Bakhtin 1984, p. 110, original emphasis).

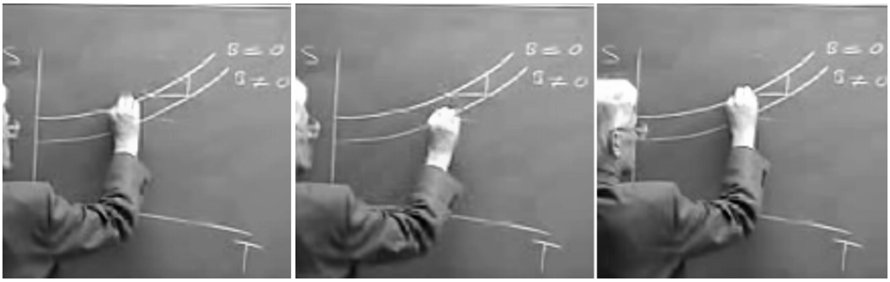


Figure 11.4. The professor's hand keeps moving and he is uncertain where to put the next line, as if he is having a hidden dialogue or argument with the inscription on the chalkboard.

Dialogical Relationship Between Thought and Language

In the previous section, the professor's utterances, gazes, gestures, and the physical appearance of the inscription show how a speaker can have a hidden dialogue with an inscription—one form of language. That is, the professor has a dialogue with language. This phenomenon encourages us to think about speakers' dialogical relationships with other forms of language, such as speech itself! That is, when we speak, in addition to having dialogues with other speakers, we inevitably have a dialogue with our speech itself. It might be easier to think about this dialogical relationship with the support of our life experience. Here I provide one vignette that I shared with Michael Roth in October 2008.

One day Michael arrived at our office and started to share his insights from a paper he had written that morning. He talked excitedly with waving hands, and I tried to follow his thinking, which sounded novel and interesting to me. During our conversation, I mainly nodded my head and produced continuers such as interjections "mm … yeah …" to show my interest and encourage him to share more. Suddenly, he said, "Oh … do you have a pen and paper, I need to write something down!" After finding a piece of paper, Michael then jotted down some words on the paper and said, "Just some ideas I suddenly have for my writing, and I need to write it down, otherwise I will forget!" Here, one might wonder: "How could Michael share his previous insights and generate new insights at the same time?" One might say it is Pei-Ling who said something to stimulate Michael's new ideas. But as I have described, I did not say anything insightful. I only produced interjections and nodded my head. I do not even know what ideas Michael jotted down on that paper. Obviously, it is not Pei-Ling who gave ideas to Michael. Then, how do we explain this phenomenon?

Bakhtin's dialogism helps me to think about and explain this vignette. That is, I suggest that a dialogical relationship exists between thought and language in speech. In other words, every time we speak, we produce a rejoinder in the discourse. Our speech is never purely our own because once we speak, we speak for the other. Thus, our speech already integrates other people's possible thoughts and voices. That is, Michael's speech is dialogically addressed to me and his speech has become another being that is different from the original thought—speech becomes a rejoinder in our discourse. Thus, although I did not say anything insightful in front of Michael on that day, my presence in the discourse oriented Michael's speech into a rejoinder that allowed him to have a dialogue with his own thoughts.

We can find the dialogical relationship between thought and language in other life experiences as well. For instance, it is not uncommon for writers to experience that once they start to write, more thoughts are generated in the process of writing than when they just sit there and think. It is as if one is having a dialogue with one's own writing and new thoughts continuously emerge in the process. Vygotsky's (1986) example of children drawing is similar. While drawing, many young children cannot name what they are drawing until it is done. The idea of a dialogical relationship between thought and language allows us to explain this phenomenon as a hidden dialogue between children and their drawing. That is, children and the drawings are negotiating and arguing a proper name for the drawing, just like the professor in Roth's chapter dialogues with the inscription for the proper next line.

Enriching the Unit Analysis

According to Vygotsky, a word without meaning is an empty sound. Meanwhile, a word does not refer to a single object but is a generalization that reflects reality. Thus as researchers we need a unit analysis that considers both the social interchange and generalizing thought rather than an element analysis that ignores the interaction between thought and language. For Vygotsky, word meaning together with its intellectual and affective consideration is a unit that captures the complex mechanism of communication and can serve as a threshold for investigating human consciousness.

Compatible with Vygotsky's theory, Bakhtin's (1984) dialogism provides a fruitful and insightful framework for analyzing communication and consciousness. In particular, Bakhtin suggests that "the thinking human consciousness and the dialogic sphere in which this consciousness exists, in all its depth and specificity, cannot be reached through a monologic artistic approach" (p. 271). That is, the dialogical overtones in people's utterances are important keys for social science researchers to understand human beings' discourse more fully. In the case of the professor's lecture discourse, Bakhtin's insights open new horizons for looking at the dynamic relationships between the professor and other interlocutors, such as the inscription. Moreover, the idea of dialogue helps me to think about an alternative explanation for the dynamic relationship between thought and language. As Bakhtin proposes, human beings' consciousness is better addressed through analyzing the layers of dialogical relationships in discourse, as "to live means to participate in dialogue: to ask questions, to heed, to respond, to agree, and so forth" (p. 293). That is, the very nature of oneself is continuously in dialogue with the other and cannot be understood without the other. Namely, human beings always need to be heard, to be responded to, and to be fulfilled by the other.

Bakhtin's insights about different dialogical relationships within and between utterances provide a thoughtful framework to understand the complex processes in people's communication and consciousness. Thus, I claim that Bakhtin's dialogism not only is consistent with Vygotsky's perspectives on the social and cultural nature of language but also serve as a threshold to enrich the unit analysis for future social science studies.

Coda

For both Vygotsky and Bakhtin, words do not mirror what people have in mind but continuously develop with thoughts during discourse. As informed by Vygotsky's insights, Roth's paper demonstrates how a professor's thoughts keep emerging in a lecture context to remind us that we cannot take people's words as stable conceptions in their minds. However, as Bakhtin asserted, the dialogical overtone in people's utterances is a key to understanding their consciousness and beings. Thus, in the chapter, I have drawn on Bakhtin's insights about dialogical relationships in discourse to propose thinking about thought and speech dialogically. I claim that thought and speech are two interlocutors who dialogue and keep influencing each other in discourse. The very reason that speech becomes a rejoinder is that speech is never one's own but is always for the other. In other words, speech itself integrates with the other. Speech has its own dynamic characteristics and so is distinguished from one's thoughts. This proposal not only confirms Roth's insights on not taking words as fixed thoughts but also emphasizes that, because of the social and cultural nature of words, we can neither attribute people's words to their minds nor view them as individuals' property. That is, words are not equal to thoughts and are always from the other and for the other. To understand human beings more fully Bakhtin's dialogical perspective on discourse serves as a plausible and fruitful framework for enriching Vygotsky's unit analysis.

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Part B

Positions and Perspectives

This second part of *ReUniting Sociological and Psychological Perspectives* is devoted to different perspectives concerning the project announced in the book title. Perspectives really are effects of the *positions* that we take in life; and these positions come with the fact that human beings are embodied. The interesting aspect of this concept is that one can develop an entire idiom around and from it with very interesting consequences for the way in which we think about knowing and learning. Many or most of the consequences and theoretical possibilities have not yet been explored on the part of scholars interested in the concept of *positionality*. The noun *position* has developed from the Latin stem *posit-*, the past participle stem of *pōnere*, itself having arisen from the Indo-Germanic pre-verb *po-* and the verb *sinere*, to put, to place. To be a human Being also means to be a being among beings, part of the material world, a thing among things; and it has and takes its place, it has and takes a position.

The term position can be combined with a variety of prefixes that on their own are *pre*positions, words positioned before *position* to form an array of concepts with implications for the way in which we think about the phenomena that across the psychology and sociology divide.

Having a body places us among bodies, and no two bodies may take the same physical space. With position, therefore, inherently comes a *dif*-ferent position, that is, a *dis*-position (*dif-* is the dissimilated form of *dis-* before *f*, both referring to duplication, two ways); and this is so because no two human beings can take the same place (Nancy 2000). Dis-position, two or more positions, however, also means differing *dis*positions, structured and structuring our ways of perceiving, thinking, speaking, and doing things. From a different place, the world looks different. It is therefore not astonishing that all of the four main contributions to this Part B of the book stress the role of position and the different observations that derive from it—whether this be a position on identity, the mutual observer roles of researcher and researched, and the function of gender and race in differentiating what is observable. A different word for structured structuring disposition is *habitus* (Bourdieu 1980), the "machinery" that underlies the ways in which we perceive and act toward the world. In this, *habitus* is different from the word habits, especially when it refers to the "mechanical" ways in which people act and react to situation. *Habitus* is a productive machinery of which we are not and never entirely in control. It is a "*modus operandi*, a mode of scientific production which presupposes a definite mode of perception, a set of principles of vision and division" (Bourdieu 1992, p. 222). We do not know why the world looks the way it looks because habitus functions in a practical state according to the norms of a community without having these norms as explicit principles. But we know that under changing conditions or to different people—taking different positions and having different *dis*positions—the world looks different. All chapters, either explicitly or implicitly, as us to accept difference, whether it be along the lines of gender, sexuality, race, culture, class, or institutional position (e.g., researcher and researched).

The concept of dis-position, different position, also allows us to think about and theorize how each *pro*position, the act of posting something, a statement about an issue, may situate itself as *op*position, *counter*position, and *contra*position to another person's proposition. In each case, *dif*ferent positions—dis-positions and *dis*positions—come to be played out against each other, confront each other. But in so doing, we may overemphasize each position as a unitary construct rather than recognizing that each position is in and by itself not unitary but heterogeneous, different within itself. If this were not the case, then a position—or, rather the person or persons taking the position—could be present to themselves, that is, they could be both present to a situation and make this presence present at the same time. This, however, is inherently impossible such that any presence in consciousness requires a re-presentation; and re-presentation requires representation (or sign, language, etc.). There is always a gap between presence and the presence of the present (Heidegger 1977). This gap, which Plato termed *khora*, the place where Being and the presence of Being (in/to consciousness) are created, leads to a continual erasure and rewriting of what we know. Opposition, counterposition, and contraposition therefore also provide opportunities for dialogue designed not to convince and erase the other but to allow different ideas to develop differently. Truth does not come by canceling out one or the other position but in a continual development of different positions in continuous interaction with all other positions, neither one of them pure but, in a continual exchange, continually working each other, hybridizing and creolizing one another in a continual process of mêlée that leads to ever further métissage. Mixing changes, transforms, irremediably and ontologically erases what has been; but mixing also keeps. Even if we cannot reverse the process to un-mix for arriving at some impossible pure state—for example, because of the laws of thermodynamics and irreversibility—we can nevertheless follow the history of a system, our system of ideas.

The idea to assemble different positions therefore is not to seek how we can triangulate a common position, which means, getting rid of some or all the differences between positions. Rather, I assemble these different pieces in the hope that readers recognize the differences within the positions that are as great as the differences between the positions. These differences within and between positions are the source for development and change, here, in our community's thinking about issues that traditionally were considered from psychological or sociological perspectives. In reading *a* text, readers are transformed, often ever so slightly (after hours of reading, we feel tired, that is, there have been extensive biochemical processes changing our bodies); and reading texts written from different positions, transforms readers differently, even if ever so slightly. Our body–minds become the field where the battle, the mêlée of ideas takes place, writing and re-writing languages we use to describe the world in the process.

In chapter 12, Kathryn Scantlebury and Sonya Martin invite us to a feminist re-visioning of psychological and social perspectives on conceptions and conceptual change, which may raise interesting issues and challenges. A psychological perspective to conceptual change proposes that learners develop a knowledge of the world through her/his experience, yet feminist research in science education has shown how gendered those experiences can be. Gender is the outcome of heterogeneous discourses within society and other social categories such as race, ethnicity, class, religion and language also influence the emergence of this concept. These authors review the research on gender issues in conceptual change and use feminist psychological and sociological theories to propose future directions for conceptual change research in science education.

In chapter 13, Michiel van Eijck focuses on theory building on conceptual change, which has led to the paradox that, in order to address teaching–learning processes, research yields an increasingly sophisticated output that alienates the teachers. The aim of this study is to explain the origin of this paradox. Drawing on exemplary data from a teaching–learning process in secondary education, van Eijck illustrates that the builders of conceptual change theory—that is, the attribution of conceptions to individuals—justify what they do by particularizing the actions of individuals. (They do so despite G.W.F. Hegel's [1979] analysis that any action of another person is recognized as an action that one could have performed oneself; this, in fact, is also a rather recent research result from the neurosciences, which found that there are mirror neurons at the basis of social cognition.) It therefore does not come as a surprise that from hermeneutic phenomenological perspectives, such justifications are problematic. Van Eijck sees the source of the theory–practice gap in this problematic justification. The implications of this explanation are discussed.

In chapter 14, Jean-François Maheux, Wolff-Michael Roth, and Jennifer Thom invite us to look at the problematic of sociological and psychological perspectives through the lens of the fact that both researcher and researched observe the other with respect to whom they are not neutral emotionally. In social sciences methods, the phenomenon is known as transference, how the observed relates to the observer, and counter-transference, how the observer relates to the observed (Devereux 1967). Research concerning conceptions commonly separates the researcher and the object under investigation (the researched). Overlooking the interdependence between the observer's posture and what is observed, they created an apparent chasm between an attribution of conceptions to the individual or to the collective, as it emerges from current debates on the topic hosted by two major journals in education. In this paper, the authors take Humberto Maturana's idea that everything said is said by an observer as the starting point for thinking about how to surmount that division. Observers essentially live in language; they operate distinctions and makes descriptions that bring forth the world they inhabit together with others. Maheux and colleagues argue that researchers as observer can define conceptions as the process by means of which individuality is realized as part of a collective, which locates conceptions within communicative contributions rather than within the individual or the collective. The authors then show that such a perspective is consistent with the idea of considering the researched as observer as well, contributing therefore in the emergence of a mathematical linguistic domain in and by their classroom interactions. Finally, the authors clarify what constitutes teachers' pedagogical responsibilities in relation to this issue by assuming a similar standpoint. Indeed, seeing teachers as observers in the constant process of creating significant differences in the relational space produced with and for the students leads to value teachers' awareness about their posture. This posture provides them with opportunities to recognize the students' contributions, essential for mathematics to arise as a meaningful way of being in the world.

In chapter 15, Christopher Emdin develops nation and nation-state as metaphors for looking at students and teachers in science classrooms. He argues that current conceptions of science (education) have evolved in a genealogy of institutionally connected science educators, characterized by established schools of thought and existent ways of thinking. He views science education through the analogy with a distinct nation that has a rich, generally accepted history, tradition, and culture. But tradition and culture come with the price: They cover up the blind spots of the discipline that do not allow researchers to discover why urban students, for example, have such difficulties with the subject matter. Emdin makes the case for a different view to iron out the complex relationship between science education, on the one hand, and urban science education, on the other hand.

Giuliano Reis reflects on these four chapters from the perspective of a teacher who has been working with adults in Brazil. His main concern lies with the question of how science specifically and schooling generally can be made relevant in and to the lives of those who find themselves in formal institutions of learning. He asks us to consider the diversity of people and voices. In and out of such consideration Reis sees the possibility for a birth of the "right kind" of science education.

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Chapter 12

How Does She Know? Re-visioning Conceptual Change from Feminist Research Perspectives

Kathryn Scantlebury, Sonya Martin*

A feminist re-visioning of psychological and social perspectives on conceptions and conceptual change raises interesting issues and challenges. A psychological perspective to conceptual change proposes that learners develop a knowledge of the world through their experiences, yet feminist research in science education has shown how gendered those experiences can be. We take gender to be a social construction and other social categories such as race, ethnicity, class, religion and language also influence that construction. Building from the feminist slogan "the personal is political" we articulate in this chapter the research on gender issues in conceptual change and use feminist psychological and sociological theories to propose future directions for conceptual change research in science education.

Introduction

Conceptual change research has dominated science education literature for over 30 years. The field has focused on examining students' conceptions regarding scientific phenomena, and to a lesser extent, how instruction may challenge and change those ideas. This book focuses on re-uniting psychological and sociological perspectives within the context of conceptual change research. Other contributors are presenting a range of perspectives on this topic, raising questions about the premise, assumptions, and value of conceptual change research. As science educators, we are particularly interested in exploring how it is that learners come to know and understand science. As researchers informed by sociocultural theory, we recognize that many different factors play a significant role in the social enactment of teaching and learning. For example, research on classroom learning environments documents students' perceptions and preferences of the sociocultural

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setting and how that mediates student achievement, learning, and engagement and the teaching practices. Other sociocultural research defines science as a unique culture and explores how students engage, understand, and ameliorate that culture with their own from a variety of perspectives such as urban and rural settings, race, ethnicity, socioeconomic status, language, and gender.

Increasingly, studies are showing that factors, such as gender, race, ethnicity, socioeconomic class, religion, sexual orientation; and, according to some new research, brain physiology of individuals also informs the ways in which people come to know and understand the world around them. Conceptual change research considers a student's learning experiences, both in and out of formal education settings. Feminist research has shown that those experiences can, and have been, highly gendered—from the types of questions teachers ask girls compared with those that they ask boys, the time and quality of laboratory experiences to students' expectations for their own ability and success in science. However, recent research has also shown that students' cultural and socioeconomic background has a greater influence on their mathematics and reading/language arts achievement than gender. Thus, it is imperative that researchers need to widen the scope of analysis in past, current, and future conceptual change research to consider the ways in which these social constructs mediate teaching and learning. Until recently, few conceptual change studies have included an examination of how social and cultural factors relate to students' science learning and how teachers engage students in that endeavor.

As researchers, our work is not only informed by sociocultural theory, but is also grounded in feminist theory, which necessitates that we recognize the complexity of the social act of teaching and learning as we engage in research. Whereas we acknowledge that each aspect of social life, including race, class, or ethnicity is significant with regards to teaching and learning, we focus on gender in this chapter because gender represents a centralized issue that can be explored across these differing categories. Where possible, we foreground what is known about girls' experiences that is also mediated by their race | class | ethnicity | ability | sexuality.[8] We do so in an attempt to highlight the complexity of these inter-connected issues and to raise awareness about the limitations of current research in science education. This way of proceeding is specifically important in the area of conceptual change research where a cursory review of the literature reveals that few studies have foregrounded students' gender when examining how they learn. Our initial analysis of the conceptual change research literature prompts us ask the following questions: Why is there an absence of gender or feminist studies within the conceptual change research? Why should we be concerned with lack of feminist studies provided in the conceptual change research?

These questions have provided us a backdrop for re-examining the existing conceptual change research from a feminist perspective to determine how gender/feminism might mediate the learner at the sociological and psychological

8. We use the "|" to indicate that these different social categories influence a person's position in the culture and also how others respond to that person.

levels. Based on our analysis of the conceptual change research, we assert that the ways in which females know or come to know science is a question, which has been ignored in the literature, but is significant for the science education community to understand. By re-visioning conceptual change research from a feminist perspective, we offer new questions about what researchers do/do not understand about females and science learning, moving from a psychological to sociological perspective. Further, we suggest that the methods used in conceptual change research have ignored the personal are positivistic in nature and as such, do not account for the individual personal experiences of people based on their differences or for individual perspectives that embed learning within a sociocultural context. A feminist re-visioning of conceptual change research proposes different theoretical and methodical lenses, which pay attention to difference (not only in gender). To place this re-visioning in context, we examine how conceptual change research has addressed gender and how this might inform an attempt to re-unite the psychological and sociological perspectives from a feminist stance. Our findings raise more questions about and implications for the practices used to conduct research in this area, which, from a feminist research perspective, are often limited and ineffective in paying attention to difference.

As women and feminists, we each share some common experiences and beliefs regarding what it means to conduct research from a feminist perspective. However, we also recognize the need to be attentive to issues of difference, both between us and among women in general. Therefore, we have decided to position this research within the sociohistorical context of the feminist movement over the last 40 years in an effort to re-examine conceptual change research from a landscape of changing feminist perspectives and feminist research praxis.

Specifically, we have chosen not to define a particular feminist stance from which to analyze the data, but rather we have chosen to describe the ways in which learning science can be embodied through the lens of the slogan “the personal as political.” The slogan encompasses research and praxis, which is fundamental for re-visioning a body of research literature that has largely ignored how learners’ gender may influence their knowledge and how those personal experiences translate into the larger sociocultural context of who learns science, what science they learn, and how that knowledge can improve an individual’s quality of life and a community’s perspective. Specifically, we discuss a feminist perspective on the methods used to conduct conceptual change research.

We assert that because researchers have opted not to recognize gender (the personal) as a construct that mediates student learning and conceptual development, few findings from these works have made a positive impact on the teaching and learning of girls and women in science (the political). Specifically, we analyze the field from a the-personal-is-political stance in an effort to highlight some of the inequities that have developed in science teaching and research praxis as a result of these studies. Thus, we embrace this slogan as a reminder that the incorporation of feminist principles in research should promote a feminist praxis, the outcomes of which should result in positive changes for women and girls or an expansion of the knowledge base on the social issues that impact their lives. This includes recognizing differences related not only to gender, but also to race | class | ethnicity | ability | sexuality. In so doing, we offer new directions for improved feminist research praxis that should expand learning opportunities for all students. The-personal-is-political provides a critical framework to meet the challenge discussed at the Springer Forum in New York and in this book: How does science education research reconcile the psychological perspectives of conceptual change research with the growing body of literature with a focus on sociological perspectives?

Plan for the Remainder of This Chapter

In the following sections, we provide, in our own voice, an overview of some major milestones in the feminist movement to provide the sociohistorical context for the origin of the feminist movement and provide the context for the-personal-is-political slogan and we explore how this slogan provides the structure for reconciling conceptual change with sociocultural research. Next, we articulate some findings from conceptual change and gender studies over the last 30 years, paying particular attention to how girls/women come to know or understand concepts in science, what science they prefer to learn, and what teaching strategies are most effective for females. Building from these two sections, we draw attention to the ways in which conceptual change research and feminist studies in science education have been informed by the evolution of thought in the feminist movement and in the development of feminist research practices. Specifically, we examine the impact these changes have had on science education research over time and draw implications for how gender has been positioned within research on conceptual understanding and the teaching and learning of science.

When the Personal Is Political

The personal is political evolved from 1970s radical feminism to challenge the patriarchic structures that disenfranchised women and girls. Thus, the personal is political is a rallying cry to action addressing women and girls to examine their individual circumstances and to connect those personal experiences to a larger context. In our chapter, we re-interpret the political as the sociological perspective as it relates to the construction of gender in society and how this construction informs teaching and learning. Whereas the personal relates to the psychological perspectives, feminist studies that have focused on examining why girls and women did not engage in science have ignored the macro-structures that support science and science education. We believe that an examination of the research from this perspective enables us to contextualize how the feminist movement, over the last 40 years has informed the evolution of differing feminist research practices. Many of these practices have shaped education research generally and science education research more specifically. In the following section, we briefly provide the context for the origin of the slogan and offer our readers background information about the feminist movement's waves from suffrage to equal rights and to the current stance of an examination of how the politics of globalization has mediated feminism and vice versa.

Waves and Stages

According to some theorist, the history of Western feminism has occurred in three waves (Fraser 2007). The first wave began in the late nineteenth and early twentieth century, the second wave spans from the early 1960s through the late 1980s, and the third wave extends from the early 1990s to the present day. We outline here an ever-so-brief history of the Western feminist movement to provide a historical context for development in feminist theory and social practice.

The first wave of feminism is framed around the establishment of women's equality and equity in terms of education and political power. Mary Wollstonecraft is regarded to be the mother of this first stage because of her seminal work *A Vindication of the Rights of Woman*, a political treatise written to counteract Jean-Jacques Rousseau's prevailing theories regarding women's education. More recently, scholars have also called her the mother of co-education because she argued that females' education should include botany, history, mechanics and the natural sciences, reading, writing, arithmetic, and religion. That is, she argued that women should receive an education similar to men, which meant an education that also included science. During this time, the pursuit of education was particularly important for women because they were denied basic citizen's rights, that is, the right to vote. Women had varying success in attaining their citizenship rights in western countries. For example, women attained voting rights[9] in Aotearoa New Zealand (1893), South Australia (1894), Commonwealth of Australia (1902), Finland (1906), United States (1920), Republic of Ireland (1922), United Kingdom (1928), Spain (1931), Brazil (1932), and France (1945). The first stage of feminism is said to have ended when women attained suffrage. However, well into the twentieth century, and in some countries the twenty-first century, Black, Middle Eastern, or illiterate women did not and still do not have voting rights.

The 1960s heralded the second feminist wave, where advocates sought equity for women within other societal institutions such as education, career and health care. The second-wave of feminism within Western society has focused primarily on identity politics located within cultural issues. Within this wave, feminists examined social structures for their inequity towards women and girls. In science education, this began with studies such as Alison Kelly's *The Missing Half*, Dale Spender's *Invisible Women*, and Jane Kahle's *Girls in School: Women in Science*. This research began with a quantification of girls' and women's science participation

9. The dates refer to full citizenship rights to vote at both local and national levels and were allowed to run for elected office without restrictions such as age, land ownership, or literacy levels.

and achievement at the school, college, and career levels. From this base, feminist researchers focused on the sociocultural settings of classrooms as well as taking a psychological perspective of what individual characteristics and variables impacted females involvement in science. The psychological research has been characterized as fixing girls, that is, programs focused on improving girls' spatial abilities, self-esteem, and self-confidence to improve their achievement and participation. Some programs focused on out of school projects that could expand girls' experiences to improve psychomotor skills and create environments to foster girls' confidence in their ability to succeed in science.

The sociocultural research examined how teachers engaged girls in science, how girls participated, what science interested them, and what pedagogical strategies would increase girls' science participation. Intervention projects worked with teachers to include examples of women scientists in the curriculum as role models for girls, they made suggestions for pedagogical changes that would generate a female-friendly culture within science classrooms and also re-position curriculum to include science topics that girls, and in most cases also boys, found interesting. Feminist researchers examined why girls preferred studying biological, rather than the physical sciences, attributing this interest to girls' preference to connect with humans and other living things rather than to abstract ideas or concepts where they could not directly align the importance of the topic to their interests.

We note that conceptual change research in particular has not examined gender differences in how girls and boys may learn things differently as a result of their perceived interests or engagement in science. It was not until the 1990s and the movement towards identity politics that feminist science educators began critiques of science and science education as patriarchic, that is, the field began to move from the personal perspective to a political one. Moreover, sociocultural researchers in science education also began to examine how other social and societal categories such as race and class were mediating students' science learning. However, conceptual change research did not consider how these learner characteristics influenced their data or informed their perspective on the interpretation of their data.

The third wave of feminism began in the early 1990s and has been described by some as a response to perceived failures of the second wave. It was a backlash against initiatives and movements started by second wave feminists. Third-wave feminists often focus on transnational politics, seek to challenge notions of femininity and gender as defined by the second-wavers, and have tended to take critical approaches to previous feminist discourses that are criticized for ignoring or marginalizing the experiences of non-White, middle class women. Some scholars indicate that the second and third waves concurrently co-exist as a range of feminist theory standpoints, which stem from differing ideologies. These standpoints include liberal feminism, radical feminism, Black feminism, postcolonial feminism, post-structural feminism, socialist feminism, multiracial feminism, ecofeminism, and critical feminism. The term wave has been coined retrospectively to describe evolutions in the feminist movement as the general focus of those involved have transitioned from gaining the right to vote, to fighting social and cultural inequities, and to critically examining the power dynamics between different peoples (across race, gender, class, ability, or sexual orientation) and in the context of transnational and global politics.

Within this third stage, feminists have engaged with globalization. Globalization has negatively impacted women's lives by ignoring the micro-credit of women's contribution to economic production through their activities within the private sphere, namely, child-care and child-rearing, and providing familial infrastructure through their labor in the home. Others have argued that globalization has provided international opportunities and connections for women. However, feminist groups have used globalization to produce gender mainstreaming as a vehicle for political activism to challenge macrosocial structures such as wages or equal access to employment and education.

Overtime, the educational research community has been informed by changing theoretical perspectives, for example, adopting a sociocultural perspective on teaching and learning examines issues that lie outside of the individual learner and are informed by the larger social structures in which the learner exists. Feminist thought and theory have also been evolving and are evidenced by the change from fixing the girls to succeed in the male-dominated culture of science to a critical critique of science and science education. However, the change in research perspective has slowly occurred and researchers need to be bold as they develop new agendas that focus on the new challenges facing women and girls in the twenty-first century. Thus, we offer a first step through this work to help unite the conceptual change and sociocultural research agendas to suggest new research methods. We enact this re-visioning of conceptual change research through a the-personal-is-political lens.

In the next sections, we explain how we have used the personal is political as a means to re-unite conceptual change and sociocultural research. We then articulate some of the findings from feminist research in science education and interpret these findings in relation to the slogan in an effort to connect feminist research and theories to conceptual change research.

Gender and Conceptual Change Research

An analysis of peer-reviewed articles generated by an ERIC search on the words gender and conceptual change revealed that few articles have been published in which gender was considered a significant issue. And while there are several review articles about conceptual changed within the field of science education, such as the *Handbook of Research on Science Education* (Abell and Lederman 2007) or the *International Handbook of Science Education* (Fraser and Tobin 1998), these comprehensive reviews do not provide any information regarding gender. One exception is Diane Bunce and Dorothy Gabel's (2002) study of gender issues with regards to students' science conceptions at the high school level documenting that girls prefer different pedagogical strategies to boys. This key study showed that introducing students to different levels of representation in chemistry improved girls' understanding and achievement. Thus different pedagogical approaches can improve students' conceptual understanding of science. The authors focused on gender differences in high school chemistry students' understanding of the level of representations in chemistry by using experimental and control groups. Students in the experimental group experienced explicit teaching of three levels of representation, namely symbolic, macro and particulate and students in the control group did not learn about the particulate level of representation. The researchers reported that girls performed significantly better on the chemistry achievement after being taught the three levels of representation, whereas for boys there were no significant differences between those who were taught the particulate level and those who were not. Thus, the study demonstrated that girls responded better to pedagogical instruction that relied on enhanced levels of representation. This means that girls may benefit from differentiated instruction in the science classroom where teachers expand learning opportunities by placing a greater emphasis on developing students' conceptual understanding of particulate matter.

Conceptual change research assumes that individuals' experiences mediate their learning, and outcomes from the gender research in the 1980s showed that encouraging girls in tinkering activities and developing their spatial abilities had positive outcomes on their science achievement and attitudes. Similarly, positive parental and teacher expectations for student involvement in science have also impacted whether girls became interested or successful in science. Other studies have used gender as one variable when examining students' understanding of science. In a study of Turkish eighth-grade students that examined achievement in biology, girls had higher achievement than boys on a two-tiered test on the conceptual understanding of photosynthesis and respiration in plants. However, the pedagogical practices that targeted students' misconceptions did not show any gender differences (Yemilmez and Tekkay 2006). In contrast, studies examining science concepts, such as heat and temperature and acids and bases, through a conceptual change approach found gender differences between students' preference for learning the concepts but not on students' achievement. In general, researchers that focused on conceptual change did not take into account the sociocultural cultural aspects of how gender may impact learning science but rather used gender as a variable to disaggregate data and conduct analysis.

Conceptual change research falls into a time-honored trap of male hegemony. That is, although sociocultural research recognizes that products are marked by the particulars of the production process, the fact that most scientists were male has not been used to question the masculine character of socially constructed scientific knowledge. Philosophers have typically treated those who construct knowledge as featureless abstractions and have defined knowledge as objective and transcending experience (Code 1990). Those who have conducted conceptual change research have also had similar views and have ignored what role experiences may have had on a learners' development of their science ideas. Moreover, the field has also focused on canonical science knowledge, ignoring how culture may contribute to students' knowledge.

A student's gender | race | class | ethnicity | ability | sexuality may mediate her/his practices which could differ from the reigning cultural expectations. The second stage of feminism is concerned with identity politics and has a focus on the socio-cultural. Yet, credibility of the knower is important when discussing knowledge production. If students create knowledge and meaning from their social interactions with their peers and teachers and also feminist perspectives that all view social relations as gendered, classed, and racialized, then the knower cannot be a featureless abstraction. Second, knowledge viewed as abstract negates the importance and value of experience, and prevents people who value experience from engaging in knowledge production. Knowledge is subjective and objective and "traditionally women have access only to experience, hence not to the stuff that knowledge is made [of]" (Code 1990, p. 223). Learners from racial groups have also been excluded from the production of knowledge and produce different types of science knowledge than canonical science. For example, a girl might be disenfranchised from science because her knowledge of the healing powers of spider webs are not valued. The possibility of using experience to provide science knowledge was not considered—how could she know? She had not completed the sacred steps of canonical science. By not acknowledging the assumed masculine discourse within the research of conceptual change, the researchers have defined masculine and white as normal and ignored other discourses: that is, the feminine or the cultural.

Why is this the case? Is it because science educators hold science's supposed values and characteristics of rationality, logic, a distancing from the subject, a disregard for emotions, thoughts, and feelings as penultimate? There is a lack of science education studies examining race and gender from conceptual change and other perspectives. However, these absences implore us to ask what kinds of challenges would arise from a study such as this in which researchers examined conceptual change in relation to gender differences across races? This research is particularly important as western education systems become more culturally and racially diverse. Recent science education research has also explored how science education should be re-constructed through an acknowledgement of indigenous peoples' science knowledge.

What Makes Research Feminist?

How would could feminist theory inform and guide future conceptual change studies? Although there are multiple feminist perspectives—including radical, liberal, critical race, Black, Latina, Chicana, or post-modernist—we first discuss what constitutes feminist research and then use critical race feminism to explore how this perspective could modify and re-unite the personal with the political. Placing the social construction of gender as central constitutes feminist research (Lather 1991). The context and focus of feminist research has changed over time from a focus on new social movements, to identity politics, and, currently, to trans-national spaces as an outcome of globalization. However, feminist research foregrounds women and girls' lives and experiences and strives to transform the situation or context under study and in particular, enhance women and girls' agency. Within this chapter, we use critical race feminist theory to re-vision conceptual change research. We assert that this perspective takes into consideration issues of power and examines how power mediates gender | race | class | ethnicity | ability | sexuality. A critical race feminist theoretical framework strives to critique patriarchic structures and propose pedagogical strategies to transform gender relations.

Feminist researchers strive for reflexivity in their practice as they identify and attempt to minimize or remove inequities within the research, and acknowledge the role and implication of power for those involved with research. Feminist researchers situate their identity within the study, and because identities are historically, socially, and culturally constructed, those identities are subject to change. But in conceptual change research, there is always a powerful differential and an unconscious hierarchy is established. Power differentials in social settings that are not subjected to a critical examination of that power can lead to the establishment of an ideology rather than production of knowledge (Smith 1990). Within conceptual change research, there are two examples of power differential between the students and the researcher. First the interviewer is always positioned as privileged, the knower of science, and thus has more status and power than the research subject being examined. (See also chapter 14 by Maheux and colleagues on the relation of observer and observed.) Second, there is typically no deconstruction of the power differential between the student and researcher. By this we mean that researchers have not typically used the exploration of understanding of students' science ideas as an opportunity to teach the student. Nor have they listened to the student to ascertain if the students' idea may be presenting a local knowledge of science. Conceptual change research has focused on canonical science—thus also privileging that knowledge above other forms. These other forms of knowledge include local and familial knowledge about how to use herbs and plants for dealing with medicinal and other purposes.

Why should we be concerned with lack of feminist studies provided in the conceptual change research? If one accepts the assumption that learners develop their knowledge through experience, we come to the first problem by ignoring gender | race | class | ethnicity | ability | sexuality. From birth, the adults who raise and care for girls and boys teach and treat them differently. Boys are encouraged to become physically and actively engaged with the world. They are provided toys, such as blocks and cars that develop spatial and psychomotor skills. Adults engage boys in physical play, and improve their psychomotor skills by encouraging them to crawl, walk, and climb. In contrast, girls are encouraged to learn the nurturing and caring strategies that society expects of females. Girls are encouraged to sit quietly in adults' laps rather than crawl. We cuddle girls and encourage them in predominantly sedentary activities such as playing with dolls. Girls' early educative experiences emphasize social skills, complacency and compliance, whereas boys' experiences embody encouragement in risk taking and exploratory behaviors, competitive games and developing their psychomotor skills. Thus, from an early age boys are encouraged to explore and observe the natural world, develop their independence and autonomy, whereas girls relate to people and respond to their needs and maintain their dependence upon others.

Psychological differences also can have consequences for individuals in the sociocultural world, especially in science. For example, science appeals to persons who are individualistic, autonomous, rational, and detached from the subject. That is, the re-configuration of what is defined as science may be one perspective of how conceptual change research could be re-organized and re-orientated through a feminist lens. Other considerations include (a) the role of race/ethnicity, gender, and class in research, (b) the objectification of research subjects, and (c) how decision-making processes mediate the selection of research subjects and a critical analysis of the field's prior research assumptions. Who has conducted the studies in conceptual change research? What was/is their gender, race, and class? Is there a reflection of the power differential in science? That is, are the researchers white? Male? We note above that in terms of science knowledge, that is, in terms of a form of cultural capital, the researchers are privileged over the subjects but what other circumstances can add to this situation? Researchers also need to examine their unconscious biases towards their subjects, for example, as we have noted there have been few studies examining gender and racial patterns in conceptual change research which poses the question—what knowledge has been ignored here? Could that knowledge help science educators develop deeper understanding about how students from different cultures and experiences learn science?

There exist several approaches to change the power differential between different participants in research (Sprague 2005). First, interviews could be an exchange of ideas between the researcher and the researched, thus destabilizing the power hierarchy. Second, researchers could foreground the role of emotions as data. Third, the use of personal experiences and insights could also inform the data. For example, we might ask questions such as "What do the researchers remember about their science learning?" or "Did they struggle with certain concepts and why?"

Re-visioning and Re-visiting Conceptual Change Research

How could critical race feminism re-vision conceptual change research? One area is the data collection techniques used. Interviews and classrooms observations are primary data collection techniques. These different data may be extended. The issue is the power differential that exists within these and other qualitative data collection techniques. Most often within the conceptual change work, adults (university researchers) interview students and there is often a difference between the gender, race, ethnicity, and class of the subject and the interviewer. In conceptual change, these differences are further exacerbated with a difference in the level of the content knowledge on which the interviews are based. For example, the interviewer has a deeper knowledge and understanding of the material than the subject that creates an inherent tension when discussing how to re-vision the research from a feminist stance. In other words, interviewers generally are in a power position over the subject because they have more scientific knowledge than the subjects—though there is evidence that the actual distribution of power/knowledge is itself an achievement of the interview (Roth and Middleton 2006). Furthermore, feminist research also finds the objectification of subjects problematic. Questions should be raised about who gets to choose the research subjects or how the subjects are chosen in the research.

Could conceptual change research using interviews become feminist? One first strategy might be for the subjects to foreground their experiences with the scientific phenomena, to talk about their feelings on the subject as well as their conceptions. Interviewers may need to show an ethic of care with subjects: Do conceptual change researchers explore the possibilities of assisting subjects in revising and refining their concepts while interviewing the participants?

What did the researchers know about the different styles of talk and expressiveness of males and females? When using interview techniques to collect data, feminist researchers attempt to maintain a reflexive approach, constantly reviewing their stances, assumptions, perspectives, identity roles of themselves and those who they are working with, and power differentials. Another aspect of interviewing is listening, the practice within feminist research to engage intellectually and emotionally with the data. That is researchers listen to words, conversations, and continually evaluate the depth and extent of power enacted by the participants. (See also chapter 8 on the technique of radical listening.) That is, usually it is the researcher who re-tells the stories, foregrounds and decides which stories are of most worth. One must struggle against allowing dominant discourse to drive the research that is done and also what is completed. However, these issues go even further when considering conceptual change research and how that data is collected. For example, Wolff-Michael Roth (2008) notes that interviewing is a societal activity and that the voicing of a learner's conception is a collective remembering—produced from learners' ideas but also how the interviewer(s) have framed the questions. Moreover, as most of the research has relied on audio recordings of interviews with researchers analyzing the transcript questions should also be raised as to what cues the interviewee picked up from the interviewer. These nuances are very important when considering interviewees who are less powerful than others. In other words, people who are subordinate, disempowered, or disenfranchised have better perceptions of non-verbal cues than others. Thus, women and people from disenfranchised groups will respond differently to an interviewer's cues. However, these types of analysis have not been done in the conceptual change research.

Another consideration is to examine the science concepts that students are interviewed about. Science education researchers could expand the knowledge base to examine other aspects of knowledge. For example, indigenous science knowledge such as the role of genetics in chronic medical conditions or re-envisioning the role of subjects such as home economics—a subject area established in the nineteenth century by the American chemist Ellen Swallow Richards. She incorporated scientific studies and principles on issues such as nutrition, childcare, microbiology and disease, etc. Richards wrote weekly pamphlets on scientific issues that were relevant to women who had primary responsibilities for their families' welfare and childcare.

Conclusion

Feminist research has identified that students have different sociocultural experiences in and out of the classroom. Those experiences mediate their science learning, attitudes towards science, and perceptions of their ability to succeed and learn in science. Further, teachers and students make various assumptions about a learner's science ability based upon their gender | race | class | ethnicity | ability | sexuality. However, few conceptual change studies have taken the learners' characteristics or their sociocultural learning environment into account. The outcomes from sociocultural studies could inform a feminist re-visioning of conceptual change research as the field has few studies that have considered how a learner's gender | race | class | ethnicity | ability | sexuality mediates their science learning from psychological and sociological perspectives. This re-visioning from the personal to the political may help to re-unite psychological and sociological perspectives in conceptual change research by re-examining (a) how culture mediates a student's learning, (b) the use of feminist research practices when conducting research, and (c) what counts as science knowledge and who produces that knowledge.

Throughout the various waves of feminism, the impact of research on the lives of women and girls was foregrounded. As feminist research continues to develop in the twenty-first century, its focus has moved from equal rights for women, through identity politics to the impact of globalization. In particular, other cultural and sociological factors such as race and socioeconomic status are more predictive of students' academic success than gender. However, gender remains a key characteristic in the type of experiences learners have in formal and informal settings. As with all aspects of science education research, the field of conceptual change would move forward by reflecting upon what is known and asking how the interpretation of that data would differ through various theoretical lenses, such as critical race feminism, which may expand our understanding of how to improve the teaching and learning of science.

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Chapter 13

Conceptions and Characterization An Explanation for the Theory-Practice Gap in Conceptual Change Theory

Michiel van Eijck*

There is nothing more practical than a good theory.
–Lewin 1952, p. 169

For more than 2 decades now, conceptual change theory has been lauded as a powerful framework for improving science teaching and learning. This has resulted in an increasingly sophisticated theory building, yielding, among other things, a comprehensive documentation of students' (mis-, alternative, naïve, etc.) conceptions across most science domains. This increasing sophistication is required to address increasingly adequate the complex phenomena of teaching and learning science. Yet, despite this sophistication, the theory is not yet practical for the practice of teaching. On the contrary, with an increasing sophistication, the gap between research output and that what is finally put into practice by teachers has increased as well. In other words, "there is the paradox that in order to adequately address teaching and learning processes research alienates the teachers and hence widens the 'theory-practice' gap" (Duit and Treagust 2003, p. 683).

In this chapter I explain the origin of this paradox. I start with an exemplary case of two students who jointly interpret a particular graph. Drawing on conceptual change theory, it can be said that they articulate "their conceptions" and that conceptual change is occurring. Departing from this case, I briefly rearticulate the current state of conceptual change theory and I illustrate that a key aspect of theory building in conceptual change, that is, the attribution of conceptions to individuals, is justified by the characterization of the individual by the practices in which they engage. To better understand this process of characterization and the way in which it is used as a rationale for the attribution of conceptions to individuals, I approach it through the lens of hermeneutic phenomenology. This investigation reveals a number of methodological problems that account for the theory-practice gap.

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I conclude this chapter by discussing the implications of this understanding of the origin of the paradox that, to address teaching-learning processes, research yields an increasingly sophisticated teacher-alienating output.

The Case: Logging the Heart with Microcomputer-Based Labs

The exemplary case is part of a larger design study in biology education, called *Logging the Heart with Microcomputer-Based Labs* (van Eijck 2006). The aim of this study was to improve the teaching of quantitative concepts by using Microcomputer-Based Laboratories. This study was rooted in a framework that overlaps theoretically with conceptual change theory to the extent that conceptions are understood as distinguishable entities that can be attributed to individuals. However, it adopts also a situated cognition perspective by analyzing how individuals' conceptions are grounded in the situations at hand. As such, this study aimed at overcoming a so-called cognitive-situative divide that plays a role in conceptual change theory as well (e.g., Vosniadou 2007).

The case features a situation in which two students (Ashley and Becky) have just measured, for a first time, the carotid pulse with a heart rate sensor (see Figure 13.1). To allow readers to understand what is happening in the situation, I illustrate first the specific artifacts and the way in which they are used.

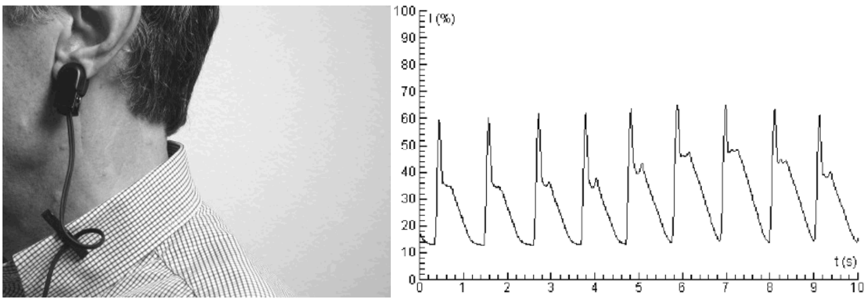

Figure 13.1. Heart Rate sensor attached to the ear lobe (*left*) and a typical outcome of students' measurement of the carotid pulse (*right*).

The heart rate sensor holds an ear clip, which consists of a light emitting diode (LED), and a photoelectric cell in between which the earlobe can be placed. The quantity depicted on the vertical axis in the graph is the relative light intensity (*I* in %) that is the relation between the light emitted by the LED and the light received by the photoelectric cell. The more the earlobe is saturated with blood, the less light is transmitted through the ear lobe. The signal of the photoelectric cell is amplified and inverted. The output signal of the heartbeat sensor is a measure for the blood saturation of the blood vessels of the ear lobe and varies with the frequency of the heartbeat. In Figure 13.1, a typical example of students' outcome of the measurement of the carotid pulse is observable. The carotid pulse is ultimately caused by the contraction of the ventricles of the heart and hence the heartbeat frequency can be derived easily from the graph. In the exemplary graph, the measurement took 10 s and nine carotid pulses are observable. The carotid pulse in the ear lobe is proportional to the blood pressure in the aorta. Consequently, the quantitative concepts—observable in the graph as typical spikes—can be explained by featuring processes taking place in the aorta during a heartbeat.

Besides the MBL equipment, the students use a hand-out with a manual that illustrates step-by-step the measurement setup, after which the students do assignments that have to do with the measurement outcomes, such as deriving the heart beat frequency. With the transcript below, we enter the conversation after Ashley and Becky have measured the carotid pulse and are working on the assignments. Ashley utters a specific question about the graph asked in one of the assignments, after which a short discussion unfolds:

1	Ashley	[Speaking out aloud the question written in teaching materials] What is the relation between what you have measured and the streaming of blood in the ear lobe?
2	Becky	When the blood pressure is higher … When the blood pressure is higher … It is streaming … It is streaming … It is streaming faster through the ear!
3	Ashley	[Observing the notes of another student]
4	Becky	Hey! [Becky attracting attention of Ashley]
5	Ashley	[Turning towards Becky]
6	Becky	[Pointing to screen] If the percentage is higher …
7	Ashley	More blood is let through
8	Becky	Yes!
		[Silence. Becky is looking in the direction of the screen for more than 5 seconds]
9	Becky	No, more blood is in the ear lobe, isn't it?

By featuring this case, I do not pretend to present solid evidence for the occurrence of conceptual change or the appearance of particular conceptions. Rather, for the purpose of my argument, I exemplify some features of theory building on conceptions and conceptual change in order to point out my position.

Conceptual Change Theory

Conceptual change theory draws on the distinction of "conceptions" which are attributed to individuals, such as students and teachers. It is said that individuals have particular "mental structures" (Vosniadou 2007) on which they draw when articulating their conceptions. For instance, in the featured case we might attribute several conceptions to Ashley and Becky. Both Becky (lines 4–6) and Ashley (line 11) express the first conception, describable as "the heart rate sensor measured the speed of blood in the ear." Only Becky (line 15) expresses the second conception, which can be described as "the heart rate sensor measured the amount of blood in the ear."

An important aspect of conceptual change theory is to compare students' (mis-, alternative, naïve, etc.) conceptions with accepted scientific conceptions. For instance, we might classify the first conception expressed by both Becky (lines 4–6) and Ashley (line 11) as "inappropriate" when compared to accepted scientific conceptions. In other words, both Ashley and Becky have particular "mental structures" by which they "inappropriately" interpret or "misconceive" the graph and maintain that "the heart rate sensor measured the speed of blood in the ear."

The term "conceptual change" is used to characterize a learning process that may occur when the new information to be learned comes in conflict with the learners' prior knowledge usually acquired on the basis of everyday experiences. It is claimed that in these situations, a reorganization of prior knowledge is required—a conceptual change. For instance, conceptual change is said to be required when the scientific concept of force comes in conflict with the everyday concept of force as a property of physical objects (Chi et al. 1994) and understanding the Copernican view of the solar system comes in conflict with the geocentric view (Vosniadou and Brewer 1992). The particular case featured in this paper does not deal with common problematic big issues featured in conceptual change theory such as the concept of force and views of the solar system. Yet, it is comparable to examples in the literature of conceptual change that deal with students' confusion between distance and its derivative, velocity, while interpreting distance-time graphs and which are featured in cases in which microcomputers are used for remedial teaching (Zietsman and Hewson 1986). In these examples, settings in which students interpreted time versus distance graphs were specifically designed by "using conceptual change strategies with the aim of helping the students to change to an acceptable conception" (p. 30). In this case, the situation is more or less comparable in the sense that there is some confusion between the amount of blood and its derivative, the streaming speed of blood, while students interpret an amount of blood versus time graph.

According to classical conceptual change theory (Posner et al. 1982), it is assumed that the learner is a rational being and will thus respond to logical and factual information. For instance, confronted with the graph in line 13–14, we could maintain that Becky's current conceptions are inadequate to allow her to grasp the phenomenon successfully. Then, in line 15, she has replaced or reorganized her central conceptions, which allowed her to accommodate the scientific conception that the heart rate sensor measured the amount of blood in the ear. Hence a conceptual change would have occurred.

Since 1982, classical conceptual change theory has undergone multiple criticisms. Specifically, the assumption that individuals respond rationally to situations fails to take into consideration the contextual components of the paths that lead to knowing and understanding and that have to do with, among other things, worldviews, artifacts, and other sociocultural aspects of the setting at hand (Saljö 1999). For instance, in the above excerpt, we might object the strictly cognitive perspective and maintain that the conception “the heart rate sensor measured the speed of blood in the ear” is due to the question posed in the teaching materials, which emphasizes the streaming rather than the amount of blood. As well, research has shown that artifacts in the setting such as graphs can induce students’ misconceptions (Roth et al. 2005). In this case, for example, the confusion between streaming and speed of blood may be due to a lack of resources that is required for appropriate interpretation of the graph. If the vertical axis of the graph in Figure 13.1 had referred to the amount of blood rather than the relative light intensity *I*, the students might not have articulated a misconception. In response to such criticism conceptual change theory has matured. There is now a more detailed account of what actually changes in conceptual change theory and recent theory building takes in consideration so-called situative perspectives according to which conceptions are flexible, malleable, and distributed and situated in the sociocultural setting.

With regard to the current mature state of conceptual change theory, the issue of the theory-practice gap is even more pertinent. Indeed, the inclusion of situative frameworks in conceptual change theory should allow a more detailed, sophisticated understanding of conceptions in the setting due to which the practice of teaching and learning is addressed in more detail. For instance, conceptual change theory should allow us to frame the case of Ashley and Becky such that we understand why and how they come to articulate the conceptions in the very setting in which they engage. This should yield a better understanding of the practice of teaching and learning, and, consequently, its improvement. In the current practice of theory building on conceptual change, however, the resulting increased detail alienates practitioners, which frustrates the improvement of teaching and learning practices. There is thus the paradox that a better understanding (theory-building) of teaching and learning practices widens rather than closes the theory-practice gap. The aim of this paper is to understand the origin of this paradox.

Conceptions and Practice

As a first exploration of the theory-practice gap, we might ask the question how teaching and learning practices are approached in conceptual change theory building. That is, what do researchers do with these practices when a conception is attributed to the individual? Conceptual change theory, to begin with, always describes the practice in which speakers make conceptions available. In the case of Ashley and Becky, for instance, I describe the practice I monitored by means of the video camera during my research, such as specific artifacts (graphs, heart rate sensor, MBL) and the speakers’ utterances and bodily positioning in the conversation. As well, interview studies, which are frequent in the field of conceptual change research, describe in detail the questioning practices as a result of which students provide specific answers that are accounts of conceptions. Even in questionnaire-based research on conceptual change, there is a detailed account of the practices in which the conceptions are supposed to emerge, namely the practices of providing a specific answer to a specific question of the questionnaire. Irrespective of the method of data collection, research rooted in conceptual change theory describes (in part) the practices in which a conception is supposed to emerge (or not).

Conceptual change theory, however, does not focus on practice in its entirety—practice is not the unit of analysis. Rather, in distinguishing conceptions, the focus is on the individual who makes the conception available in a way that allows its registration in a suitable medium (usually written text). Conceptual change theory "takes as a unit of analysis the individual in a constructive interaction with the world through a variety of mediated symbolic structures, some internal and some external, in rich sociocultural settings" (Vosniadou 2007, p. 55). Accordingly, a conception, the thing thought by the individual, is considered to reside in some form in the memory system and as such perceived as being part of the core of the individual's personality, in the form of a mental structure. Conceptual change theory describes the practice in which conceptions are supposed to emerge to the extent that the external mediating symbolic structures (speech, writing, gestures, and images) are intelligible for the reader in science journals; the reader must be enabled to resituate these symbols in the practice in which the individual engages at the moment on which s/he is making the conception available. Thus, the individual remains the link between conceptions and practices: the individual is characterized by describing the practices in which s/he engages and this is in turn a rationale for attributing a conception to the individual. This attribution of conceptions justified by characterizing the practice in which the individual engages is irrespective of the method of data collection. Even in questionnaire studies, the attribution of the conception to the individual is justified by characterizing the individual in a specific practice, namely the practice of writing down a specific answer to a specific question of the questionnaire.

In short, through a characterization of the individual by the practices in which s/he engages, a key aspect of theory building in conceptual change is justified, namely the attribution of the conception to the individual. Hence, to better understand the origin of the theory–practice gap, I focus in more detail on this characterization of the individual. The lens of hermeneutic phenomenology precisely makes this focus possible.

Characterization and Identity

The characterization of the individual is a key issue in hermeneutic phenomenology, specifically in regard to the question of the nature of identity (Ricoeur 1992). Ricœur attempts to solve the problem how individuals remain one and the same throughout all physical and psychological changes they undergo. For instance, in the case of Ashley and Becky, we might ask the question how we can determine whether the individual articulating the words described in lines 4–6 is the same as the individual articulating the words in line 15, based on the practice at hand. In both situations the individual is articulating different sounds and is behaving differently, based on which we can attribute different conceptions to these individuals and assume a number of physical and psychological changes that have occurred in between the two situations. Nevertheless, I recognize that the two individuals in each of the situations actually belong to one and the same Self denoted by the name Becky.

The solution to the question of the nature of identity and its seemingly paradoxical inferences starts with a notion of self as duality. As such, self presupposes two notions of identity that induce confusion once reflectively conflated. One mode of identity, which is referred to as idem-identity (sameness): “Identity in the sense of idem unfolds an entire hierarchy of significations, in which permanence in time constitutes the highest order” (Ricoeur 1992, p. 2). For instance, a number of physical similarities can be distinguished between the situations referred to in lines 4–6 and line 15 respectively. Based on these similarities—permanence in time, one may conclude that in both situations the same individual is present, namely Becky. More generally, we can say that who Becky is and was is part of a biography—a narrative featuring the same person (character), Becky, with both constant and changing character traits in the course of the teaching-learning case, which highlights a fragment of her life (a plot).

However, idem-identity does not give answer to the question who Becky is, as she is changing over time. For instance, the similarities we have distinguished previously in two situations and based on which we have concluded that Becky is present in each of two situations, might not be present in other situations occurring later. This is a fundamental aspect of identity: When Becky is moving from situation to situation in her daily life, she is someone different with respect to the others surrounding her. The question who Becky is, can thus only be answered by adopting the notion of an identity that is opposed to idem-identity, namely ipse-identity (selfhood), which “implies no assertion concerning some unchanging core of the personality” (p. 2). Ipse-identity gives the self its unique ability to initiate something new and attributable to itself. Thus, in contrast to idem-identity, ipse-identity is not dependent on something permanent for its existence. That is, while Becky changes both psychologically (different conceptions) and physically (producing different sounds) between lines 4 and 15, we can still identify her as Becky.

There are therefore at least two aspects to identity. On the one hand, a person appears to have an idem-identity, which undergoes developments that are articulated in autobiographical narratives of self. In this perspective, events in the lives of individuals may provide resources to understand these individuals differently, leading to changes in their biographies. Second, in contrast to the contention of identity as a (relatively) stable phenomenon that is constructed in biographical narratives, ipse-identity is the experience of the different ways in which individuals relate to others in the varying contexts of everyday life and which entails the individual to be perceived as something that continuously changes. The difference between the two aspects of identity—ipse-identity and idem-identity—is thus precisely how we can conceive characterization: character is “the set of distinctive marks which permit the re-identification of a human being as the same. By the descriptive features that will be given, the individual compounds numerical and qualitative identity, uninterrupted continuity and permanence in time" (Ricoeur 1992, p. 119). Hence, idem-identity emerges out of ipse-identity due to characterization. For instance, in order to re-identify Becky, who articulates sound in line 15, as actually being the same as Becky, who articulates sounds in line 4, we narratively sketch Becky's character by descriptive features, based on which we can conclude that she remains the same. Note that these descriptive features are physical. This is why characterizing Becky makes her spatiotemporally permanent in the resulting narrative.

The fact that idem-identity is narratively sketched also reveals an important role of language in understanding identity: We understand identity by means of interpreting signs as accounts of human action. Language can thus be seen as one of the available sets of descriptive features by means of which we understand identity and hence narratively construct idem-identity. Indeed, in the case of Ashley and Becky, an excerpt of their discourse is presented as a resource for narratively constructing both Ashley's and Becky's idem-identity. Yet, despite the resources provided, the Becky that is thus permanent in time, the idem-identity, is not the real Becky, that is, Becky herself. Without both idem-identity and an ipse-identity, we cannot explain self. Self therefore has both sorts of identity—it is constituted by two irreducible orders of causality, namely the physical (idem) and the intentional (ipse) orders. Any comprehensive account of human action must express the way it is related to both of these orders. Therefore, any causal explanation for what Becky is doing what she does and saying what she says, has to do with both her intentions and the spatiotemporal setting of which she is part. But, as intentions are realized through embodiment, a self actually produces its spatiotemporal setting and as such its idem-identity will emerge from ipse-identity. Ipse-identity therefore consists of the realization of possibilities through human action while idem-identity emerges out of ipse-identity by characterization of the possibilities that are realized by human action.

Revisiting the Theory-Practice Gap

Given the attribution of conceptions to the individual by characterization, how does the theory–practice gap emerge in conceptual change theory building? In order to illustrate this, I return to the case of Ashley and Becky. In the beginning of this chapter, I approach this case through a conceptual change perspective and I attribute two conceptions to Becky that I justify by describing Becky's actions. Let me consider in detail the first conception, which can be described as "the heart rate sensor measured the speed of blood in the ear." In conceptual change theory, the rationale for the attribution of this conception follows from characterization: By means of a description of physical features, I narratively sketch a biography that constitutes in part Becky's idem-identity. For instance, I present the text of the excerpt (lines 4–6 in particular) to account for the sounds Becky is making, a photograph representing artifacts she is handling, a graph representing another artifact, and so on. All of these physical features characterize Becky's actions by means of which I justify that I attribute to her idem-identity the conception "the heart rate sensor measured the speed of blood in the ear." In hermeneutic phenomenological sense, I let Becky's idem-identity emerge out of ipse-identity by characterizing her spatiotemporally, which is the justification for the attribution of a conception to Becky.

This analysis of the attribution of conceptions in terms of the two types of identity reveals thus an important feature of conceptual change theory building: the attribution of conceptions is justified by narratively constructing idem-identities. Learning in conceptual change theory, that is, the change from one conception to another is thus illustrated by presenting two different idem-identities to which conceptions are narratively attributed. To the one idem-identity we attribute a scientifically unacceptable conception, such as "the heart rate sensor measured the speed of blood in the ear" (lines 4–6). To the other idem-identity we attribute the scientifically acceptable conception "the heart rate sensor measured the amount of blood in the ear" (line 15). The change in conceptual change is thus illustrated by characterizing two different idem-identities. Herewith, we can make another important inference about how conceptual change theory builds theory from the collected data. The causal explanation for what Becky is doing what she does and saying what she says, is usually constituted by a physical order of causality only.

However, as Becky's self is constituted by two irreducible orders of causality (physical and intentional—idem and ipse), a comprehensive account of her actions must express the way it is related to both of these orders. Because idem-identity has emerged out of ipse-identity by characterization, there is a relation between the physical order of causality and Becky's actions. Such a relation has not yet been established for the intentional order of causality, because we cannot describe this by characterization. It is related to ipse-identity, which is the realization of possibilities embodied in action by Becky. Therefore, the attribution of the conception "the heart rate sensor measured the speed of blood in the ear" to Becky expresses a way of relating the account of her actions to the intentional order of causality, which is thus instantly made plausible for it realizes her actions to be comprehensible. Thus, by reframing Becky's ipse-identity as a conception, we propose intentions for what she is doing, which is immediately plausible because it makes the characterization of her actions, the changes between the subsequent idem-identities, comprehensible.

This improved understanding of what researchers *do* do with practices when conceptions are attributed to individuals reveals a number of methodological limitations in the way conceptual change theory addresses teaching-learning practices. To begin with, by reframing Becky's ipse-identity as a conception, part of her self becomes an unchanging core of the personality. Thus, we introduce a Cartesian dualism to explain the intentional order of causality, which makes our account of Becky's actions comprehensible. Conceptions in conceptual change theory, then, can be conceived as manifestations of *cogito ergo sum* ("I think, therefore I am"). However, this induced Cartesian dualism is a methodological limitation because it overlooks the way in which individuals transact with the natural world around them, that is, through embodied action with which they produce rather than only experience practice.

Moreover, whereas the attribution of a conception to Becky makes what we observe through characterization of her actions comprehensible, this is no reason to assume that the conception actually exists. Indeed, following the Duhem-Quine thesis, the hypothesized conception is by itself incapable of making predictions about human action, that is, about what Becky is doing. Hence the conceptions that are attributed to Becky are ontologically problematic in this case. Related to this issue is that Becky's idem-identity has been constructed by a particular characterization of her actions. There is thus the problem that there is simply no way to test the assumption that this characterization is a valid and reliable account of the conceptions that we are observing. On the contrary, it is likely that the account of her actions as the observer characterizes it is inherently colored by the conceptions s/he wants to observe and which is made hence plausible by characterization. (On researching and observing, see especially chapter 14.) This is another reason to believe that the conceptions that are attributed to Becky are methodologically problematic.

These methodological issues likely play a role in the theory–practice gap that appears in addressing teaching learning practices through conceptual change theory, that is, when conceptions are attributed to individuals to explain their actions. This gap is not yet experienced when we initially build the theory, that is, when we attribute a conception for the first time and justify it by characterization (i.e., the creation of idem-identity out of ipse-identity). It rather becomes emergent whenever these justified conceptions are applied to address new teaching and learning practices in which individuals other than the ones in the previous situation play a role. The reattribution of conceptions to individuals in new teaching learning practices must then be validated by the re-characterization of the previously "justifying" idem-identities out of ipse-identity. This, however, is exactly what is methodologically problematic. Ipse-identity, as stated previously, is that what implies no assertion concerning some unchanging core of the personality. Moreover, in new teaching and learning settings, different individuals set the stage, which implies that the previously justifying idem-identities must emerge by characterization from different ipse-identities. The resulting characterization of individuals, by which the previously justifying idem-identities are narratively reconstructed and by which conceptions are justified, are constructed such that the individuals' actions are comprehensible in regard to a predetermined intentional order of causality, namely the conception by means of which teaching and learning processes are addressed. However, such a characterization does not warrant a valid and reliable narratively constructed understanding of the individuals' actions in terms of both the physical and intentional orders of causality. On the contrary, the validity and reliability of the resulting account of the individuals' actions are questionable both with respect to the physical and intentional orders of causality. In regard to the intentional order of causality, I point out above that the validity and reliability of the resulting characterization is questionable on forehand. With respect to the physical order of causality, the resulting characterization rather serves to make the resulting account of the individuals' actions comprehensible. The theory–practice gap thus emerges as the difference between a true account of the individuals' actions (i.e., an account that is by definition valid and reliable in terms of both the physical and intentional orders of causality) and the account of the individuals' actions resulting from a conceptual change view (the validity and reliability of which are questionable in terms of both the physical and intentional orders of causality).

This analysis of the theory–practice gap explains why conceptions are usually only observed in teaching and learning practices that are highly conditional and experimental (clinical) settings and therewith closely resemble the practices in which conceptions are identified for the first time. These conditions ensure that, to a limited but crucial extent, the previously justifying idem-identities can be narratively reconstructed. To practitioners, however, it is difficult to realize or to observe such previously justifying idem-identities, not at least because of the methodological limitations pointed out previously. Moreover, practitioners, through their embodied actions in the practices in which they engage, continuously characterize their own and students' identities. These idem-identities may be crucial for addressing these teaching and learning practices but also may be completely different from the ones characterized as a result of addressing teaching and learning practices through the perspective of conceptual change. In addition, because of the methodological reasons pointed out previously, there is no reason to assume that such idem-identities are similar to the idem-identities that are the result of characterizations by conceptual change theory. On the contrary, it is likely that practitioners have difficulty to recognize the idem-identities that are the yield of conceptual change theory. This is why the theory–practice gap widens despite the sophistication of the conceptual change theory and what thus accounts for the origin of the paradox I explain in this chapter.

Coda

The aim of this chapter is to articulate the origin of the paradox that theory building on conceptual change yields an increasingly sophisticated teacher-alienating output. Given its origin, the question remains how to overcome this paradox and there-with to close the theory-practice gap. The solution may be to abandon the idea of conceptions as an unchanging core of the personality residing in individuals as mental structures. Therewith, one can overcome the requirement of attributing conceptions to individuals and the inherent narrative construction of idem-identities by characterization that justify such attributions. One way to do this is to perceive conceptions as consisting of a dialectical unit of all relevant (meaning-making) semiotic resources publicly made available by a speaker in a situation such as talk, gesture, and context (Givry and Roth 2006). Here, the situation rather than the individual is the unit of analysis, which conforms to a contemporary notion of knowledge as a distributed and situated entity. Indeed, such a notion allows us to construct a narrative identity of the speaker that makes a conception available which is valid and reliable with respect to both the physical and intentional orders of causality. That is, in such an approach there is no need to reduce the intentional order of causality to a particular conception. Rather, a conception is the result of the transaction between the speaker who is publicly making it available and the practice in which s/he is engaging, which accounts for both the intentional and physical orders of causality. This approach thus overcomes the Cartesian dualism and therewith the methodological limitations that occur when attributing conceptions to individuals and therewith failing to take into account how individuals simultaneously experience and produce practice through embodied actions. Then we can understand and explain why Ashley and Becky say what they say and do what they do in situations as explicated in the case in the beginning of this paper. For instance, by abandoning conceptions as individual entities, it would become logical that Becky articulates two times "It is streaming … It is streaming …" (line 5), for this utterance realizes the transaction between Becky and the practice in which s/he is engaging. Moreover, rather than assuming that Becky thinks that "the heart rate sensor measured the speed of blood in the ear," we come understand why she says subsequently that "It is streaming faster through the ear!" Indeed, she thereby makes publicly available the scientifically unacceptable conception that "the heart rate sensor measured the speed of blood in the ear." But this is, after all, an acceptable answer to the confusingly posed question encountered in the complicated teaching learning practice in which she is engaging at that moment.

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Chapter 14

Looking at the Observer Challenges to the Study of Conceptions and Conceptual Change

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In a typical study of students' conceptions and conceptual change, researchers analyze what a student does or says in a classroom or in an interview and recognizes ideas that match or do not match their own understanding of the topic. Attributing the perspective they recognize in the student, those studies support the idea that a conception is the way by means of which an individual intrinsically conceives (of) a given phenomenon. They then hypothesize the existence of some mental structures that can be theoretically and objectively re-constructed based on what is observed in a student's performance. Thus, researchers studying conceptions commonly assume that the observer and the observed are separate entities. However, even in the most theoretical and hardest of all sciences, physics, the independence of the measured object and the measuring subject is not taken for granted: Light, for example, will present itself as waves or as particles depending on how we examine it. The artificial sense of separation from the object(s) of study found in many accounts on students' conceptions makes irrelevant the relationship that exists between the observer and the observed: an interdependence and co-emergence of the observer and the observed. This tight relation exists because each participant not only reacts upon what others say but also acts upon the reactions that his/her own actions give rise to. With this situation come epistemological, practical, and ethical implications for those researching in mathematics and science education. Positing or questioning the existence of an objective reality mediates how we accept or reject another human being and the worldviews s/he develops. It provides a rationale that guides our actions. This is especially important when it comes to teaching and learning at a time where the ability to deal with the plurality and diversity of human culture have emerged as significant referents for our social behavior.

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The most central challenge we face today is the question of reality (Maturana 1988). With respect to the relation of the observer and the observed, the author suggests that there are two postures to reality and objectivity. One assumes that what an observer's actions and knowledge does not affect the object of observation. The other posture recognizes that the observer is constitutive of the observed phenomenon, particularly in his or her ability to distinguish different aspect of a situation. Thus, this framework helps us understand how psychological and sociocultural perspectives distinctly define the observer. That difference in nature can be captured the following way. Whereas the former attributes conceptions to the students, the latter situates conceptions in the observer who identifies them. The significant epistemological divergence entailed by these two postures has practical implications. Rejecting the observer-observed contingency necessarily leads to the confrontation between exclusive interpretations, for their validity is founded on the posited objective reality. If we pretend to know how things really are, then other interpretations are objectively wrong. This affects not only the work of researchers, but also promotes a certain attitude toward others, the students. In that perspective, we forget that students, too, are observers, thereby examining performances solely in the light of a given (objective) concept and judging them on the base of their compatibility with that single idea. In contrast, the ethical responsibility we have for the others is to fully recognize, and encourage, the legitimacy of various possible understandings brought forth. Understanding how an explanation contributes to different conversations opens the discussion of how desirable these are. Dissimilarities then become invitations "to a responsible reflection of coexistence, and not an irresponsible negation of the other" (p. 32).

In this chapter, we articulate a perspective on the observer and the implications that result from taking a psychological or a sociocultural approach to education research. Drawing on an excerpt from a mathematics lesson in which three second-grade students learn geometry, we argue in favor of a sociocultural approach to conceptions in a two-folded argumentation. First, we enter the epistemological domain to articulate the differences in how sociocultural and psychological approaches define the relation of the observer (student or researcher) and the observed. Second, we illustrate implications by showing how conceptions are not the mere figments from the students' minds but that students' performances can be better understood as discursive co-productions. We conclude by elucidating how the observer-observed interdependence foregrounds ethics as an important dimension of research in mathematics and science education.

The Observer and the Observed

In this first section, we articulate how sociocultural and psychological approaches differently define the relations of the observer (student, researcher) and the observed. We introduce the relationship of the observer and the observed and then examine what it specifically tells us about each approach. For each, we discuss

(a) the observer-observed relationship, and then (b) what entails the reading of students' performances. The subsequent case analysis follows a similar organization.

In the mid 1960, Humberto Maturana became conscious that as a biologist he had no means to make any claim about objects, entities or relations as if they existed independently of what the researcher was doing. That led him to realize that the most central question in any scientific debate about the existence and nature of a given phenomenon implies the nature of the observer. To explain a phenomenon demands delineating the position of the observer in relation to it. When we explain a phenomenon, such as a student's utterances during a conceptual change interview, we propose a reformulation of the particular situation that we are attending to and simultaneously define the extent in which that reformulation is taken as valid. Fundamentally, we can conceptualize how the object of observation is considered in two different ways: as independent or as contingent of the observer. Indeed, the fundamental operation of an observer is one of making distinctions and creating descriptions. These descriptions partially take up the infinite complexity of a situation and organize themselves to provide a re-formulation, an account of what is taking place. As researchers we tend to focus on certain aspects of a phenomenon to answer particular questions. We select data and examine them with a specific theoretical lens. We know that a significant aspect in any researcher's work lies in its personal involvement with its research object.

The Observer from a Psychological Perspective

Many researchers working on students' conceptions position themselves as if reality (a conceptions) exists independently of the observer and the act of observation. This trend is particularly present among researchers who assume psychological or cognitive perspectives. Take this example:

> [W]hen we, as radical constructivists, focus on analyzing children's schemes, we work as first-order observers. Although a first-order observer makes a concerted attempt to assume the position of the child and think as the child does, the observer's ways and means of operating are left implicit, and the observer does not intentionally analyze the mental structures of the child relative to his or her own mental structures. However, the first-order observer does interpret the interactions of the child and by this means tests the interpretations for their viability. … When we focus on analyzing the mathematical learning of a child … in both actual interaction and retrospectively, we focus specifically on explaining the child's learning relative to our own purposes, intentions, and contributions to mathematical interaction. (Steffe and Thompson 2000, p. 202)

When researchers position themselves as if conceptions existed objectively, they develop a perspective in which these conceptions are independent of the operations by means of which they are identified. In this trend, researchers examine students' understandings by analyzing what they do in the classroom or what they say during an interview and theoretically deconstruct and reconstruct students' thinking. It thus makes sense to discuss why students think that way and how they could be prompted to do otherwise. Students hold conceptions and undergo conceptual changes that the researcher-observer pretends to simply report. Such an approach makes irrelevant the ways and means of operation of the observer, and ignores the relationship of her or his own understanding relative to the children's. The preceding quote is clear about this: When analyzing children's schemes, researchers leave implicit their own operations and do not consider the children mental structures relative to their own.

This corresponds to what can be called the path of transcendental objectivity. Blind to his or her participation in the observation, the observer here "implicitly or explicitly assumes that existence takes place independently of what he or she does" (Maturana 1988, p. 28). The observer accepts his/her cognitive abilities without questioning how they work and influence what is observed. Accordingly, entities like mental structures or interactions can exist independently of what the observer does. In this perspective, even though one might acknowledge that the observer's perception or reason is limited and sometimes fails, what is striven for is an objective account for the observed event. For that reason, researcher-observers naturally find in the common agreement of each other's interpretations a support for the belief that they rightfully account for an event. (See chapter 13 for the justification of observations and their attributions to a particular aspect of identity.) In this, two important facts are put aside: (a) that any observation is secondary to the observer's experience of the world, and (b) that agreement among observers cannot determine the validity of a claim that none of them can make individually.

These are fundamental epistemological implications and they are partially recognized by some researchers in the psychological tradition. Some research complements the search for cognitive structures with an attempt to take into account their own research endeavor by "explaining the child's learning relative to our own purposes, intentions, and contributions to mathematical interaction" (Steffe and Thompson 2000, p. 202). However, there is a fundamental contradiction that comes with this. If the account of students' learning depends on the researcher's purposes and intentions, then the conceptual changes to be observed in the students depend on those motives as well. Thereby, how schemes undergo cognitive restructuring is based on theoretical entities defined by the researcher and not something intrinsically characteristic of the students. Researchers cannot divorce themselves from their objects of observation when analyzing children's schemes. The consequence is this: Not only (a) can students' conceptions and conceptual changes not simply be reported and (b) observations cannot merely indicate what the students are thinking and why, but also (c) it also makes little sense to deduce from these conceptualizations any form of prescription to lead students to perform differently.

Intertwined in the separation of the observer and the observed is the posited existence of an objective reality. Looking for universal features of development in the child, a typical study in the psychological perspective presents a researcher's analysis of students' performances and theoretically attributes his/her interpretation as being that of the students. The researcher then discusses why students "hold" or "acquire" those conceptions and suggests how they could be "changed" or "replaced."

Belonging to the students, conceptions are then seen as the way in which an individual intrinsically conceives a given phenomenon. Those conceptions are thought as the rendering of mental or cognitive structure made implicitly or explicitly available to others by students' talk or actions. A conception is something that the individual possesses, a "cluster of internal representations and associations evoked by [a] concept—the concept's counterpart in the internal, subjective 'universe of human knowing'" (Sfard 1991, p. 3). In this view, common to much constructivist research, conceptions are imprinted in the mind (some will even say: in the brain) and later are simply acted out when called upon. Thereby, what is (objectively) presented to the students is cognitively re-presented by them and, in their performances, re-presented again for the researcher to examine. Through some sort of reverse engineering, the researcher searches for schemes or mental structures that s/he validates in the observation of an objective reality. An example of this can be found in the first part of the quoted text: Researchers turn to an objective reality that bears the possibility to "tests the interpretations for their viability" through perception or reason. We recognize again the path of transcendental objectivity. Researchers here ultimately validate their explanation by referring to entities like mental structures and interactions that constitute the real: a transcendental referent to which the observer reduces the observed. Such approaches therefore require a single reality (a conception) that explains what was observed by the observer.

This is problematic because cognitive scientists now widely reject the existence of cognitive structures in which representations of the world can be embedded. An additional difficulty with this perspective concerns the constitutive part of the socio-material environment for what is observed in students' actions. Nowadays, researchers generally recognize the situated nature of what students bring forth. It is agreed that we need to consider that what students say or do is closely related to the specific context of the performance. Problems and phenomena are not addressed in the same way when encountered in mathematics or science classroom versus everyday life. Because they have dissimilar goals, means and rules, and because they are in different relations with different people, students do not always do things the same way. The perspective we develop here therefore invites us to consider this by examining coordination of behaviors to understand how "each individual is continually adjusting its position in the network of interactions" (Maturana and Varela 1998, p. 192) that forms the collectives and situations. Being themselves observers, students coordinate with their societal-material world and with others, contributing differently into diverse activities, with and for distinctive "communities of observers."

Most researchers who study students' conceptions are aware of this problem and have tried to answer it by acknowledging the constitutive role of the context in the realization of what they observe. However, this poses an epistemological contradiction. If the context is recognized as shaping individual cognitive structure(s), then it is impossible to assume that what an individual does is based solely on the conception(s) in his/her mind. When what students say or do cannot be isolated from the context in which it exists and is observed, then it cannot be assigned to a conception that an individual is said to have; it is not a characteristic (internally) belonging to individual students, but also is marked through and through by the context, a fact captured in the notion of ipse-identity that van Eijck presents in chapter 13. A legitimate alternative then is a perspective that focuses on the ways in which students' cognitive and contextual structures play out in the realization of activity. However, such a perspective challenges the notion that individuals construct and reconstruct fixed schema in the mind.

The Observer from a Sociocultural Perspective

Researchers in a sociocultural perspective do not normally talk about conceptions and conceptual change, because their work does not focus on the individuals but on the situations these find themselves in, and on the meaning they create with and for each other. In this section, we briefly outline (a) how the constitutive role of the observer and what is observed is taken into account in sociocultural perspectives and (b) give some insight concerning how students' performances are made with and for the other(s).

"Everything said is said by an observer to another observer that could be him – or herself" (Maturana 1988, p. 27) and the observer and the observed arise together, emerging from one another in the act of observing. A sociocultural approach to science and mathematics education research defines the observer in a very similar way. To begin with, this approach clearly asks researchers to consider how the object of observation is constituted. Instead of striving to objectively assess what a student knows or can do, or to identify transcendental features to the human psyche (on the basis of talk or actions), the observer studies the way cultural traditions and social practices appear to be at play. The observer not only recognizes his/her purposes and intentions, but also delineates a unit of analysis that incorporates "goals, needs, affect, and cognition while locating the individual in the cultural life that precedes all of us" (Lerman 2000, p. 211).

This corresponds to a path of constituted objectivity. In that path, the observer accepts that s/he is constitutive of the phenomenon s/he observes, recognizing that the observer's observation depends on his/her cognitive abilities. We may use as example our inability to distinguish between perceptions and illusions to reject the independence of the observer and the observed. Existence "is constituted with what the observer does, and the observer brings forth the objects that he or she distinguishes with his or her operations of distinction as distinctions of distinctions" (Maturana 1988, p. 30).

In sociocultural approaches, the mutually constitutive role of the observer and the observed is recognized both in the researcher's and in the student's activity. On the one hand, researchers turn their attention to the elements from which what was called a conception can be identified and they try to understand how this happens. In an interview, there is a collective activity from which any data spring forth as a result of the interaction between two types of participants (Roth et al. 2008).

From a researcher-observer perspective, this should mediate our understanding of what was achieved. In other words, conceptions from this perspective are not something that belongs to the children, but to the situation that produces the talk from which conceptions are abstracted by means of multiple reductions.

On the other hand, a sociocultural approach stresses the constitution of consciousness through discourse, which includes all forms of communication such as speech, gestures, written text, and so on. This helps us see how the student's activity is also conceptualized as the work of an observer contingent on its object of observation. In this view, students do not present conceptions stored in some cognitive structure, but participate in mathematical or scientific discourses by which they learn to distinguish different aspects of a situation. In other words, they become scientific or mathematical observers by creating mathematical or scientific objects of observations or by attending to what they observe in those particular ways. Communication includes more than the words a person speaks and encompasses all perceptuomotor activities exhibited to the researcher. Distinctions and distinctions of distinctions are operations in language in which the observer and the observed co-emerge. In the process of making distinctions, the observer is affected by what he or she observes, but simultaneously responds by selecting what is relevant and sensorially accessible to him or her, and therefore affect what is observed. Being an observer implies both agency and passivity because we are both observers and observed:

> I am not a neutral factor. Together with others, we researchers both constitute the situation and are constituted by it. … I have no transcendental position, but neither is my theorizing, as a mathematics education researcher or as a teacher, on a separate level from my work on mathematic. Sociocultural theory does not need the separation of levels of analysis required by Steffe and Thompson's model. (Lerman 2000, p. 224)

These reflections stress the need to avoid attributing conceptions to individuals. Examining how we make sense of things and situations, a sociocultural approach situates knowledge in the social. Researchers from that perspective thus characterized knowing as participation in an activity, and especially turn their attention to examine how meaning is discursively constructed in communicating with others. Sociocultural researchers do not negate the potential existence of some mental plane in which conceptual development might take place for the individual. But recognizing the inescapable dependence of the observer's position and what is observed, sociocultural researchers deliberately orient their undertaking to the conditions in which that mental plane is formed.

This perspective is consistent with the type of observations we make as educational researchers: Whereas it is not possible for us to see inside a student's mind, we can observe what is made available to us by that student's verbal or physical actions. Here, the explanatory domain, in which the observer observes the student, is based on what discourse and actions make available, not on the student herself. The essence of communication is the coordination between an individual and his/her social and material environment. What counts here is not only the content and the form of people's talk and actions, but also, and more importantly, what they contribute with respect to the coordination of actions they bring about. In that sense, a researcher-observer is interested in understanding what a student's contribution in/to an activity reveals about the conditions in which s/he coordinates him/herself with the societal-material setting. A contribution can take different forms: speech, gesture, action, or any combinations of these. Attributed to the individual, a contribution makes sense in the relation it establishes to an ongoing activity, together responding to a particular situation and affecting its unfolding. These contributions are not the result of an individual conception, but are created with others and for them as much as for oneself. We recognize in this a path of constituted objectivity in which everything is said by one observer/observed to another observer/observed.

A Case in Point

The contrasts between sociocultural theories and psychological perspectives have been well debated over the years, particularly in mathematics education. Our own work led us to articulate the problematic in terms of how the observer is considered. Here we illustrate this position by (a) showing how the observer and the observed co-emerge from the student and the researcher's perspective and (b) illustrating how we can examine their talk and actions as discursive contributions. The following excerpt, in which three students talk about a cone, serves to exemplify this. The episode was videotaped during a lesson in which the students examined whether various solids could stack, slide, or roll.

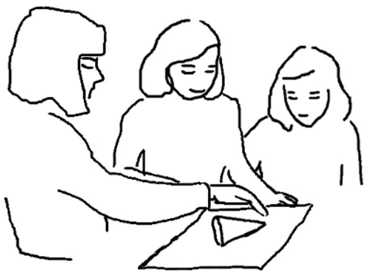

Figure 14.1. Sonia, Jade and Maeve experiencing with the cone.

```
01 Je: You can go ahead and record your predictions, okay.
02 Ma: My prediction [is].
03 So: [Slide]
04 Ma: do you remember that if you put it side ways and then it
       will roll like that? ((Maeve place her pen on its side,
       pushes it and finally rotates it on the table, see Fig.
       9.2))
05 Ja: It will slide.
06 Ma: So it rolls actually.
07 Ja: But if you put it on its side it will roll, but if you
       put it up straight it kind of slides.
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08 So: Roll means-
09 Ma: But, but if-
10 So: Ah Maeve, roll means when it goes back, back. ((Sonia
       rotates her hands backward one around the other))
11 Ja: Or keeps on going like in circle. ((Jade rotates her
       hands one around the other like Sonia is doing, but moving
       forward))
12 So: Yea like this. ((Sonia transforms her backward rotation
       in a forward one similar to Jade's))
13 Ma: So which one do we write?
```

How the Observer and the Observed Co-emerge

To clarify how the observer, the operation of observing, and the observed simultaneously arise, we examine Sonia, Jade, and Maeve's perspective on whether a cone can roll or not. Asked to make a prediction before they first try whether a cone will stack, slide, or roll, Jade first suggests that the cone will slide, and then nuances her perspective: Placed up straight or on its side, it will either slide or roll. Contrastively, Sonia then insists that a cone could not roll because its movement is not linear, which Jade quickly supports. The three girls discuss some more and Maeve finally concludes, "Oh yeah, because it goes in circles, it's not going down."

As observers, the students make distinctions in what affect them. From those distinctions, they develop an explanation for what they frame as the phenomenon to be examined. This comes from focusing attention on only some of the infinite number of aspects of an event to define what counts as a phenomenon. For instance, the girls here delineate that deciding whether a cone rolls or not has to do with its orientation, the movement and the trajectory of the cone, not its color, the temperature of the room, or the angle of the inclined plane on which it would be positioned. In this, they select some aspect of the situation to attend to, and also define what it means to roll. A selection of what the observer looks at is not only necessary for any explanation to be developed, but is constitutive of what it means to observe (Lat. *observāre*, to attend to, from *ob-*, before, against + *servāre*, to watch, keep). Observing the motion of a cone down an inclined plane thus cannot be realized without adopting an observer position, making distinctions that delineate what count as the phenomenon. For example, in Jade's utterances in turns 05, 07, and 11, the orientation of the cone (placed on its side or upright) and its trajectory (circular or linear) consecutively appear in the explanation of the thought experiment she conducts to make a prediction.

The same happens when students experiment with material objects. Soon after they made their predictions, the three students observed the motion of a cone as it was going down an inclined plane (Figure 14.1). After the cone is released and ungainly moves down the plane, Jade and Sonia observe the phenomenon and briefly pause before they conclude, "Yea … but it rolls. Yea it's okay." The observer's position they adopt now leads them to see the cone as rolling. However, a few minutes later, they reproduce the experiment. Whereas Sonia affirms beforehand that the cone would roll, when she releases it to look at what happens, she turns to Jade, and the two girls decide, “No, not really, just put slide.”

In these two observations, it seems that the trajectory of the cone, taken as an important part of the phenomenon, is no longer included in their observation. Focusing on the revolution of the cone around its axis or considering the path down the plane defines the phenomenon in two different ways. What is observed in each case is different, and that observation arises together with the observer’s position with respect to the phenomenon. Because not everything can be attended to and accounted for, the observer and the observed are contingent on one another. Even if here, for us, the articulation of two dimensions of the movement of the cone is not highly problematic, there are still other aspects we can (not so easily) take in consideration. For example, if a cone were to be released on a large and long enough plane, would its overall trajectory be linear or not? Are the wooden block and board adequate approximation of a cone and a plane? These questions are directly related to the means of operation of the observer, which include both his/her disposition and the setting in which the observation is realized.

This example also illustrates how common agreement in different observers’ interpretations does not guarantee objective validity to a claim. The girls can differently position themselves as observers, and thus dis/agree about what they perceive and how to report their perceptions. Moreover, they can transform and overcome their agreements or disagreement by changing their observing posture. This is why looking at the observer-observed relation demands considering aspects such as goals, needs, and affect. The movement of the cone on a plane is not absolutely foreign to us. We experience something similar with objects like screws or pens, when their points of contact with a plane (e.g., a table) make them similar to cones. However, because these are part of very different activities, we do not observe them in the way students might do in a science or mathematics classroom. A student observes similar phenomena in different contexts. In each case, we ought not be astonished if the observations have little in common even if a psychologist claims that the situations are structurally identical. We thus see why the mutually constitutive role of the observer and the observed is in itself secondary to the observer’s experience of the world in the very moment of making an observation.

It is clear that Maeve, Sonia, and Jade situate themselves as observers making certain kinds of observations. Doing so, they define an observable domain by specifying what counts as a legitimate observation. Similarly, what allow us researcher-observers to analyze bears family resemblance with what the three girls experience. Introducing a piece of data (like a transcript) we delineate an approach in which only some aspects come to the fore, and we make observations from which we emerge with an observed object. What is captured on video is a small part of the students’ lives that we frame and isolate. Within those limits, we can portray the students’ achievement in school or interpersonal relationships as a lens for our analysis, or describe students’ gestures in mathematics communication. By all these means, we create an object of observation by situating ourselves as observers making certain types of descriptions. Inasmuch, the text we present here is indeed a description that reifies our researchers' experience with the students and the material, it is a commentary co-produced by our observers' activity and what the world is offering us.

The foregoing highlights the fact that the observer cannot be removed from the phenomenon under observation, and, thus, that our observations are something we create in the practical activity of observing. Observers can look for instances in which they recognize that students draw on primitive knowings (everything that they bring to bear on the task at hand), make images of mathematical phenomena, notice properties, or formalize observations. Seeing them as moving from one dimension of mathematical engagement to another, we can evoke growth in mathematical understanding when, for instance, students create new mathematics questions, or new concepts. In our case, we can use this framework to assert that the three girls draw on an intuitive understanding of what a cone is and what rolling means because they do not define them at first. We recognize as images making the moment in which they distinguish rolling trajectories or possible positions for the cone. Similarly, combining these images appears to us as articulating properties relevant in the context. In the same way, we can recognize a form of generalization, as the students do not only discuss a particular cone, but also cones generally. The association of all these elements within the conversation could also be described as forecasting the articulation of formal theories, being like theorems in the talk. For example, the three girls appear to develop an understanding of the task of making a prediction under the law of excluded middle: (a) Since the cone must either slide or roll but not both and (b) if to roll means having a linear movement, then (c) the cone does not roll (from [b]), and therefore (d) it slides (from [c] and [a]).

Such a reading is but one possible approach to these students' activity. It is one in which we do not leave implicit our means of operation, our own observer cognitive abilities, our intentions, and so on. Considering our researcher-observer engagement, it is a perspective in which regardless of what the data might "objectively" present, the researcher looks into how people and material things affect his/her perception and in/form the interpretations of what is happening. It is an approach in which researchers are observers observing themselves and others (students). This is one of the reasons why, in contrast to psychological approaches, sociocultural perspectives would attribute conceptions not to students but to the observer–observed transactions.

Students' Actions Are Made with and for the Other(s)

Considering the co-emergence of observer and observed calls attention to the problems that come with the attribution of conceptions to the students. To exemplify this, we examine Maeve's utterance in turn 04 and pay close attention to how a researcher develops his/her own understanding from the student's engagement with the societal-material world. Saying "if you put it side-ways and then it will roll like that" (turn 04), Maeve gestures with her felt-tip pen (Figure 14.2). She first places it on its side (G1), then gives it an impulsion and follows its rolling motion on the table (G2) and finally grasps it to describe a circle (G3):

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04 Ma: [do you remember that if you put it side-ways]G1 [and
       then it will rolls]G2 [like that?]G3
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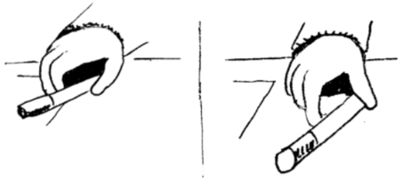
[G1] Maeve places her pen upright and then on its side. She repeat the gesture three times while looking at Jade and Sonia.

[G2] Maeve pushes the pen and follows its motion with her hand but lets it roll.



[G3] Maeve rotates the pen so it describes a circle.

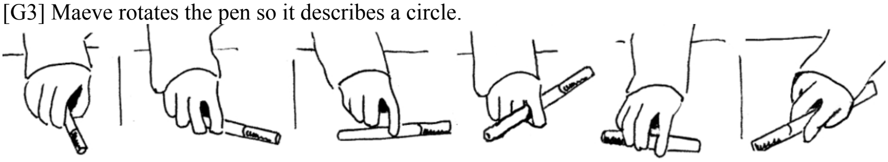


Figure 14.2. Maeve's gestures in turn 04.

If we want to identify a conception by discussing what Maeve means with her utterance, we need to associate speech and gestures and assume they represent a specific understanding of the situation. But here, we face a problem. As she pronounces "it will roll," Maeve pushes her pen which moves linearly. Maeve then seizes the pen and rotates it to trace a circle, emphasizing "like that." The change in her gesture and talk contrasts two rolling motions. But does Maeve expect the pen to roll in a circular way, and then observes that its motion is not the anticipated one, or does she realize from the movement itself that what she has previously observed with a cone differs? In terms of how students' conceptions are traditionally analyzed, these two interpretations are profoundly different. On the one hand, Maeve would have a correct conception of how a cone rolls, and simply adjusts her performance according to that understanding. In the second case, she would have an incomplete conception and, through a cognitive conflict generated by observing a phenomenon, went through a conceptual change by expanding her understanding (to take into account the direction of the rolling object).

As observers, we can only make inferences based on our transactions with the data and make conclusions based on what appears to our eyes. We are here in a situation in which we examine a student's talk and gestures (not a cognitive structure). We see Maeve producing an observation, but we have no means to ascertain what is effectively happening for her. Even if we try to "assume the position of the child and think as the child does" (Steffe and Thompson 2000,

p. 202), there is no way for us to ensure the validity, or even the likeliness of one interpretation over the other. The impossibility to overcome such a simple dilemma (concerning a single utterance of a student in a conversation) captures the limits of an approach in terms of students' conceptions. If we want to explain what a student does or says based on some mental structure, we are forced to impose our own understanding as being that of the student. And if we posit the objective existence of such a structure as belonging to the student, we have to ignore the fact that it is by no means accessible to us.

A sociocultural approach to the work on conceptions foresees the impossibility to objectively decide what a person knows or thinks. The difficulty exemplified in Maeve's utterance also similarly applies to Jade and Sonia's talk: How would we explain the change in what they state about the cone (roll or does not roll) if such affirmations were the sole reflection of their conceptions? As researcher-observers, we also have to admit that what students say or do only partially reveals what they are capable of, and that what is enacted just as much reveals a socio-cultural possibility. Indeed, there is no limit to the number of ways of expressing a concept, and it is the infinite set of possible applications of a given idea that constitutes the concept in the most general sense (Roth and Thom 2009). To go beyond these limitations and contradictions, sociocultural perspectives suggest turning our attention to the observable coordination between individuals and their context, and examine student's performances as contributions made in a discursive domain. We exemplify this by returning to our episode to see how Maeve, Sonia, and Jade brought into being their activity with and for each other by situating themselves as observers.

The communicative functions of language stress that it is the listener's response to an utterance that completes it and, thereby, reveals the actual meaning of what was first contributed (Bakhtin 1986). Maeve's contribution ("Do you remember that if you put it sideways and then it will roll like that" [turn 04]) turned out to become functionally a statement about the cone only following to Sonia's and Jade's responses. Had Sonia and Jade asked about the particular event Maeve was referring to, the conversation might have taken a different course and not focused on the properties of the cone. In other words, students' contributions are not simply individual productions, but what they are worth is made with the other(s). Moreover, students also contribute to an activity not only because it makes sense to them, but also because they assume their contributions will be intelligible for others. For instance, in turn 06, Maeve repeats her conclusion. This affirmation signifies that she has heard Jade and Julia's contributions and that she interprets them as different from hers. It is to this difference that she draws attention.

Students do not simply make neutral and independent responses, because each participant is oriented to responsive understanding from the others. They contribute to the conversation for their interlocutors' and their own benefit and thus do not merely represent their personal conceptions. In turns 08 and 10, Sonia offers a definition of what it means to roll. This consideration marks the departure of the conversation from merely deciding whether the cone slides or rolls, to examine and clarify what these two motions denote. The emergence of that concern, however, cannot be solely attributed to Sonia; we do not know what precisely she means by rolling. Sonia's utterance is in the first place a response to what was contributed before, including Maeve's speech and gesture in turn 04. Indeed, Sonia's contribution is made in contrast with what Maeve has brought forth. It is thanks to Maeve's suggestion, in its manner and its moment, that Sonia can oppose an alternative view. Therefore, what would appear—from a perspective centered on the individual—as the expression of a conception is in fact developed from turn to turn, at the very heart of the conversation. Each utterance takes an active position in a chain of utterances, made for oneself and with and for the other(s), each one connects to what precedes and what follows. It is in that succession that not only do students reveal their observer positions, but also that questions and observations acquire their productive, functional meaning.

This collective dimension unfolding from students' contributions is not free from external influences. Together they take place in and from a discursive domain closely related to the ongoing activity. Maeve, Sonia, and Jade produce observations about the cone and by doing so, they define an observable domain by specifying what counts as a legitimate observation. It is not surprising to us to find evidence of mathematical thinking in the girls' activity because they are part of a societal situation in which certain forms of talk are valued over others. In search for compelling arguments, mathematical forms of observations provide the students (and us) with both structure and agential possibilities. Classroom mathematics demands to talk about certain things and in certain ways. Because they correspond to typical communication situations, concern particular themes and attribute specific meanings to communicative resources (such as words and gestures) in relation to the circumstances in which they are used, these forms of talk guide the students (and us) in observing. Indeed, what happens between Maeve, Jade, and Sonia is not accidental: at the same moment, Jordan's group is facing a similar dilemma and (after discussion) turns to the teacher (Je), who asks Jordan to repeat the question for the whole classroom:

```
Jo: Do we gotta put it like this or like this? ((placing his
    pen upright and then on its side))
Je: Okay, that's a good question. You are gonna be working
    with your group and you are gonna put the object any way
    you want down the ramp.
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Both at the individual and at the collective level, a discursive domain emerges because students contribute with and for others to the conversation, and because those contributions take place in the same sociomaterial context, with similar resources, the participants do so with similar goals and similar rules. It is as part of that emerging geometrical discursive domain at the classroom level that Maeve then concludes clearly addressing her partners: "Look! It will slide and roll!" This we have to take as the, to her most relevant way of examining what happens with the cone in that situation. In another context, she might have maintained her co-ordination with the sociomaterial world by characterizing the cone as a rolling object, stressing for example, what is most remarkable about it. In this, she would have enacted a different understanding of the question, making a different contribution in a different activity. A researcher who would not take into consideration and include in the analysis this decisive aspect coming from the context could easily and misleadingly make inferences about Maeve's "conception" of the cone. Examining how participants in an activity create meaning indeed reveals that students bring into being a discursive domain for and with each other, a domain that might, or might not, promote their observations as mathematical or scientific. Against the narrowing of an evaluation of student's conceptual development to what is observed in a specific situation, we show here that a sociocultural approach focus of the conditions in which certain aspects of a cone are discussed when the students produce classroom events.

Research and the Ethical Ground

We see in the previous sections that psychological and the sociocultural approaches differ in the path of objectivity they take. This distinction naturally unfolds in an ethical reflection on the legitimacy of the other and of what he or she brings forth in making observations (Maturana 1988). Objectivity is often associated with the absence of value and responsibility for what is said. By simply stating how things are and what students think or know, we do not appear to take a position, unlike when we say that something is right or wrong. The change of discourse over the years in the psychological approach on conceptions captures this very well. Researchers nowadays tend to refrain from talking about misconceptions or naïve conceptions and rather use adjectives like non-scientific, everyday, or incomplete. Such an attitude is typical for the path toward transcendental objectivity. Through reason, observers claim access to an objective reality and the validity of the argumentation that are independent of the researcher. However, presupposing an ultimate source of validation also leads one to define a single reality in which only one interpretation is acceptable. In this view, claims about knowledge are demands for obedience. Because the observers do not take responsibility for their explanations, others are then implicitly or explicitly forced to accept what is said to be true and are not legitimate in their own understanding. We clearly show, however, that observers have the possibility to develop different explanations. For example, a researcher examining a video excerpt will account for different things by examining isolated utterances of a student, or considering how each utterance is a response to what was said before. Observers are thus responsible for the explanations they give, which is why researchers in a sociocultural perspective call to the examination of the implicit elements and the limitations of the theories they, and others, adopt. Blaming learning difficulties on cognitive immaturity or underdevelopment—as psychological approaches often do—blinds the examination of the social, economic, and cultural dimensions of knowledge, learning, teaching, and what it means to succeed or fail. This has ethical implications because in and through language, explanations or discourses, individuals position themselves and others. Saying that students hold conceptions, their perspectives are not recognized as legitimate explanations because the researcher-observers keep the focus on their understanding. Thus, they (rightfully) note that it would not be acceptable to them to say or do things that way and see students' performances as non-scientific in contrast to what they personally delineate as scientific, and incomplete in comparison to their personal understanding.

Although not all explanations are equivalent, they are all equally legitimate (Maturana 1988). To take responsibility for their explanations, observers are not to decide which explanation is right, but to understand how desirable each one might be with respect to the goals the observers set themselves. We can take on that responsibility if, instead of attributing conceptions to the students, we question how as researcher-observers we recognize forms of mathematical or scientific thinking. Making such observations does not lead to conjectures about what is going on in the student's mind, does not posit the existence of some static mental structure and does not require the acceptance of a single, transcendental reality by means of which our observations can be validated. It opens room to legitimate students' performances and discuss how they do, or do not, bring forth a mathematical discursive domain by positioning themselves as mathematical observers. This applies not only to the researchers, but also to the students as observers. From a sociocultural point of view, objectivity is replaced by something dynamic, discursively constituted in and by experiences: praxis. The concept of praxis entails the adoption of an attitude ethical toward the other because it recognizes the value and the validity of what students do or say, but also makes possible to discuss why it is contextually desirable or not. Such an attitude opens up a "responsible reflection of coexistence" (p. 32) because it avoids reducing students' understandings to another observer's interpretation and thus accepts students as legitimate others by valuing their contributions for what they are. Discussing how and why different understandings are equally legitimate, but not necessarily equally desirable, allows us to situate knowing and thinking not in a student' cognitive structures, but in the action itself, which includes both the individual and his/her context.

Traditional perspectives focusing on cognitive or psychological aspects of learning are unable to value the uniqueness of each student because they treat difference as a derivative of sameness. Talking about students' conceptions is trying to identify something that would be essentially the same about them. It is to create an object of observation that reduces what is brought forth in conversation to singular, well-defined ideas that represent universal features of children's development. The positions such researchers adopt make differences indifferent to difference instead of valuing the heterogeneity of personal experiences. At best addressing students' discrepancies, these perspectives look for standard procedures to approach students' understandings and fix them. Against an instrumental orientation of science or mathematics education, a sociocultural approach places the students' uniqueness at the center of the ethical relation to the other. Aligned with the acceptance of the other and his or her perspective characteristic to constituted objectivity, researchers adopting sociocultural frameworks count that individuals are always more than what they offer in a single moment, or in a collage of isolated utterances. This "surplus of humanness" comes with any encounter with others, and asks us to "take the performed act not as a fact contemplated from outside or thought of theoretically, but to take it from within … in all its concrete historicity and individuality" (Bakhtin 1993, p. 28). Rather than seeing students' contributions exposing context-free conceptions belonging to the students, these contributions are, for example, to be examined as once-occurring, situated attempts to maintain coherence with the environment. Including what is observed, but also including the others with and for whom observations are made, students' contributions are not widows on the mind, but a moment in a process of becoming.

To undertake our ethical responsibility for the other as non-indifference to differences, a fully developed sociocultural perspective is opposed to the assessment of what students, as individuals, knows or can do as incomplete, naive or inappropriate conceptions. To support students' learning, a sociocultural perspective examines how they contribute to a situation the way they do, and what it is that they create in doing so. Accordingly, researchers will define themselves as a certain type of observer whose intentions are not, in the end, to get the students to a correct or a complete conception (or any predetermined understanding of a situation). Non-indifference to differences exists when we support students to enter in a certain kind of discursive domain, or in other words, by helping them position themselves as observers in a mathematic or scientific way. Inasmuch, difference is theorized in and for itself: It is because they are different that students ought to enter in a shared discursive domain, and they can do so precisely because they are different and, thus, have something unique to contribute. Taking in account the surplus of humanness inherent to the encounter with another, a sociocultural approach sees difference as prerequisite for and constitutive of dialogical engagement and participation with others (i.e., with other's differences). In addition, examining what students say or do informs us about how they position themselves as observers. Consistent with an ethical orientation to the other, what is assess from this are conditions with which students coordinate themselves, not their ability to do so. If Maeve, Sonia, and Jade discuss the cone and its properties in a mathematical way, it is not merely because they have the appropriate cognitive structures imprinted in their mind. It is most importantly because of the societal-material conditions they are in and that they change with their actions.

Such a perspective also allows us to take an ethical stand as to what is going on in a classroom without positioning students and their performances negatively. On the contrary, we value students' differences, give them attention and draw on them to revisit our own understanding of what doing science or mathematics is about. Because mathematics is something we societally (institutionally, culturally, and historically) define, it is justified, for researcher-observers, to discuss whether the situations in which students find themselves lead them to create what corresponds to our vision of a scientific or a mathematical activity. Moreover, we, as mathematics or science educators, have a special responsibility to produce and reproduce, to define and redefine, what is a mathematical or scientific activity as a societal phenomenon. We thus assume our ethical accountability by examining not only the conditions, but also the explanations in and by means of which students are positioned and position others and what is brought forth in making observations. In contrast, such an ethical ground cannot be found to support making judgment on what students know or do not know.

Conclusion

The path of constituted objectivity is in essence welcoming a variety of world-views, and thus recognizes the path of transcendental objectivity as a legitimate one, because even though one pretends to make observations in transcendental objectivity, the human praxis in which these observations are made is still a path of constituted objectivity. Sociocultural approaches are able to welcome conceptions and conceptual changes perspectives as one possible way to examine students talk and actions, but do not see them as compatible or complementary with their own effort. They are possible alternative views that reveal different assumptions, undertakings, and focal points. But, according to the goals we set ourselves as researchers or educators, conceptions and conceptual change frameworks are not the most desirable way to examine students' talk and actions. The reasons for this lie in the problematic attribution of conceptions to the students in a way that neglects the contingency of the observer and the observed, and in the ethical implication that comes with this contingency. We recognize here a comprehensive ethical approach in which the observer takes on responsibility to discuss how and why different understanding, although equally legitimate, are not equally desirable. This is especially important today because our ability to deal with plurality and diversity guides social behavior. Western culture has long been characterized by separation and universalism, dividing the world from the person. Such division and dislocation leads to the systematic negation of the existence of the other by applying the same cultural logic to all people, as if everybody and all contexts were essentially the same. Although this principle has led to some positive outcomes, it is generally for the benefit of those who are already culturally well positioned, and to the detriment of the disadvantaged, like indigenous or working class peoples, women, immigrants, and so on. Similarly, an approach that reduces language use to the individual is rooted in an ontology that underlies "all inequities, including those along the lines of gender, culture, socioeconomic status, class, and age" (Roth 2007, p. 742). By challenging the assumptions made in research on conceptions and conceptual changes in mathematics and science education, we offer here a practical answer to the urging of those who ask us to address this situation.

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Chapter 15

It Doesn't Matter What You Think, *This* is Real Expanding Conceptions About Urban Students in Science Classrooms

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We are at a point in time in the field of science education where many of the recommendations for improving teaching and learning are presented in very interesting and innovative ways. Researchers have various avenues to present their work and have developed the ability to utilize various means to disseminate it. There are conferences, symposia, journals, online journals, professional organizations, and even blogs that support the sharing and discussion of the outcomes of science education research. However, despite the innovations in the realms of presentation and dissemination, many of the approaches to science education are firmly rooted in pre-established precedents and accepted preconceptions. In other words, the outcomes of research are often new representations of old ideas developed in times past to connect students from a specific time and very specific demographic to science. Whereas science education research and practice appears to be inclusive, the view of urban populations as participants in science is not as expansive. For example, burgeoning areas of interest include the teaching for inquiry and the nature of science. These areas have a space within the framework for connecting marginalized youth to science but do not attack what is at the core of students' exclusion from full participation in the discipline. Educators and researchers who nest their actions and practices in existing approaches often replicate past practice and engage in actions that reify age-old approaches to the discipline. These educators often engage in work based on what they think of the students in the classroom and not on what are the true reflections of students' experiences. This is the case with the focus on teaching only for disseminating content and strict classroom management that has been closely tied to instruction in the science classrooms where I have conducted research.

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My work lies in the domain of urban science education and in classrooms where, by and large, teachers become the embodiment of approaches to instruction and ways of teaching that reflect who they think a science teacher is, or should be—a strict disciplinarian who is explicitly content based, purposely distant from the student's understandings about teaching/learning and aloof about connecting students to science in ways beyond the traditional. For these teachers, actions that are associated with the prototypic successful teacher become closely linked to what science education is or looks like. I argue that this is the case because "action with a sense is symbolic. It goes together with a set of other actions in the sense that it commits the agent to behaving one way rather than another" (Winch 1990, p. 50). In other words, when science educators and researchers engage in actions that are part of an established set of understandings, they become more apt to enact new behaviors that align with these understandings. For example, the teacher who engages in an action like teaching only from the front on the classroom becomes more likely to engage in another aligned action like teaching for the most part in a lecture format. One action (standing only in front of the classroom) triggers the next (teaching exclusively in a lecture format) and these actions and practices become rituals. Since every consistent patterned action over a period of time develops into a ritual, the consistency of the teachers actions almost force their future actions to fall within an established set of understandings that cause the classroom to be viewed through the lens of an established viewpoint and reality.

In addition to the replication of traditional approaches to science education, the enactment of limited and prescribed actions, and the establishment of rituals that support the proliferation of each of these phenomena, established approaches to broader issues related to knowing and learning lock the field of science education into rather limited spaces. By this, I mean that the needs of non-mainstream students are not necessarily accounted for within science education. This becomes glowingly apparent when sociocultural, and cultural-historical approaches to science education take a back seat to psychological models that nest human experience in a stark, individual-focused, mental model that opposes the ways certain communities interrelate with each other.

The inherited approach to science education in conjunction with established psychological models of knowing forces the creation of a science teacher who believes that the classroom is a space where she is responsible for making the student behave as a particular science student. The classroom is seen as a place where science information is disseminated and moreover, a place where students are molded to become docile sponges of scientific facts. In a sense, this is a neo-Pavlovian system where students are conditioned to respond to the teacher's presence by being silent and where they are inundated with drill and practice of science problems and taught to exhibit predictable, and visible and identifiable routines. Recovery in this sense refers to a return to an established order and an existent past and in the case of science education, a continuum of past and present research and practice that creates a distinct science education reality.

Versions of Science Education Reality

It is rather easy to link many threads in current science education research to chief points of interest over the last 30 years. The current focus on inquiry, scientific reasoning, and developing student interest can be traced to science education research that was conducted many years ago. For example, then significant investigations and approaches continue to be the primary research foci of many researchers today: a focus on inquiry and teachers attitudes about teaching science, models for in-service teacher training, student performance as a function of interest, and science teaching and reasoning. Current researchers and practitioners within the field of science education come with distinct lenses based on their unique experiences. But they look at the classroom through ways of seeing the world that for the most part, have been handed to them by their predecessors. Current perceptions about the purpose of science and education follows a history of deeply seeded ideas that are the outcomes of genealogies of science educators not connected by blood or family, but by institutions, established schools of thought, and existent ways of thinking. In this sense, science education is analogous to a distinct nation with a rich history that has a generally accepted culture that has been passed down for generations. It can be seen as a nation where scholars and practitioners grow and new teacher and researcher offspring are developed. It has its own ways of looking at the world cloaked in the high esteem given to its history and in the way the community sees itself. This view of self is rather sanitized and encompasses a large focus on strengths and a small focus on weaknesses as though the latter did not exist. There is an absence of scholarly work that problematizes the field and in some respects, the field should be viewed as out of touch with contemporary issues that plague large groups of students within urban settings. Science education's sanitized view of self is coupled with a distinct perception of reality held by representatives of the science education nation. This perception of reality is the determinant of the type of work that the community produces and includes a specific worldview about the ideal science classroom and the students within it. This reality is socially constructed. This means that people who are in the field of science education, through their collective positioning as scholars or practitioners in the field, form a belief system that becomes a chief component of a shared science education reality.

The Case for a Different View

Much of my work focuses on urban science education and youths whose needs have not been met under present approaches to science education. Utilizing existent models of knowledge, currently in-use approaches to teaching/learning, and solely psychological approaches to what the science classroom looks like and who the science student is only functions to limit the depth of research that can uncover why students struggle to connect to science. Urban youth who are from different socioeconomic, racial, and ethnic backgrounds have their own ways of looking at the world that require new ways to look at science education in general and at urban science education in particular.

In this chapter, I present a focus on science classrooms in urban settings in a way that moves beyond established models and inherited approaches through a more expansive theoretical approach, I suggest a focus on science education as a distinct entity and urban science education as a related but distinct one. This approach utilizes the concepts of nation and nation-state and theories to iron out the complex relationship between science education and urban science education. I take the nation and nation-state as metaphors for rethinking the relationship between science education and urban science education. This approach is viable for engaging in work that attempts to meet the needs of urban youth in science classrooms. This explicitly allows for an acknowledgement that (a) cultural conceptions of who is and is not a part of science are the chief determinants of who becomes successful in science classrooms and (b) these cultural conceptions are easily aligned to who is and who is not represented within certain social fields. This expansion beyond a purely psychological or sociocultural model to a more metaphorical and allegorical one is not dismissive of either. Rather, it allows a space for multiple theoretical frameworks to efficiently attack the fact that neither a psychological or sociological model on its own can fully account for the structural exclusions of certain groups from science. The fact that science education is presented as a nation within this approach is beneficial for looking at its inheritance of histories, established practices, and the constant air of nostalgia for simpler times that is analogous to the discourse in studies of the nation and its history. In addition, the view of science education as nation introduces the notion of citizenship, which provides the space for an interrogation of who gets allowed or denied full participation in science education.

Full citizenship in a nation is a powerful construct that encompasses the ability to be a leader of the nation, an active participant in government, and responsible for upholding a responsibility for others who also have citizenship. Full participation in the science classroom holds these same qualities in the sense that a citizen of science education can someday become a scientist, is scientifically literate, and sees himself as responsible for others within the nation. Beyond this construction of science education as nation and urban science education as nation state, I utilize a more progressive and reflexive sociocultural approach to look at the enactment of relevant pedagogy for urban youth. Within this model, I focus on the stance/standpoint of urban science education as nation-state and students as citizens of a nation-state with goals that may or may not align to that of the nation.

The Nation and Nation State

In a new and expansive view of science education, I tie the construct of science education as nation to the fact that it can be seen as a national community with an identity and reality shared among its citizens. Science education can be viewed as a self-sufficient nation that produces new offspring of teachers and researchers with a relatively similar view of the world. As is the case with any nation, one of the key issues that relate to its existence is citizenship. A citizen is an individual with certain rights who also has particular responsibilities associated with being a part of the nation/nation-state (Banks 2007). Within science education, both teachers and students can be viewed as citizens of the nation. Therefore, full citizens in the nation are afforded the rights to participate in the political process within the nation and are responsible for each other. Students with citizenship in the nation are constantly affirmed as scientists within their classrooms because they exhibit certain characteristics or are in schools that support their ways of knowing. They constantly see people who look like them as scientists, are allowed to explore scientific areas of interest and as a result, are generally more successful at science than others who are not citizens.

In settings where certain students are not seen as citizens of the nation they are not given the same rights as citizens as their counterparts in non-urban schools. These students, who are often from a different racial and ethnic background, are denied the ability to express their identities in the science classroom. Consequently, they are neither seen nor see themselves as true citizens. For these groups, there is a push to maintain their various identities as key components of who they are and a collective effort to connect to each other in ways that afford them the same rights as citizens within their own local spheres.

When the adjective urban modifies the term science education, a group within science education begins to challenge its nationhood and establish its nation-statehood. Urban science education stands as an entity on its own that grants students who have not been allowed to be citizens of the nation full citizenship into another entity. Rather than a separate nation, its position as a nation-state demands that institutions within the nation begin to identify and acknowledge efforts of populations who want to be citizens who have been denied citizenship. The nation state shares a larger goal of connecting students to science with the nation (science education) but breaks from the commonality of nationalists (traditional science educators) by moving beyond the national reality which includes exclusionary practices when it comes to granting and supporting the citizenship of certain groups. To meet the goal of connecting students to science, the nation-state of urban science education requires a focus on versions of reality that have been silenced and traditionally been forced to take a back seat to the established national one. These new realities focus more on the fact that the work in urban science education is inherently urban and that being urban means focusing on the diverse racial, ethnic, and socioeconomic positions of populations within urban areas that have been ignored by the nation. In urban science education, it is important that the issues surrounding exclusionary practices within spaces like science classrooms are brought to the forefront in discussions about connecting all students to science. Part of the work of urban science educators is to make it clear to the nation of science education that populations who make up the nation-state have always existed and are looking to have their own spaces where they can connect to science. These groups are geared to gain the rights of full immersion in science and await the opportunity to share the responsibilities of citizenship.

Beneath the Surface of the Nation-State

As mentioned above, the chief project of the fledgling nation-state is similar to that of the nation in the sense that it functions to bring students to science. It functions in a way that requires a focus on the needs of its diverse populations and their realities rather than an adoption of a shared national identity that spurs on a singular reality. The dynamics between science education and urban science education is similar to the dynamics within nations in general where "old nations once thought fully consolidated, [to] find themselves challenged by sub-nationalisms within their borders" (Anderson 2006, p. 3). These sub-nationalisms are the realities of the citizens of the nation-state.

It is important to recognize that the nation-state is a part of the nation. However, to those within the nation-state, full participation or citizenship in the nation is viewed as unreal or imagined. The nation-state becomes a launch pad for the recognition of realities that the nation may have perceived as anomalous. Consequently, the dynamic clashes between a shared national identity and multiple views of reality in the nation-state are important to recognize. For example, a student within the nation-state may not respond, to may respond negatively to the language of instruction in the classroom, the types of examples or analogies the teacher uses or that are in the textbook or the way the teacher addresses students in the classroom. In these scenarios, there is so much effort focused on indoctrinating students within the nation-state to the mold of what a student should be like in the nation that the work to truly connect them to science becomes secondary to attempting to diminish the clashes that exist by molding the teacher to be other.

Within the contemporary nation-state certain forms of knowledge and ways of viewing the world finally become identified as important. However, even within these spaces, new ideas about teaching science and expanded perceptions about the roles of the student and teacher fight against inherited roles and ideas from the nation through textbooks, administrators, and science education research. To move into new ways of viewing the urban student, it is important to allow the standpoints of those in the nation-state to fight against established perceptions of science education.

Validating the Standpoints of Urban Youths

Standpoints can be viewed as the true experiences of an oppressed group in a nation-state. They are based upon the fact that those within the nation-state or a particular oppressed group have the ability to "see more, further, and better … because of their marginalized and oppressed condition" (Smith 2005, p. 12). The use of this construct allows us to see that urban youth in science classrooms hold the information necessary for connecting themselves to science. The consideration of the standpoint of a student within the nation-state places value on human thought and identity formation and also considers that these phenomena are not immune to the ideologies of the setting in which an individual operates. Therefore, it serves as an avenue that connects the earlier discussed psychological approaches and sociological approaches to science education. The focus on the standpoint of the citizens of the nation-state leads to the fact that the contexts that stand as a referent for either the nation or the nation-state have an impact on how individuals with allegiances to either entity think, act, and perceive the world. For example, If I consider myself a scientist and an educator with training that allows me to be effective in these roles, I look at the world with a lens that positions me as an expert. The social contexts of the laboratory and the university that inform my position push me into the ways that I see myself. Students in urban science classrooms that have rich information about urban contexts, and the shared experiences and histories that come with these contexts understand each other and view the world firstly through their distinct urban lenses.

Understanding the Urban Student's Reality

An understanding of the experiences of the citizenry within the nation-state requires a study of what inhabitants perceive to be the ties that bind them to each other. Thus, "communities are to be distinguished not by their falsity/genuineness, but by the style in which they are imagined" (Anderson 2006, p. 6). Therefore, if the nation of science education were to question the falsity/genuineness of accepting the nation-state role of urban science education, the exercise would be fruitless in comparison to an understanding of the distinctions between the two. The role of a responsive nation and the scholars within it is to work towards an understanding of the realities of the nation-state. Furthermore, it is important for the nation to understand that the realities within the nation-state are partly constructed in response to the established national reality. To move beyond existing frameworks, students within urban science classrooms must be given an avenue to have voice in instruction. They also need to be valued for their differences. Finally, there needs to be a persistent effort to understand the students' realities and use information from these realities to connect them to the classroom.

Expanding Ways to Connect Students to Science

There are ways of expanding students' possibilities. Take for instance a science lesson in an urban classroom on electric current. The teacher describes all the parts of a circuit and mentions that when a circuit is closed, a bulb will light. A student in the class gets upset with the classroom discussion and decides to walk out of the classroom. The teacher thinks that the student is disinterested in the lesson and that the student is not worth going after or spending the extra effort to teach. The teacher begins to think that in another school, with a different demographic, a student would not be so disrespectful. While the teacher is thinking about the student through a national, traditional lens, a window into a nation-state reality has presented itself. The student who walked out of the class is dealing with the reality that her family has no electricity. Her response to the classroom lesson occurred because she was reminded of what she has to face at home. In these types of scenarios, the national approach to science education could not possibly apply to the nation-state because it does not accounts for the type of reality that the student is experiencing. When the student returns to the classroom, she is reprimanded for walking out. In response she turns off to the classroom.

It is unfair to compare a student who does not have to worry about issues such as electricity in the home to another student of a certain socioeconomic status from a different context. In a sense, "the oppressed are forced to compare themselves to their oppressors who put themselves as the norm or standard against which the oppressed are found inferior, [and] the oppressed are thrown in to a vicious cycle of finding their known self worth by virtue of this impossible comparison" (Oliver 2001, p. 36). In other words, since the established reality within the nation of science education dictates the type of student in the classroom and the appropriate behavior of such a student, any behavior or action that reflects anything other than an established reaction is seen as an indication of deficiency rather than a reaction to a scenario or social context.

The traditional model of science education does not consider that "we have a readiness for action proper to every specific lived situation" (Varela 1999, p. 9). In a more expansive look at the classroom, particularly in an attempt to gain insight into the nation-state, student behaviors or actions in the classroom can be viewed as reactions to specific lived situations. This is the case whether or not these behaviors align to an established script about the ways they should engage in response to a particular classroom lesson. It becomes necessary then to move beyond functioning based on archetypes of who and what we expect the citizen to be without the granting of citizenship status or the understandings of what nation-state citizenship is and why it differs from nation citizenship. The larger argument here is not to bring the nation-state citizen into citizenship in the nation, but rather to expand our conceptions of citizenship in the nation to include the understandings of those within the nation-state.

Extending Citizenship to the Nation-State

In an expansion of the requirements or established understandings of what it takes to be a full participant in, or citizen of science, it is necessary for the teacher and researcher to focus on specific practices that nation-state students engage in and whether these practices indicate that students are connected to the classroom, the subject matter, or the teacher. Over time, the teacher can identify what the students respond to and determine whether their responses are to the constraints put in the place by the nation or a true misunderstanding of conceptual understandings integral to learning science. This level of analysis will allow the teacher to become a part of a process that provides an insight into students' subjugated realities and standpoints. For example, does a student who ignores a teachers question in class do so because of a lack of conceptual understanding of the topic or because the teacher has presented the class or the lesson in a way that inherently denies the student an opportunity to engage. The study of the student's reaction to the teacher may constitute only a few snapshots of the students' realities; but we also need to study the students' real response to the classroom.

With a focus on student responses and an awareness of the ways that actions or behaviors can be viewed, it becomes clear that student behaviors are often misconstrued as indicators of disinterest. This approach can be tied to a behaviorist stance in that it focuses on student's reactions to certain stimuli. However, it expands beyond the frame of behaviorism in that it is used only as a study of what is happening in the classroom and not as a mechanism for control or as training for a certain behavior. The fact that the urban science classroom is a nation-state opens up the ability to utilize a psychological approach and then extend beyond it for the benefits of making sense of the students' experiences in the classroom.

The next step is to focus on the structures within the science classroom that can be manipulated to successfully affect the students' science agency. For example, if the teacher asks questions in a different manner than usual in the classroom, does the student respond differently? If so, the teacher has found a structure within the classroom that allows the student to feel comfortable with her nation-state status. Through this process, the teacher gathers tools for teaching from the behavioral observations of the students and uses them to connect students to science by replicating the structures that breed success. This naturalization of the student as part of, and participant in, the nation of science education allows the student to have an existence within the nation that considers her reality and supports her agency. If the ways that instruction is presented in the science classroom limits students' agency and causes them not to connect to science, then the structures in the classroom are manipulated so that the possibilities for students to connect to the classroom are expanded. Therefore, new ways to expand their agency and new opportunities to connect to the classroom are enabled.

To facilitate the connection of student identities to science, there has to be a focus on the structures in the classroom that allow students to see a connection to science as something that is feasible, and then a constant focus on ensuring that this structure is in place. For example, if students in the classroom do not focus when the teacher is balancing equations on the board in a chemistry class, but are engaged when one of their peers who understands the process does understand, then the teacher must learn to work less on problems at the board and allow students to present their work more. Since citizenship requires both to have rights and responsibilities, this process allows the students to feel as citizens of the nation and nation-state because they are responsible for each other's learning and feel like they have been given the right to teach and learn.

Reaching the points discussed in this section comes with constantly experimenting with both animate and inanimate entities in the classroom by moving them or using them in different ways. Each time that this maneuvering occurs, it is necessary to pay close attention to the ways that each change in structure affects students' science agency. Each instance when students react positively to the maneuvered structure and become engaged in science, it is important to document the structure and the ways that it affected the students. The goal then is to maneuver the structures within the classroom so that they allow students to retain their nation-state identities while they connect to the shared goal of connecting to science.

Outside of Class Approaches to Connecting Students to Science

Outside the classroom, an understanding of the realities of the citizens requires an immersion in the local culture. It also requires a search for the mutual ties that allow them to be grouped or to group themselves as a nation-state. The representatives for the nation must become a part of the student activities, practices, and rituals and attempt to immerse themselves in their complex understandings about the world. This may require a conscious attempt to detach oneself from preconceived notions and a temporary denouncing of ones national identity for the purposes of forging a connection to the nation-state and its diverse understandings. By this, I mean that the teacher must become a student of the nation-state and its citizens. This approach allows for an understanding of urban youth in science classrooms that goes beyond established notions of who they are and includes understandings about what they experience. In addition, it provides the teacher a rich amount of culturally relevant examples to utilize in classroom instruction. Through this process, the ties that bind the citizens of the nation-state and the possible connections to science in their everyday lives become highlighted. The next step is to enact a distinct brand of pedagogy that takes all the information gained from insight into the nation-state into consideration for instruction.

Witnessing and Reality Pedagogy

Embarking on the journey towards this pedagogy is an opportunity for the representatives of the nation of science education to bear witness to the realities of those within the nation-state. Bearing witness to urban science education comes from viewing the effects of the nation on the nation state and then teaching based on these understandings. It is the approach to teaching science that looks explicitly at how traditional science education and structures both within and beyond the classroom have negatively affected the ability of urban students to connect to science. It uses this understanding as the point from which to re-connect students to science and address misconceptions about students that limit them from full participation to begin with.

Witnessing is a process that goes beyond seeing and recognizing; it is a process where one understands what cannot be seen. The student who walked out of the electric current lesson had an experience in the classroom based on a reality that may not have been seen by the teacher but that could have been witnessed. The push here is to get a critical mass of teachers and researchers within the nation of science education to engage in a collective witnessing of the experiences of urban youth within the nation-state. It is important to note that "collective witnessing is also understood in relation to others and in relation to personal and cultural histories and material conditions" (Boler 1999, p. 178). In its relation to others, witnessing focuses on the citizens of the nation-state, their realities, and the ineffective relationship between a national identity and student realities based on "genealogies of one's positionalities and emotional resistances" (p. 178). This key piece of witnessing refers to deconstructing the nation identity and directly speaks to existing science education genealogies that. Witnessing is the piece of *Reality Pedagogy*, which is a brand of pedagogy nested in connecting students to the classroom based on their experiences. This type of pedagogy begins with an understanding of the constitutive entities represented by self so that one can teach with an acknowledgment and upfront discussion of the oppressive structures in side and outside of school and move beyond them.

The Role of Cogenerative Dialogue

None of the processes outlined here can be fully manifested in the absence of dialogue with urban youth about their experiences in the world. The reality of the urban student is a function of their experiences and of what they speak or write. The urban science educator stands as the interlocutor who is familiar with the reality passed down by the nation and its representatives but understands that connecting urban youth to science requires the realities of citizens of the nation-state. The reality pedagogy thus enacted combines psychological and sociocultural approaches to science education and combines them with the experiences of students.

Cogenerative dialogues are conversations about classroom events involving students and teachers. They allow teachers to have deeper insight into the students' realities than they would have by solely studying students' lifeworlds or viewing them solely through established conceptions of the nature of urban students. When married to other transformative approaches to urban science education, these dialogues allow those in the nation state to see how they can connect to the shared nation and nation-state goal of connecting all students to science. Through cogenerative dialogue, stakeholders build or seek to build shared commitments and once these commitments have been articulated, they can critique the practices of all participants in relation to the current goals.

Conclusion

The work in this chapter serves as an avenue through which perceptions about urban science education and youth in urban science classrooms. The main purpose here is to bring a new lens to the forefront and focus on ways to move beyond established deficit perceptions about urban youth. Reaching this goal comes with a valuing of urban youth inside and outside of the science classroom. I argue for an interrogation of past ideological allegiances of science educators for the purposes of re-connecting them to a burgeoning nation-state filled with urban youth who disconnect from science when their realities are silenced and identities are misconstrued. The goal here is to utilize new tools for looking at the classroom in order to gain a more rich perspective on what is at the root of the disconnections of certain groups from science and work towards addressing them. The extension of the ideas laid out here is a set of questions that if consistently asked and honestly answered will improve our effectiveness as science educators and allow us to be more inclusive of students in urban settings. Do we reaffirm the existing deficit view of urban youth in science education through our current research and practice? Do we involve ourselves in research that is transformative in the lives of urban youth who have traditionally been disconnected to science? Do we allow students' citizenship within a nation-state to inhibit them from citizenship in the nation of science education? The answers lie in the hands of pedagogues and researchers who begin to see beyond an established science education reality.

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Chapter 16

Making Science Relevant Conceptual Change and the Politics of Science Education

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The present is a commentary on the previous four chapters that collectively make up this section of the book ("Positions and Perspectives"). As such, I have selected one major theme common to the four contributions to discuss its relevance to the field of science education research. In addition, I articulate (or bring forth) an issue that I believe was missing in all four texts. My intention is to provide readers with something that they have not yet encountered in any of the pieces individually—at least not as explicit as they will here. Ultimately, the present chapter contemplates another aspect of what has been carefully laid out on the prospect of re-uniting psychological and sociological perspectives within the context of conceptual change. Thus, I am supplementing and deepening the conversation amongst all four pieces that were intentionally *positioned* in this part of the book.

Introduction: The Night Biology Class

> People learn by telling stories [from their own experiences] and not listening to them. … A curriculum should be seen as an elaborate story—not a story to be told, but a story to be lived. (Schank and Berman 2006, p. 222)

It is early February 2003. The first day of class. I am the biology teacher for grades 10 and 11 for the second consecutive year at the school. It is past 7 p.m. and the night has fallen. The classroom lights are on and they reveal the chairs and faces of the students who fill the room with sounds of life—laughter, conversations, opening notebooks, and ringing cell phones. Some students are still coming in as others insist on staying a little longer in the hallway chatting with friends until a teacher (or a staff member) asks them to go back into the classroom. On average, there are 35 students on every class list. If a professor is lucky enough not to teach

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in the last two blocks—there are five every night whenever all the teachers show up for work—then there is a chance that more than half of the students will be in the classroom. These students are not children. They are adults (18+ years) who, for one reason or another, have decided to return to the public school system. They cannot afford anything different: They are bus drivers, house cleaners, supermarket cashiers, gardeners, or cooks. They have to work all day—and it has been like that for a while now. They are of all colors and creeds. I remember a couple of students whose religious faith prohibited them to attend school on Friday evenings. They missed half of my classes throughout that year. In case any student wants to keep a perfect attendance record, s/he has to go to school five nights a week from 7 to 11 p.m. Some students drive their own used cars and maybe carpool to the school, while others have to walk from home or the nearest bus stop (about one kilometer away) to take classes. They are tired. I am tired. It is late. They would rather be home with their spouses watching the news or the soap opera and tucking in their children.

I wait for them to notice that I want to take attendance—I have to. They quiet down. I call out their names, some of which have the pronunciation corrected by the students. I introduce myself and ask them if they know what the word biology means. "The study of life" is what I hear most of the time. They are right. The noun biology has developed from the Greek stem *bio-*, "life," and *logia*, "study of." I congratulate the students by saying that we have started on the right foot: At least they know the name of the course. We laugh. Next, I ask them to write on a scrap paper why they believe they should learn biology with all the complicated words and concepts. They write it down. I ask them to share their answers and some read them aloud. "To know how to do my personal hygiene" is one that I still remember to this day. I reply, "Shouldn't you know how to do that by now?" The sympathetic tall skinny black lady—who is older than I—shakes her head positively and cracks a timid smile. "Well," I continue, "then we have that you already know what I am supposed to teach you this year. In which case you don't need to be here, right?" She disagrees. They all must have thought I was doing that to kill time on the first day of class or that I was trying to show them how little they knew about their needs for the biological knowledge. They were wrong. I was struggling to make sense of the fact that we were put in the same classroom, so that I could teach them something and that they could learn that something to my satisfaction. The whole system is based on the official high school curriculum in combination with old established assessment practices—that is, (re)production of written documents, like tests or essays. After a while, I assume they do not know (or cannot articulate) why they have to study biology. I probably do not know myself. I try to convince them that the discipline offers another way of looking at the world around them. A world of exclusion and poverty, that is. How is it that knowing biology can make a difference in their lives on a pragmatic dimension? That I dare not ask. I come back to this story below.

Positioning Ideas

The second part of our book (Part B) is devoted to different perspectives concerning the project of reuniting sociological and psychological perspectives. More specifically, the four preceding chapters—each one in its own way—raise questions about the premise, assumptions and value of conceptual change research. They delineate the existing distinctions of the two stances—sociological and psychological—in favor of the former. Although there seems to exist a contradiction between what is proposed in the introduction of the section (to re-unite the sociological and the psychological perspectives as considered here) and how the arguments in every chapter support the sociological standpoint over the psychological one, our reader needs not to forget that this tension results from the positioning that the various authors assumed in their interpretation of what their contributions to this book should be. In the end, they all offer an inspiring and passionate collection of ideas that is both an indicator of current thinking on conceptual change research in science education and a source for that same thinking. They all put forward first-class material for a fascinating conversation with those in the field, where the reader is invited to accept or reject the worldviews that are presented.

A Cry to Honor the Diversity of Voices in Science Education

Conceptual change—like any other subject within science education—is not a simple matter. Yes, we all know firsthand that we develop knowledge of the world through our experiences. However, we are not merely absorbing "raw" information through our bodies. The image we construct of ourselves as social beings also mediates (and is mediated by) the experiences we have, thus affecting what and how we learn. In this way, identity and learning are inseparable (Kirkup 2002). For instance, consider the following quote that illustrates how what we come to know/understand/learn intersects with the maturation of our identities:

> I consider a tree. … The tree is no impression, no play of my imagination, no value depending on my mood; but it is bodied over against me and has to do with me, as I with it—only in a different way. (Buber 1958, p. 7)

The presence of the tree makes it impossible to negate its compelling existence upon the author: The tree is "bodied over against" him. This forceful being co-exist with other bodies with which it shares space and resources—the tree is not alone. More so: It brings to bear the Other that is inherent to (and presupposes) the recognition of additional individual bodies—the limit of the tree is always another organism. If the tree is "no play of my imagination, no value depending on my mood," it is because the author accepts it as itself. That is, he recognizes the tree as a tree because he also recognizes non-tree organisms (like himself). Hence, this process of recognition of the Other helps to construct the author's own identity as human—he differs from the tree he sees before him in many ways. This is also an ontological passivity that makes him unable to deny his own materiality. But the physical presence of the tree goes beyond its mere corporality: The existence of the tree is not detached from an interpretation if. What is the tree to the author will determine the possible actions he might take. Is the tree an obstacle to creating more parking spaces? A place to rest after lunch on a sunny day? A specimen that holds the potential for treating cancer? The habitat of some rare bird? The symbol of a happy childhood memory? A tree like any other with no meaning attached to it? An icon of the local community's ecological values? In the end, any appraisal of the (learning) situation that the author finds himself in is paramount in determining how he reacts to it, thus affecting both the way learning takes place and the quality and quantity of what is learned in relation to the surrounding world to which he is connected (Zajonc 2001). In general, our common experiences inform us that our evaluation of these situations is colored by our backgrounds—and the fact that people respond differently to similar situations (and vice-versa) underpins the unpredictability of our attitudes and behaviors. According to Niebuhr (1963),

> [w]e interpret the things that force themselves upon us … And these large patterns of interpretation we employ seem to determine—though in no mechanical way—our responses to action upon us. … Such interpretation, it need scarcely to be added, is not simply an affair of our conscious, and rational, mind, but also of the deep memories that are buried within us, of feelings and institutions that are only partly under our immediate control. (pp. 61–63)

From this brief discussion one can learn that cognition is not the sole factor affecting the way we understand and represent/reproduce scientific knowledge—whether in school or outside. Other elements that constitute (and are constituted by) the social fabric into which we breath our existence play a significant (and complex) role in the process of learning—also affecting and being affected by our learning experiences. These elements include our emotions and feelings, gender, family socioeconomics, education levels of parents, race, sexual orientation, religion, and ethnicity. Consequently, it would be unwise expecting science teachers to get the same results from students issuing from widely varying walks of life. Research has established that what students have experienced before they enter school will differ dramatically and influences their performances accordingly. That is, students are not empty vessels.

Learning is not only situated, but also distributed. To ignore this dynamic social web of learning in the construction of scientific concepts would be to don blinkers and look into the direction we are being asked to—that is, always straight ahead instead of around. It is to create artificial mechanisms, conditions, and rituals to validate and support just one type of knowledge (canonical) to the detriment of others that are deemed deviant from the norm (i.e., culturally diverse). We would simply be recreating—and have been for the most part as the previous chapters denounced—a partial picture of the reality of our science classrooms. This, in turn, would account for the significance of adopting a feminist approach to the study of conceptual change (chapter 12). It also emphasizes the legitimacy of the call for reconsideration of the individualistic lenses through which we have approached the problem and that only widens the theory–practice gap in conceptual change theory (chapter 13), thus privileging a researcher's perception of conceptual change over that of the observed (chapter 14). In preventing (excluding) practitioners (i.e., teachers and students) from benefiting of decades of research, we deny them full participation in the re-production of scientific knowledge within the self-sustaining "nation" of science education (chapter 15). Ultimately, inclusion of diversity in research—that is, the alternative and socially complex—is the overarching point that permeates all the four chapters in this Part B.

One practical question remains: How can science education research on conceptual change account for so many variants in the equation? Would it be reasonable to expect one to take it all in consideration whenever looking at conceptual change? Here, it took four chapters, seven people, and over 65 pages to bring forth the authors' takes on how this kind of research should be conducted and suggest how its outcomes should be interpreted by those in the field. Of course the arguments are not entirely foreign to our reader. Nevertheless, it is unlikely at this moment—and maybe precipitated to speculate it possible—that one will be able (or have the desire) to integrate all these perceptions at once into any piece of research. There is much to consider and the interests within the research community is as diverse as the number of people who belong to it. Moreover, I do not presume that imbuing the members of the science education community with this spirit of sociological revolution was ever the purpose of this book. Otherwise, we would only be recreating the same tone of authority, exclusion, and individualism that we criticized so much in the past.

The present chapter has so far identified with two components of Wenger's (1998) model of social learning: (a) community, where the process of belonging is one of learning and (b) identity, which is produced through learning. In the next section, I turn my attention to the remaining two that I believe were left on the margin of the conversation until now: meaning and practice.

Giving Birth to the Right Kind of Science Education

As science educators we are particularly interested in how it is that our students (i.e., learners) come to know and understand science so that we can engage more and more students in that endeavor—this is our job. In other words, once those children—or adults—are placed under our care, we are expected to make them learn science. As a consequence, the more our students know about scientific concepts, ideas, and modes of inquiry (reasoning), the better teachers we are considered to be by our peers, parents, and the school administration. It is a tough task—one that is probably impossible according to Freud's (1937) general interpretation of education. Paradoxically as it may be, the reality is that we intend our students to perceive something in science that requires knowing the very theory that they are supposed to learn (Roth 2006). We have become masters of the impossible and responsible for disseminating science information in our classrooms to make students behave like little scientists.

In this scenario, the accumulation of content knowledge and the development of general scientific abilities are justified as being critical not only to enhance student academic achievement, but also to enable them to successfully handle their future careers and fully participate in the democratic societies of our globalized world. As a result, science conceptual and procedural types of knowledge are now equated with greater agency/decision-making competence/freedom/happiness and as such they have been considered invaluable assets for individuals to posses. This, in turn, implies that these skills can be developed through training and that they can be transferred to an endless range of situations.

Such a perspective on the value of learning science neglects almost always the evidence that science is not for all (Roth and Lee 2002). Besides, to know science does not translate into knowing how to put this knowledge to use whenever necessary. For instance, one should not lose sight of the existing disarticulation between content knowledge of science and performance rates on tasks that require reasoning skills (e.g., Bao et al. 2009). I argue that part of the problem lies in the tension involving students' and teachers' interests and perspectives on what school science is for. In terms of the model of social learning proposed by Wenger (1998), this is equivalent to saying that two (out of the four) of its elements are lacking: (a) meaning, which comes out of experiences of members of a community and (b) practice, which is the engagement with a community in a joint activity. Put bluntly, for the most part students do not see the relevance of what they do/experience in their science classes at school—besides working towards getting a passing mark every term and avoiding to be punished. They were neither asked to be science schooled nor given the opportunity to opt out from it. Even when they are home-schooled or go to one of the few alternative schools, there are certain curricular and evaluative constraints they still have to work within. It is the politics of science education. It is the politics of our school system. That is the way our society works: With schools being a precious part of it. Overall, students are discontent—and so are the teachers. Discipline problems and low grades mirror this discontentment. On this note, Paul Feyerabend (1991) comments the following when asked if he is against education:

> I regard education—the right kind of education—as a most necessary aid to life. … They [children] got life without having asked for it. … Why should those upon whom we have imposed existence not view this existence in their own terms? Don't they have a right to lead their own lives? Don't they have a right to please themselves …? … This is everybody's good right and it must not be taken from us by an education that aims instead of helping us to develop our own being to the fullest.… I didn't beg my parents to take care of me and my teachers to instruct me and so I owe them nothing. (pp. 55–56)

In his quote, the philosopher talks about the "right kind of education," the type that allows students to develop their beings "to the fullest." Science is no exception, especially in the techno-scientific society of our days where reality is saturated with socio-scientific issues. This right kind of education should be able to liberate students from the oppression school can enforce upon students and teachers. However, as Freire (1970) points out, “liberation is thus a childbirth, and a painful one” (p. 49) because it is far more convenient to persist in the system than to change it. In these circumstances, science education research should take us beyond the understanding of how to connect people to science and seek to inform practice by unveiling the meaning our students make of the science teaching and learning environments into which they are immersed 5 days a week. From the perspective of our students we might ask, “Why should there be so much investment on teaching and learning science?” Maybe then we will be able to address conceptual change more adequately and for clearer and more significant purposes.

As I write this chapter, I am in Brazil collecting data for the second consecutive year at a school in a shantytown near Brasilia (Reis et al. 2009). In sum, the project deals with environmental education and social justice, and uses new media technologies—that is, production of radio podcasts, photo essays, video documentaries and newsletters—as means to introduce critical elements of mass media analysis, generate science-based meaningful interactions amongst students, and create a more engaging science learning setting for those marginalized students. I was talking to one of the groups in grade five and asked them to pick out a topic that would draw attention from other students in the school to their project. I explained that people—their audience—should be interested in what they have to say or else they will not listen to their radio podcast. Then, one student suggested they could talk about climate change in their 3-min long radio program. I asked this student what climate change was and he nearly described the water cycle instead. As for the other group members, they simply admitted that although they had heard of climate change in previous years at school, they could not articulate what it was. In contrast, another group had decided to talk about swine flu prevention. Using a small pamphlet that the government distributed to the students as their chief source of information, the students of this other group could recite almost by heart the main prevention tips that they had written down in the draft they prepared as a script for their radio program. I was not surprised to see the discrepancy between these two groups, even though they were differently organized. It explains: The pandemic of swine flu has become tangible in and relevant to the students’ lives through the efforts put by the local government, media, and teachers to call for everyone to practice flu prevention techniques. Possibly not knowing exactly what exactly a virus is or looks like, or what the acronym H1N1 means, or how the prevention tips work (what exactly does soap do to the virus?), students now are closer to understanding the general mechanism of transmission, treatment, and prevention of viruses than they possibly were before the outbreak. In a way, they are relatively well versed on the new disease and its killing potential. Meanwhile, climate change has not been able to draw as much attention during these months of my stay.

This is not to say climate change has become obsolete or that I ignore the fact that students of all ages typically are aware of the flu symptoms and treatments. My point is that one should not think that the erroneous concept of climate change that a student might hold is due to some individual cognitive fault that makes him/her inapt to science. On the contrary, this is an example of how one can make students' experiences in (or outside of) class meaningful to them to the point of raising an interest in developing a concept or idea—which is perfectly legitimate. Besides, from time to time the environment affords/supports one type of conceptual development over the other. To embrace this perspective on conceptual change requires one to go further the reality pedagogy outlined in chapter 15: It not only connects the science classroom to students' lifeworld experiences, but also improves an individual's quality of life and a community's perspective on conceptions. If education is to be effective, its goal should not only be to prepare students for life, but also to engage students wholly in life at the present moment.

Back to the Night Biology Class

How do students and teachers make sense of what they do in school? How do they position themselves and how they come to see themselves within the science education context of their classrooms? Do teachers understand why they are expected to teach certain science topics and not others? Do students understand why they are expected to learn certain science topics and not others? How can the level of success in science be measured other than in tests of canonical knowledge? These are fundamental issues that should be raised and that could affect the content and quality of the concepts that are taught and learned in science. We (researchers) should investigate ways to allow the stories of students' and teachers' experiences to penetrate more deeply into the science praxis of schools. Otherwise, teachers and researchers will continue to engage in work based on what they think of the students in the classroom and not on what the true reflections of their (students') experiences are (chapter 15). In other words,

> Without the richness of narratives and narrative subjects that define and elaborate place, the connection between our lived experience and our sense of space and time is reduced, and life lacks immediacy, becomes flat, impersonal and placeless. Place loses agency along salience, and places themselves become interchangeable, irrelevant and intru-mentalisable, neutral surfaces upon which "rational" human projects can be inscribed. (Plumwood 2002, p. 231)

Examining what students say or do inform us about how they position themselves as observers in spaces like their schools, where much science education takes place. Now I turn back to my first story. That night I realized that my students did not have an understanding of what doing science is about. Alternatively, they could have chosen not to be part of the science education nation that evening—they could have not shown up. Maybe science can meet resistance (nation-state) within its own nation, or maybe it is just another symbolic system, instrument of knowledge and domination that contribute to the reproduction of the social order. Nevertheless, how could I possibly help my students to expand their learning possibilities to attain greater levels of agency in that space? How could I given that (a) what I teach is not grounded in their experiences and (b) they do not understand the reasons for learning what they are expected to. Despite these questions, I, like many others, claim to teach for citizenship or conceptual change. I still remember struggling to teach my adult students about genetics and how to use the Hardy-Weinberg equilibrium theory to predict the behavior of genes in populations. I cannot blame them if they still find the works of genes really strange. Considering that my ideas as outlined here do align with a utilitarian perspective of science education, they might for now at least serve to continue the conversation on how to make school science relevant.

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Part C

Science Agency Across the Lifespan

This third part of *ReUniting Sociological and Psychological Perspectives* is devoted to some fundamental ideas about agency and its mediation by structure concerning science and science education across the lifespan. In cultural sociology (e.g., Sewell 1992), the relation of agency and structure is theorized as a dialectical one. We should not think of structure and agency in the abstract but always in terms of actual situation of interest. In looking at any concrete situation, we always find agency as mediated by structure, locatable both within (schema) and outside of (resources) the agents. That is, structure itself consists of the dialectical relation of material and social resources that the human agent recognizes in his or her lifeworld and the schema that are, as Pierre Bourdieu (1990) would say, homologous to these structures. Through their agency, human beings mobilize resources, and in so doing, produce new resources that expand and transform agency. That is, we must not think about agency in the abstract but, again, in concrete situations; and here we can find corresponding structures within and outside the agents that are linked such that they transcend the inside–outside dichotomy. At the same time, as Karl Marx (1973) realized, acting uses up energy, which changes the make-up of the human body and therefore leaves traces in it. This, therefore, transforms the schema. Any form of action, therefore, transforms the body in ways that are not available to consciousness other than in generality—like saying that practice makes perfect, working tires the body, and so on. That is, in the course of a lifespan, the schema of a human being continually change, both leading to more efficient existing practices and to the production of new practices. This is so, as our research in a variety of workplaces shows, even in the case of the most routine forms of work, such as using a trowel to through 200 kg of fish food per day into the ponds of a hatchery. One can recognize differences between those who have thrown the food for a few years and those who are new to the job.

In cultural-historical activity theory, any form of human engagement involves both material and ideal dimensions. On the one hand, there is the world objectively available by all members to a setting—this objective world, as Émile Durkheim (1894) suggested, includes the social world. We see other people act, we can point to a chair or computer, and we hear others speak. All of these things and actions are perceptually accessible by those present in the situation. At the same time, human beings are conscious of some aspect of the world, and this consciousness is an aspect of the ideal dimension of the situation. This form of consciousness also has been referred to as *participative thinking* (Bakhtin 1993), which should not be understood as form of cogitation described by a computer metaphor but as a form of understanding our presence in the world. Thus, when we get out onto the street and greet a neighbor, we do not have to stop, think, and reflect, but we get caught up in a neighborly conversation, which unfolds almost despite of ourselves. We do not have to cogitate the spatiotemporal coordinates of our interlocutor, as do computers, but we simply relate to the neighbor and talk, taking into account the ways in which they orient in and to the world.

Whatever our engagement with the world, cultural-historical activity theory conceptualizes this engagement in terms of the use of energy and wearing down of our bodies. That is, engagement with the world, whether this pertains to the ideal or material dimensions, leaves traces in and therefore transforms our bodies. Transformation is cumulative, allowing human bodies to adapt to recurrent situations, that is, to learn. The chapters in this third part of the book can be read through the lens of the bodily engagement in social-material situations; and this engagement transforms human bodies, and therefore, the possibilities they harbor for subsequent engagements: Agency means transformation, not only of the world but also of the bodies that change this world; and agency inherently means learning.

In the first four chapters (17–20) of this section, the authors present us with description of learners of different ages and different types and amounts of experiences—therefore different schema—who learn science or how to teach science. We can understand all of the individuals involved as producing new understandings in the dialectic of cultural production, which both reproduces cultural practices and transforms these practices. Because the relationship of resources and schema is a dialectical one, the precise outcome of the production—knowing and learning—cannot ever be predicted. This is so because dialectic means there is an abyss such that ideal-ideological (mental) schema and the material world cannot ever be the same. They are two planes connected only by means of singularities (Deleuze 1990). We can think of the two planes and the singularities that connect them in the discourses of catastrophe or quantum theories, where there are multiple parallel states possible that are, in an act of observation or changed, collapsed into a single observation. In the present instance, the observation may be one concerning the ideal-ideological (schema) or the material world (resources). The important point is that we cannot think the change and transformation independently of the combined but mutually exclusive states even though in the act of observation, we come to focus on one or the other.

In chapter 17, Katherine Richardson Bruna examines the experience of one Mexican newcomer student, Omar, as he participates in the rock cycle unit of a mainstream Earth Science course in a demographically transitioning rural Midwest high school. Grounded in the framework of cultural-historical activity theory and drawing on data from student, parent, and teacher interviews as well as classroom observations, the paper situates Omar's experience in that unit as one of four life moments in which his social interactions were mediated by rocks or rock material as critical environmental artifacts: building his home in Mexico, crossing the Mexico-US border, studying the rock cycle, and leaving school to work in construction. The discussion illuminates the relationship between individual subjectivity and collective material social practice and, in so doing, inform the ongoing conversation about the role of the affective dimension in conceptual change, particularly as it relates to transnational learners in the context of globalization.

In chapter 18, Maria Varelas, Justin Kane, and Christine Pappas explore concept development as part of a learnerhood (a term modeled on that of neighborhood), an ecosystem of interacting entities governed by certain rules and characteristics that regulate participation and in which dialectical relationships, identity, power, and learning unfold and evolve. The authors study an urban primary-grade classroom in which spaces are co-constructed by young African American children and their white, female teacher. They consider spaces as intersections of symbolic (personal, social, ideological, political) and physical dimensions, where issues of power, hegemony, agency, structure, control, and knowledge define boundaries that are flexible and permeable. Varelas and colleagues explore how these fluid and dynamic spaces are sites of dialectics and relationships among children, teacher, materials, and ideas. The authors also consider how particular structures, expectations, pressures, and possibilities in the classroom community influence the creation of the various spaces within which children exercise their agency. Within the spaces they co-create, the authors study how children's engagements in and with science involves different, possibly non-canonical ideas, emergent, or even fragile understandings, and semi-formed concepts expressed in various modalities—including language, body expression, movement, stance, appearance, gesturing, and so forth—and forms of participation. Varelas and her colleagues further explore how these young African American children engage with science ideas with their teacher who, at times, privileged them and other times limited their participation making them Others, recognized their ideas or marginalized them, gave them access to resources and capital or left them on their own.

An important conundrum that the science education community faces is "why is it so difficult to bridge everyday science with school science?" Drawing upon cultural historical activity theory and pedagogy of place and critical ethnographic research methods, Edna Tan, Angela Calabrese Barton, and Miyoun Lim examine in chapter 19 students' changing participation within middle school learning science. Their findings reveal the importance of place in how and why these youth pursue science learning. We argue that one way in which place shapes their learning is in how the youth take up science as a context and a participatory tool for change. They study two interrelated kinds of changes within the classroom: crafting new forms of participation and new points on entry into the science learning community, and redefining the purpose of science activity. The authors argue that students are more agential when science is a context and when science is used as a tool in addition to serving as a goal. The students have more reasons, more impetus to participate in science because more than just the world of school science is at stake. What is at stake is their place which is not merely condensed into a physical environment but rather, who they are and who they can be. Students exhibit a greater degree of agency when they can inhabit more than the world of school science in the classroom, because when more roles and perspectives are valued, more kinds of knowledge are valued. Students therefore have more opportunities to act when they feel empowered as experts to act in pursuit of a particular outcome, be it voicing an opinion or applying scientific knowledge in an outside setting such as their out of school communities.

In chapter 20, Maria Rivera Maulucci reports findings from a larger, ongoing study aimed at exploring interactions between teacher identity, teacher learning, and classroom practices in a social justice teacher education program in New York. The individual | collective dialectic indicates that individual learning presupposes collective learning and vice versa and that neither individual conceptions, stored in memory, nor the collective performance of a conception, may be reduced to the other. Thus, it is appropriate to theorize conceptions we might attribute to individuals, while recognizing the role of collective performance. Research shows science teachers bring conceptions about science, science pedagogy, how children learn, and schools that may not be in harmony with reform-based teaching methods, and may be firmly held and resistant to change. Rivera Maulucci's study explores one teacher's (Elena) journey towards becoming an urban science teacher, tracing linkages between her learning in a science methods course and during specific pedagogical interventions in elementary classrooms, and how changes in Elena's schema, resources, and practices inform her instructional goals and teaching practices.

In chapter 21, Jennifer Adams, Christine Siry, Koshy Dingra, and Gillian Bayne engage in a dialogical inquiry concerning the four preceding chapters. The four authors use the diversity of their backgrounds and experiences as a position and as a tool to bring to light central issues that emerged from their reading. They pose themselves four questions that they then elaborate in the form of a conversation: "What is the goal of formal learning spaces?" "How can we bring to the forefront teachers' roles and agency in educational research?" "How can we use students' and teachers' individual life stories to create an inclusive learning community in the science classroom?" and "What is the role of emotions in learning science?"

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Chapter 17

Glocalizing Artifact, Agency, and Activity
An Argument for the Practical Relevance of Economic Injustice and Transformation in the Science Education of Mexican Newcomers

Katherine Richardson Bruna*

Hear me?
Here, me!
This me, this me, *desde este lado*,
On this side, este yo
Y no el yo del otro,
not your me.
But this me …
– Rubén Martínez, 1992, *The Other Side*, p. 82

Hear me? Here, me! As a multicultural teacher educator and scholar who does engaged ethnographic work with Mexican newcomer students and families, these lines of Martínez' poem speak deeply to me. They invite me to understand anew that issues of representation, of having one's voice heard (Hear me?), are intricately linked to issues of recognition, of being seen, not as how others would perceive one to be, but as one *is*. To close the gap between perception and reality, Martínez calls for a coming-closer that leads to the discovery of the real self (Here, me!). This movement from an abstracted, distant, way-of-knowing, which Martínez interrogates with his use of a question mark, towards one which is more concretized and immediate, is, as Martínez signals with his use of the exclamation point, imperative. Trying to re-present the roles and resources of Mexican newcomers so that science educators and researchers can re-cognize who these learners are and what they bring to the classroom constitutes the heart of my work. This work has involved *acercándome*/bringing myself closer to these students, their families, and communities, both in the US and Mexico. Whereas I would never claim to be getting to the reality or the what-*is* of Mexican (im)migrant experience

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and subjectivity, my work is responding to the invitation-to-learn that this population's increasing presence in U.S. schools not only extends but demands.

Unlike some multicultural teacher education colleagues, I am not interested in merely identifying the learning preferences or communication styles of Mexican kids. If I take up such constructs, I do so with a radically contextualized interest in what sociohistorical configuration of influences made such preferences or styles possible cultural practices in the first place. As a critical multicultural teacher educator, I bring to my work a predisposition to see society, schools, and selves as haunted spaces where not only can we encounter "the lingering past" (Gordon 1997, p. 205) but we can also divine the hastening future. From this view, both past and future are luminous, though seemingly invisible, in the very presence of the present.

My work in this chapter is to argue for the practical relevance of this view to understandings of science teaching and learning; that is, I want to describe what the lingering past and the hastening future look like in terms of science educators' and students' experiences in the classroom. As an alternative to the construct of conceptual change that has driven inquiry related to science teaching and learning from both psychologically- and socioculturally-oriented perspectives, I suggest that the construct of self as leading activity (Stetsenko and Arievitch 2004), grounded as it is in an expanded exposition of cultural-historical activity theory (CHAT), affords us a much more adequate tool for understanding science education. This is precisely because the construct of self as leading activity, with its orientation to world- and self-change, is attuned to the materiality of experience and thus attentive to the practical relevance of the past and the future. CHAT makes practical the ideas of injustice and transformation in human development.

Introduction

Attending to the materiality of injustice and transformation in science education means examining agency, which Stetsenko and Arievitch set forth as a position of contributing to meaningfully changing the world and one's self in the process. These authors, writing, as they do, from a cultural-historical perspective, understand and embed agency within artifact-rich activity. Here I address the topic of student agency with a similar sensibility toward artifact-rich activity. This sensibility, I believe, allows me to describe the constraints in the lives of undocumented Mexican newcomer youth (to represent this invisible student population in the scholarly literature) while detailing the lived experience of one such youth as strives for world- and self-expansion (to recognize the particularity of his experience). I center my account around this youth's experience with artifact, agency, and activity as it is construed in four life-moments: building a home in Mexico, crossing the Mexico-US border, participating in a science lesson, and working for a construction crew. The general context surrounding and connecting these life-moments is applicable to any undocumented Mexican youth; it describes the socio-economic structure of Mexican-U.S. immigration and schooling. Yet the details of activity within the life-moments are highly individualistic. In this way, my account speaks simultaneously to the constraints on student agency, on the ability for world- and self-change, posed by social structure, as well as to the possibility of student change-agency in negotiating between such constraint and expansion.

I use an artifact that is common to all four life-moments—rocks or rock-related material—as a touch*stone* against which to illuminate how the structural and the individual, in this youth's lived experience, meet. Of special interest is how his lived experiences and science instruction intersect. In examining this intersection, we can begin to understand that the globalized system of social and economic injustice has not just political but practical relevance for science teaching and learning. My central argument is that this injustice influences his experience-in-instruction in a way that certainly psychological and even sociocultural approaches to science learning cannot capture; his science learning cannot be reduced to the context-free, mechanistic functioning of the psychologist's idealized individual mind nor either, as the socioculturalists would have it, to context-embedded information-processing distributed across and interwoven with multiple domains of practice. Instead, his experience-in-instruction is about the materiality of his goal of world- and self-change as defined by the collective practices of his familial and cultural communities and the sociohistorically construed conditions of their labor. In short, Omar, the youth in question, belongs to a community of practice enmeshed in and interwoven with a reality of economic distress and disparity, a reality which is not merely backdrop to his learning by either a psychological or a sociocultural understanding of what that would mean, but, instead, absolutely immediately co-constitutive with it.

Injustice, then, is not a political abstraction to be applied in anticipation of or retrospective to his learning (as it is often applied in discussing the antecedent conditions or outcomes of the schooling of Mexican immigrant youth), but a matter of the concrete pragmatics of his unfolding learning processes. Talking about Omar's experience-in-instruction from a psychological or sociocultural perspective, without taking account of the practical relevance of injustice, is to continue to tell the cultural story of the possessive investment (Lipsitz 1998), in science, of White advantage. Why? Because the luxury of ignoring the practical relevance of injustice is the very proof of such an advantage. Such a story is, in the end, whitewash. Only with presence of mind in the face of such a beguiling cultural story can we "tame this sorcerer and conjure otherwise" (Gordon 1997, p. 28). We can critique and counter with a different cultural story, one that reaches beyond representation and recognition to the redistribution of knowledge activity, authority, and assets—to a practice of science that is of all and for all people.

Radically Agential Science Learning: Self-as-Leading-Activity

In theorizing self as leading activity, Stetsenko and Arievitch (2004) reconcile the often-dichotomized tension between individual and social formulations of the self; they explain how the self can be simultaneously individually agential and structurally determined. Rejecting mentalist positions that foreground individual cognition and treat social factors as merely background, and also rejecting transactionalist positions that treat the individual as merely a pawn of the contextual collective social processes bearing upon her science learning, these scholars offer instead a CHAT-derived dialogical approach that examines the self in profound relationality, but not absolute identity, with the entire semiotic realm. Science learning is not reduced to relatively context-free conceptual change processes nor is it reduced to context-loaded structural replication. Science learning is about a learner's world- and self-creation using the tools available to her in her environment, only one element of which is her science classroom.

In "socially and historically specific cultural processes, people not only transform and create their environment; they also create and constantly transform their lives, consequently changing themselves in fundamental ways and, in the process, gaining self-knowledge" (pp. 482–483). In this CHAT-inspired approach, subjectivity and self emerge out of artifact-mediated interactive activity within the environment. This activity is both "enabled and constrained by unique contextual conditions facing each individual [the particular historical moment, for example] … and by individual facts and forces [like race and other identity dimensions]" (p. 485, my insertions), but it is not overdetermined. This is because, first, the contextual and the individual are not simply imprinted onto the self but are part of a much larger process through which the self is formed, and because, second, the contextual and the individual are absorbed by activity that transforms and is in turn transformed by them.

Importantly, in this CHAT-derived approach, particular activities are driven by particular motives that reflect the particular individual's particular mode of engagement with the material world. Thus, "human subjectivity, the collective processes of material production and social interactions all co-evolve as parties of a unified system constitutive of human social life, interpenetrating and influencing each other, while never becoming completely detached or independent from each other" (p. 490). The self is, therefore, both a product and producer of culture. It may internalize as individual goals the motives of collective cultural practices, but also transform those goals and in so doing the motives of the collective cultural practices from which they arose. In this way, self is leading activity because people, in participating in activity, inevitably make an impression on, are "absorbed" by, activity and, in the interaction, are impressed by the activity and absorbers of it. It's not about activity but the construal of self (and, in the process, world) through activity that is the "meaningful life project" (p. 494).

Now, given my interest in documenting the educational experiences of Mexican newcomer youth, I want bring these insights to the telling of Omar's story. I want to ask (and attempt to begin to answer) what these processes look like in the era of globalization where the project of world- and self-formation utilizes artifacts, agencies, and activities that span national, political, cultural, and economic borders that define and have been defined by systemic injustice. And, working towards divesting ourselves of the possessive investment in the whitewashed cultural story, I explain how they inform science education; that is, I explain what the practical relevance of injustice (and transformation) is to science teaching and learning.

The New Borderlands in the Heartland

I write from the heart of the U.S. Midwest where communities are undergoing what is referred to, with distanced sterility, as "rapid ethnic diversification." Some of the world's largest packing plants that work to put meat on plates across the nation are located here. Their presence draws increasing numbers of laborers from Mexico who are attracted by the prospect of more permanent, as opposed to seasonal, work, the low cost of living, and high hopes for the quality of education that schools can provide for their children. The dramatic increase of Mexicans immigrating directly to traditionally non-settlement communities, such as communities in the rural Midwest (as opposed to historical "gateway" entry points like California and Texas), is part of what scholars term *The New Latino Diaspora*. These new (diasporic) Iowans transform rural Midwest communities, which are invigorated in ways both tangible and intangible. Plant employees increase in numbers, stores expand, and school enrollment soars. In Captainville, Iowa, the community I study, 13% of residents have, over the last 10 years, come to be Latino, the majority of Mexican descent. Eighteen percent of the otherwise predominantly white (77%) student body at the high school is Latino, a figure nine times the state average. Of total enrollment, 13% are designated ELs or English Learners (overwhelmingly from Spanish-speaking households). Stated most generally, describing how histories, cultures, and languages confront, conflict, and coalesce in this New Borderlands is what gives shape to my work.

The data drawn on in this chapter comes from the third year of what has been my ongoing ethnographic project in Captainville (now in its sixth year). That year I was following a small subset of students from the "English Learner (EL) Science" course of the year previous (at Captainville High School—CHS), where I had a co-teaching role on Fridays, into their present placement in the mainstream earth science classroom. All of these students had been newcomers, or new arrivals, to the US when I first met them in the EL Science course. None of them spoke any English. That first year they were taught by a teacher with limited background in second language acquisition theory, language development practice, and science. The subsequent year, the year from which these data come, they were transitioned to the mainstream earth science course where they studied alongside White peers with a science teacher who had just begun to attend workshops on EL instruction. I observed in this classroom to see how my case study students managed the transition.

Over the year of observation, my work got easier: With the exception of one student who was able to return to Mexico over the winter holidays and bring back his transcript (because he, unlike many, had legal residency status) to prove to the administration he had already taken and passed earth science, I watched one after another of my case study students drop away from school. First were Oscar and Roberto. These two always came to school but just never came to class (the first had a suspected gang affiliation and supposed ADHD; the latter a girlfriend who kept him busy). Then there was Verónica who, rumor had it, wound up (pregnant) with an older man. That left Edelberto, María, and Omar. Edelberto had just missed qualifying for a professional soccer team in Mexico when he came to the US to be with his father. He lived for soccer and when he did not get good enough grades to allow him to continue to play for the high school team, there was no more reason for him to stay enrolled. María broke her ankle from her star-soccer-playing on the girl's team and the doctor's bill was too much for her sister, with whom she was living, to cover unassisted. María began working on the cleaning crew during the overnight shift at the plant and, by the end of the year, was maintaining only sporadic attendance. And then there was Omar.

About Omar

Omar's mother had diabetes and *nervios*/anxiety disorder and couldn't work. His father did not earn enough at the plant to adequately provide for the family. Omar felt pressure to contribute to the household. He had worked in Mexico, first making large burlap sacks and then laying bricks. He made 300 pesos a week (30 dollars) and was, as his mother reported, very happy: "*Se sentía bien contento él . Todo me lo daba . El nunca se quedaba con dinero*/He felt very happy, he did. He gave me everything. He never kept any money for himself." Omar's mother was trying to maintain her position that, in the US, school was more important than work. She would say, "*Mijo, échale ganas, échale ganas a la estudiada. Nosotros no tenemos nada más que darte. Tú estudia con sacrificio. Ustedes échenle ganas porque Uds. van pa'delante*/My son, have motivation, have motivation toward your studies. We don't have anything more to give you. Study with sacrifice. You [and your brother] are moving forward."

Omar attended science class every day that year but I knew from my family interviews that the idea of work was becoming increasingly attractive. He had an uncle who worked in construction and could set him up with a job. The temptation to take a job, especially a job that was not work at the plant, would eventually be too great. Omar, too, would fall away from school.

In actuality, Omar's falling away from school had begun just a few days after he enrolled at the high school mid-year. From the accounts that the principal and his mother have given me, Omar set off the fire alarm and was taken to juvenile court. Here a deal was struck that they would waive his fine if he showed up for community service, which he did. The school's response to this event, happening as it did so early in Omar's schooling in the US, created distrust between Omar, his family, and the high school. His mother insists that when the school spoke to her about the event, through an interpreter, they told her it was no big deal. So when the call to appear before a judge and pay a fine came, she was naturally confused, distressed, and anxious. Omar became "*muy, muy deprimido*/very, very depressed," his mother said. He had been a good student in Mexico. In fact, they tried to pass him from fourth to sixth grade but his mother refused. He even had been given a scholarship to support his school attendance. In fact, Omar, his mother said, had told her he wanted to go to college. He wanted to be a doctor. "*Yo voy a ser doctor porque la voy a curar*/I want to be doctor because I am going to cure you," he had told her.

So the fire alarm event troubled him. He insisted it wasn't his fault. His mother gave him the advice to take the fall, urging him to understand how important school was to his family's future: "*Yo le dije . Mijo . pues . declárate culpable . Diles que lo hiciste sin pensar . verdad . pues . que lo hiciste . y dije vamos a andar en problemas y en problemas*/I told him . My son . well . say that you're guilty . Say that you did it without realizing it . right . that you did it . and I said [if you don't] we will have many problems."

Omar, as his mother put it, *se desilusionó*/became disillusioned and told her he did not want to go to school anymore. He cried, she said, and shut himself in his room. She pressed him to reconsider, making a plea about how essential it was that he stay in school to learn English: "*Sí vas a ir a la escuela . ¿Sabes por que? Porque aquí en este país si tú no sabes hablar inglés . no somos nada . No vas a encontrar en ninguna parte trabajo*/Yes, you are going to go to school . Do you know why? Because here in this country if you don't know how to speak English . we aren't anybody . You aren't going to find work anywhere."

When I first saw Omar sitting behind a desk in the EL science classroom, I remember two impressions I had of him: He was considerably darker than his other Mexican classmates (this earned him the nickname of "*indio*/indian") and he had a smile that, when breaking out of his usual silent solemnity, lit up his whole face, replete with dimples. His mother described him, with some concern, as "*serio*/serious"; his father, a fisherman in Mexico, as naturally good with numbers. The family had lived on Lake Chapala in Jalisco where the men caught small white fish (*charal*), which they fried in oil, salted, and sold as food. (Because there isn't much more to eat in their village—"*vivía uno de puro pescado*/one lives only on fish," his mother told me—families migrate to the US.) Omar's father said he was well known among the other fisherman for having an uncanny ability to estimate with impressive accuracy the number of fish in a catch. This skill he was proud, he said, to have passed along to his sons. When Omar described to me how he saw science relating to his everyday life, he talked, then, not surprisingly, of fish. He talked of ways of classifying different kinds of fish and of ways of changing their state through cooking.

Omar was enrolled in Mr. Robert's third-period course. He was one of 24 students; four of these were Mexican, three designated non- or limited-English proficient. My notes from the beginning of the school year indicate that I observed Omar to be well prepared in class. He came with his textbook, a notebook (with the word "America" written in pen across it) and a pencil. My notes also indicate that I only observed him to follow very simple requests ("turn the page," etc). Beyond this, when he could not understand what was going on, his preferred strategy was to closely observe the work of his peers and try to figure out from their activity what he was expected to do.

About Mr. Roberts

Omar's easy connection between fish and science would likely have been more difficult for Mr. Roberts, his teacher. For him, the purpose of science was that of technological advancement. Science education, to him, was about teaching "the concepts." In the following quotes, we see the emphasis he put on concepts, as well as on his preferred hands-on approach to teaching them. Notably, Mr. Roberts had a bilingual aide in his classroom, but he restricted her role, as she would tell me, to "just putting out individual fires." For Mr. Roberts, his control over "the concepts" to be taught was essential. He told me:

– [Talking about working with ELs] "I found that kids struggled with a lot of the major concepts because they couldn't put their hands on something to manipulate it or see it in a different way."
– [Talking about the changes he made to the course of instruction when he arrived at the high school] "The curriculum was in a can … so basically when I got the sequence down . the processes down . the labs . then I said . Now how can we expand this lab or look at this concept in a different way or do we need to go the next step with another concept?"
– [Talking about his perception of the difficulty of his course] "If you understand the concepts and you learn the material . you learn how to manipulate it and you learn what's supposed to be learned . the grade should come along with it."
– [On his concern over using the bilingual aide in instruction] "In the classroom . the teacher needs to be in charge and the interpreter needs to know what they need to do . know their place . okay? Ultimately . the concept has to come straight from the teacher because the teacher is the one with the certification and the interpreter is not."

These quotes illustrate Mr. Roberts' understanding of science teaching as concept-driven. A sequence of concepts drives instruction; they are "what's supposed to be learned." It is Mr. Roberts who has the authority over the concepts to be taught and learned because he is the science teacher. The aide and, by extension, the students do not share any of this authority. They need to, as he states, "know their place." This was true for all his students, White and Mexican, alike.

Mr. Roberts walked a fine line between race-and-power cognizance, on the one hand, and evasiveness, on the other. He was aware that racism and racial segregation was an issue in the community (the school board had just decided to rezone the middle schools so that the students who lived in what the community called Little Mexico would not all go to the same middle school, as they had been), but was reluctant to name it as such at the high school. For example, he told me in one breath that a male student, Juan, had just come up to him complaining of a White kid calling him a "damn Mexican," and, in another, that he saw it as an "individual thing and not a Whites against Hispanics thing." Parroting something I feared he learned in some multicultural education course, he informed me with great confidence about the value system of Mexicans. Enumerating on his fingers, he declared that "family is number one, religion number two, and schooling number three." He took this as absolute and unchanging, a fact ungrounded in any sociohistorical context. Given what we know about Omar's mother's testimony to her support of his continued schooling, Mr. Roberts' list represented a distorted view of Omar's motivation in his classroom. Beyond the fact that Omar was designated non-English proficient, Mr. Roberts knew very little about him. "Omar, I think, really struggles with language," he stated.

The Research and the Researcher

I videotaped three periods of Mr. Robert's Earth Science course approximately once a week over an entire school year in order to collect data for my case studies. I also conducted audiotaped formal interviews with the students at the beginning of the school year and informal interviews as the year progressed. Additionally, I visited their homes at least once and, in the case of some students whose mothers were particularly available, interested, and welcoming (Omar's was all three), up to five times. I audiotaped my formal interviews, made field notes on my informal interviews and observations, and took occasional photographs. A graduate research assistant who is native to Mexico assisted me with transcription, translation, and interpretation. For this chapter, I am using data from Omar's record to tell his story.

When thinking about Omar's story, I have always been struck by three life-moments: him helping his mother build their home in Mexico; he and his brother making the perilous border-crossing with his aunt; and his decision to stop going to school and work with his uncle's construction crew instead. With further reflection, I realized that these three life-moments share a common thematic element: they all had something to do with rocks or rock-related material. In reviewing the videotapes of classroom observations, I was fascinated by the fact that there was another rock connection: Omar did a mineral identification lab in Mr. Roberts' classroom. Given my interest in CHAT, I decided that using these four life-moments to theorize about agency, artifact, and activity in the transnational context was an intriguing opportunity worth pursuing. Given the early state of the science education field in theorizing about the social/affective domains within and without the ongoing debates over conceptual change, I decided to use Omar's experiences to enrich the dialogue by bringing to it awareness of the lived reality of the transnational experience. Given current demographic trends, I believe this is the reality that science educators, researchers, and stakeholders need to begin to reference more centrally in their practice and policy planning.

Having said this, I admit, I am not a science educator. I am an educational anthropologist by training. By virtue of a certain configuration of personal and professional experiences, I have taken an interest in and become an advocate for Mexican immigrant children and their families. My attention to the science education context draws from the specialization I took, in my graduate studies, in critical theory. I learned to interrogate systems of knowledge, identity, and power and was particularly entranced by the way feminist science scholars accomplished this. I realize this means I lack science credentials, but believe those positioned at the margins are sometimes best able to see what's being left out. I also am a White, middle-class, non-native, though proficient, speaker of Spanish. This means I do not share the cultural and linguistic heritage of the community I study. I have, I believe, gained their trust in other ways, through my home visits, attention to their concerns (specifically their children's lives), and increasing work in the rural Mexican context from where they come (and to which they want to return, someday).

There is something more that needs to be said. When I was growing up, my mother collected "grinders," or rocks, she believed were used by Pacific Northwest tribes (I grew up in Portland, Oregon) to grind nuts and grain. On hikes through the woods, she would linger trailside, peering down at the rocks in the river, occasionally picking one up to hold it, first one way, then another, before, usually, discarding it back into the water. There was one such rock that has accompanied me throughout my childhood, as an ornament near the fireplace or, more commonly, as a doorstop. It has a broad, flat base, about the size of an adult female foot, but wider, that then becomes quickly thinner for a couple of inches in the vertical direction, before starting to widen out again to a rounded knob at the top. I see this rock clearly as I remember it. Like a favorite family pet, it is a constant and dear recollection from my childhood landscape.

My mother now is in the advanced stages of Alzheimer's and with each sibling's visit to her home, some sorting out of her possessions, in anticipation of her move to a care facility, occurs. During my most recent visit, one of my older sisters showed me a box full of rocks. They were all the grinders my mother had collected, including the big one I remembered so well. She had taken them in that box to an anthropologist at Portland State University who had confirmed her suspicion that they could, in fact, really be ancient tools. I picked up the big rock and instantly felt my hands find their place, both gripping the narrow part in perfect position to grind. I picked up smaller rocks in the box and with each one there was a way that it fit, perfectly, the human hand. They were just rocks but, in my hands, they became tools and I their imagined user. Holding them connected me to every hand that had held them (hands that had, in fact, over how many of years, given them the form they now have). In this way, I was absorbed into them. And they altered me, physically, in my act of holding them in their coolness and smoothness. And they altered me emotionally. I experienced joy in reliving my childhood experiences of seeing and touching that rock; I also felt sadness for my mother's life that had confined her largely to the home so that this incredible intellectual curiosity and passion was never nurtured, and I felt mourning for the fact that my mother was already gone in one sense and soon would be gone in another and that she would never know how happy her riverside discoveries had made me. I experienced my self in that present moment with a profound awareness of the past and future spreading out behind and before me, as if a voice in my head said to me "Look, here you are."

I bring to bear this experience on my choosing to tell Omar's four rock life-moment stories. I felt a point of connection as I considered his stories in light of my own. My specific purpose in the next section is to similarly foreground the social/affective realm of Omar's self-experience and, in his case, to explain its relationship to the materiality of the economic injustice he is trying to transform.

Life-Moment 1: The House

In Captainville, Omar lived in the area adjacent to the plant known by locals as Little Mexico. His home was grayish-blue and decidedly run-down, as were many on his street. They were rentals for Mexicans who knew nothing of landlord-tenants rights, and if they did, given their illegal status, could not do anything about it anyway. A sign hung in the window to the right of the stairs leading up to the front door announced that tacos were for sale. This was part of Omar's mother's plan to bring in extra money for the household. The living room was small and crowded with relatives. As in all the Mexican homes I have visited, there were white lace doilies on shelves, plastic flowers, photographs of family, images of Christ, Mary, and various saints, and a television tuned to a Mexican *telenovela*/soap opera.

Retreating with me to her kitchen, Omar's mother was forthcoming about their situation. She talked easily and quickly, challenging my ability to keep up with her Spanish. She got particularly animated when I showed her a drawing Omar had made. As part of my coteaching role the previous year I had organized a visit by the EL Science students to my campus where they participated, with university multicultural education students, in an art project and discussion. They had been asked to draw images that represented who they were and, with the assistance of student translators we had recruited for the day, to have a cross-cultural dialogue.

The university students (who were all White) drew books (representing education), sports-related images (representing leisure activities), diamond rings (representing engagement or married status), and people (representing friends and family). They drew crosses (expressing their faith) and wrote out the names of which Iowa football rival they supported—the Cyclones or the Hawkeyes. The Mexican high school students' drawings were significantly different in theme: they drew only two things—family (figures holding hands or grouped closely together) and places (houses, crops in fields, or other representative images of the communities they had left behind, such as a regional landmark like a lake, or the local *hacienda* at which their grandparents had worked as peasants).

What I showed Omar's mother was a picture he had drawn of his house in Mexico. It was a simple drawing of a simple structure (Photo 17.1). I showed it to her as a way of talking about my history with the students and to demonstrate to them I was interested in learning about their lives.

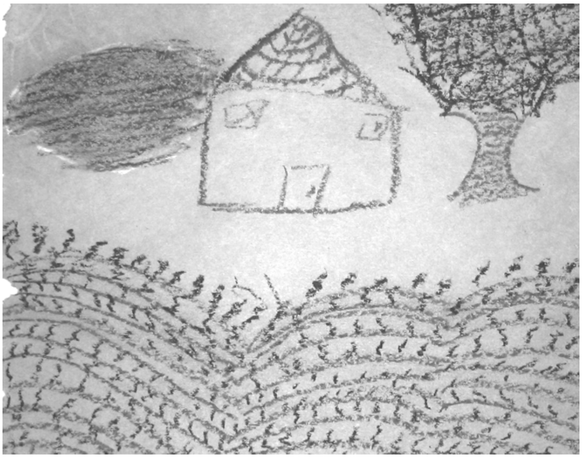

Photo 17.1 Omar's drawing of the house he built with rocks in Mexico.

As she looked at it, she told me this story.

Hicimos una casita de madera . entre nosotros . entre un señor y yo . a cargar tablas y las pegabamos . La hicimos solitos . Su papá no se daba cuenta porque él andaba trabajando en el D.F. en el estado de México . allá . y cuando él vino miró la casa que habíamos hecho . Este . él estaba chiquito . acarreaba piedras grandes . piedras grandotas y hacíamos cerca y este . él hacía bien bonita mi casa y él se ponía y chiquito . pues estaba chico . y la arreglaba porque le daba verguenza salir afuera y él barria y tendía camas y trapeaba y el otro niño lavaba los trastes . porque yo me iba a trabajar . a sacar filete de pescado . Después de eso. el presidente me ayudó a hacer mi casa de material . me tumbaron esa y estaba ya aquí pero él hizo la mezcla para que me levantaran mi cuartito . El trabajó como peón/We built a wood house . between us . between a man and I . we carried planks of wood and put them up . We did it ourselves . his father didn't know because he was working in Mexico City in the state of Mexico . there . and when he came he saw the house that we had made . He . Omar . He was really young and he carted big rocks . really big rocks . and we made a fence and Omar he made the house really nice . He fixed it up and young . he was young . and he cleaned it up because it made him embarrassed when he went out and he swept it and he made the beds . and he mopped and his brother took out the garbage and did the dishes because I went to work . to skin fish . After all this . the mayor helped me build my house out of bricks and concrete . and they knocked down that one that was already there but Omar made up the concrete mix that put up my house. He worked like a peasant.

Life-Moment 2: The Crossing

At the end of the school year, Mexican students at CHS surprised everyone by organizing a 1-day walkout and march. It was a response to a series of marches around the country in support of immigration reform. Supposedly, one student masterminded the event by passing around small notes that announced the date and exact time at which students were to just get up and leave school. The event drew even more attention when CHS locals observed, through comments in the local newspaper, that students carried the Mexican flag higher than the U.S. flag. The students said they had no intention of being disrespectful; they were trying to show their unity as students who shared, regardless of length of residence in Captainville, a homeland of origin in Mexico, and an endorsement of immigration reform to support their families. Eager to understand how the parents of my case study students responded to the march, I made a number of visits.

I caught Omar's mother, her sister, her sister-in-law, and her 2-month old niece and 3-year-old nephew, all watching television. They were happy to talk to me about their support of the march and how proud the students' actions had made them. When I had already packed up my audio recorder, which had fascinated the 3-year-old, I asked Omar's aunt about her crossing experience, not knowing whether I would get a bite or not. I had begun collecting these stories and saw this as a chance to learn more about the challenges faced by families in coming to the US. Before I could ask her to wait so I could get my audio recorder out, she launched into what was the most dramatic crossing story I have ever heard. It wasn't just a story; it was a full-body recounting, a re-enactment of the movements and emotions of the trip across the border. When I got in my car to leave, I drove around the corner, stopped, turned on the audio recorder and tried to retell what I had just seen and heard:

Omar's aunt was the one who crossed over with Omar and Leopoldo . Omar's younger brother . and they crossed . she said . through *canales*/canals . big *canales* full of water . she said like nearly all of the time knee high . but many times up to their necks high with rushing water . and that there were mountains of human skulls . human bones . and she actually acted out what it was like to be in of these *canales* and to see human skulls . human bones around her and she moved off her chair and crouched on the ground and she looked to her right and she looked to her left and she covered her head and tried to enact for me how scared she was and the *coyotes*/human smugglers and the people around her said . You want to be like this? These people died here . You want to die here? And that it was Leopoldo who saved her from drowning in one of these *canales*. And she talked about walking through the desert without food or water because if the *coyote* knows that you have food . or money to buy food or water . he'll take the money from you . so you can't tell them that you brought money along . so you can't spend your money while you're with the *coyote* and so nobody knew she had the money . but she had a little wallet around her waist . the details are going to come in pieces here as I put this together . She talked about crawling over rocks and having blood dripping down her legs . She talked about being picked up by the *migra*/border patrol and being detained . again without food or water . detained in a wet and soaking state without been even told what was going to happen next . without being able to call their family and tell them what was going on . The story she told is one of being absolutely scared for one's life . She said that she would have gone back if it hadn't been for the fact that she had the two boys with her and she was bringing the boys to their mother . She was frightened the whole time and her leg was in danger the whole time and only the fact that she had the two boys allowed her to cross and she went on and on with much more detail than I can tell here . She said the boys arrived with cut fingers . attended their first days of school . with fingers that still weren't healed from scrambling over and behind rocks to hide from the *migra*.

Life-Moment 3: The Science Lesson

In early spring, Mr. Roberts began what he considered his specialty, the rock unit. "There is very little I don't know about it," he told me confidently. He saw the unit as huge, comprising five tests in which students, for example, tested rocks for 30 different qualities, like hardness, breakage, and luster. "You know, some of the stuff we go over is kind of hard in the conception," he told me. "Conceptually, it is kind of hard."

The day of my observation, the students were doing a paired mineral identification activity. They had to place rocks into the categories of "igneous," "sedimentary," and "metamorphic" based on their assessment of certain observed characteristics. The following comes from my research memo on the transcript:

0 mins: The video opens with the camera focused on Omar, with Mr. Roberts in the background busily collecting the supplies for the day's activity. Omar is wearing a black t-shirt with a yellow Nike swoosh. He looks up at the camera and gives me a big smile that shows off his dimples. The bell rings. Mr. Roberts says, "Okay. I'm going to need you to get out your notes for today." Omar appears to be daydreaming now, looking off into space. He notices the movement of others around him, looks around and, following the cue, begins to open his notebook. Mr. Roberts approaches Omar with a rock in his hand and opens the lid of the plastic container in front of Omar and puts the rock into it. "You guys remember that I owe you a 19" (referring to rock #19 in the activity), he says. As he says the word "19," Mr. Roberts turns his head toward Omar and looks at his face. Omar does not return his gaze. Mr. Roberts pauses momentarily with the container lid in his hand looking down at Omar. He appears to be waiting for some sign of understanding. Without looking at Mr. Roberts, Omar finally nods his head to indicate understanding. Mr. Roberts says, "Okay?" and Omar nods a couple more times. Mr. Roberts puts the lid on the container and walks away. Omar's activity partner (an LEP-designated Mexican girl) says something inaudible to him. Omar nods and busies himself with his notebook.

5 mins: Mr. Roberts is at the front of the classroom explaining instructions for the mineral identification activity. Because students are seated along each side of two long tables that run parallel to each other perpendicular to the front whiteboard, they have to turn their heads and look over their shoulders in order to see him. Omar is seated at the very end of the outermost table (from the classroom door), about as far from Mr. Roberts as he could possibly be. While Mr. Roberts speaks, Omar does not turn his head but looks directly ahead of him as if staring through the windows that line the wall. Mr. Roberts is explaining why there is an index card on top of the "rock kit" (rocks in plastic containers) in front of the students (the cards indicate the numbers of missing rocks that he has ordered but are late in coming). He passes around some handouts and says, "Here's what I want you to do . I want you to copy down what's on the front board because that's what you're going to be looking for. Exactly what you see up there." Hearing this, most students turn and look at the white board. Omar continues looking straight ahead until, again, he hears the shuffle of movement around him and observes that students are drawing in their notebooks the pictures that Mr. Roberts has prepared on the white board. He begins to draw them too (Figure 17.1).

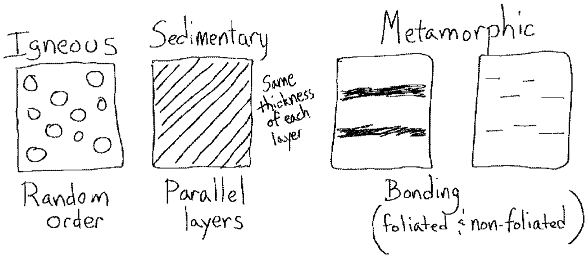

Figure 17.1. Mr. Roberts' rock drawings from the whiteboard.

10 mins: Mr. Roberts is still at the front of the classroom giving instructions. "First of all, remember, we went through the three types of rock: igneous, sedimentary, and metamorphic. What we're looking for in igneous rocks is when you pick up a rock trying to figure out what type of rock it is we're looking for something with a random order of grain . Remember the things that we looked at were stuff like this [camera zooms in to show Mr. Roberts holding a rock slab the size of a large floor tile] . There's no layering . Here [pointing to the slab] you can see the grains . So this is . extrusive or intrusive? [In response to a student's inaudible answer] Why is it intrusive? They're bigger crystals so what does that mean? A student says, "You can see 'em." Mr. Roberts replies, "You definitely can see 'em." The student continues, "So they cooled slowly." Mr. Roberts says, "They cooled slowly . Good . So this is an igneous rock . So anytime you're looking for an igneous rock you're seeing just the random order of grains . What would be just the opposite of that? What would be another way of saying that? Instead of random order what are you NOT looking for? What should the other two have? Well . On the board . What do you see on the board that the other two have [looking at the board]." A student says, "Lines." Mr. Roberts replies, "What

are those lines?” “Layers,” says the students. “Layers,” repeats Mr. Roberts. “So if you see layers it can’t be an igneous rock.” (Mr. Roberts continues in this way through explanations of sedimentary and metamorphic rock.) So, the first thing you’re gonna do is . You have a kit of rocks . And what you’re gonna do is put them all in a line to make sure you have them all . And you’re gonna have numbers zero through 20 so flip your sheets over to the backside and cross out numbers 21 though 25. You won’t have those . Okay? (Omar sees other students turning their handouts over so he follows suit.)

15 mins: Mr. Roberts is continuing to give directions at the front of the room. Omar has begun sifting through the rocks in the container in front of him. Mr. Roberts interrupts his directions to admonish Omar for the noise he is creating. “Omar?,” he says. Omar turns to look at Mr. Roberts and immediately takes his hand out of the container. Mr. Roberts says, “Thank you.” Omar smiles with an embarrassed look. He then stares expressionless at the books on the table before him. Mr. Roberts finishes his instructions, asks if there are any questions and says, “Okay . Go ahead and get started.”

20 mins: Omar dumps out the rocks in the container, saying something in Spanish to his partner. Heads together, they hold up the rocks and look at them. Omar, holding a rock in his right hand, turns his head toward Mr. Roberts as if wanting to catch his attention. Mr. Roberts comes over, as Omar says something inaudible to him, and takes the rock from Omar’s hand. He says something inaudible and puts it back in Omar’s hand. Omar and his partner continue picking up, examining, and talking about rocks. The audio is very noisy, but Omar can be heard saying “*rayas*/stripes” as he points to a rock and also the numbers *tres/*three and *seis/*six, referring to the rocks’ numbers and where they go in the line-up. Omar leans forward and looks to his right to observe what his neighboring partners are doing (Photo 17.2).

Photo 17.2 Omar looking for cues from his peers during the mineral classification lab.

25 mins: Omar and his partner have lined up their rocks. They dust off their table and settle back in their chairs as if done with the whole activity. Noticing the sheets of paper in front of them, they reach forward to grab them and start looking

around to what other students are doing with them. Omar turns to a bilingual Mexican-American girl to his right and asks her something in Spanish while making motions of scribbling with his pencil over the paper. She tucks her hair behind her ear, and replies, “Okay. Um,” and begins a nearly inaudible explanation in Spanish of what they’re supposed to do. After hearing this, an expression of discomfort takes over Omar’s face. He spreads his mouth and widens is eyes, as if saying the equivalent of “Yikes.” He turns to his partner, says something and she laughs. He looks to his neighbors to the right again for a clue for what to do next.

30 mins: Apparently worried now about running out of time, Omar and his partner begin to move very quickly, putting the rocks into piles without even picking them up and looking at them. Omar turns to his neighbors to the right again, this time looking for similar rocks in his neighbors’ piles and trying to discern in which pile they have placed them so he can do the same.

35 mins: Mr. Roberts is evaluating the piles of Omar’s neighbors to the right. He pulls incorrectly categorized rocks out of their piles, drops them back in the container and says, “Redo those.” Omar is watching intently, looking every so often down at his own piles, thinking about the implications of Mr. Roberts’ evaluation for his own placements. When Mr. Roberts is done, Omar gives a final turn to his own rocks, raises his eyebrows, shakes his head slightly, and smiles as if sheepish about the verdict to come. Mr. Roberts approaches Omar and his partner and says, “Okay. Which ones you got here, buddy?” He reaches for the plastic container while asking “What pile is what?” Omar points to the pile closest to him and says something very, very softly. Mr. Roberts say “Igneous?” and Omar says, again very quietly, “Yeah.” “Okay,” asks Mr. Roberts. “What’s this pile? (Pointing an index finger at the center pile). Omar says nothing and looks toward a piece of paper in his notebook. Omar’s partner points to something on the paper and then Omar points to the center pile of rocks and then to a word on the paper. Omar’s partner looks toward the white board and Mr. Roberts says, “See . Look up.” He taps Omar on the shoulder, but Omar won’t look up. Mr. Roberts says, “Igneous . Sedimentary . Metamorphic.” Omar still doesn’t look up. He sits back slightly, nods his head, and says, “Okay.” There is ongoing negotiation of meaning as Mr. Roberts makes out which pile is which. When this is settled, he goes through each pile, picking up most of the rocks for re-categorization and dropping them back in the plastic container. Three rocks remain in the igneous pile, two in the sedimentary pile, and none in the metamorphic pile. He puts his hand over each of the rock piles and says, “Igneous . Sedimentary . Metamorphic” in turn. He drops the again-full container between Omar and his partner. Omar picks up the container and he and his partner put their heads together again to re-categorize. Mr. Roberts stands up and walks away.

35 mins: Having re-categorized their rocks, Omar and his partner sit quietly, talking about something in their notebooks. Omar seems a bit impatient now, bouncing up and down slightly in his chair. When Mr. Roberts finishes with the pair across the table, Omar looks up directly at him and says quietly, “Mr. Roberts.” Mr. Roberts does not appear to hear (or ignores) Omar. Omar raises his right hand and extends his index finger toward the ceiling, trying to get Mr. Robert’s attention.

Mr. Roberts walks past him, and in a brash tone, says, "Working my way around, guys." Omar watches as Mr. Roberts interacts with other pairs of students and occasionally makes changes in his piles depending on what he sees Mr. Roberts do. He switches between leaning forward and leaning backward, resting his arms on the table or letting them hang at his sides, as if feeling growingly antsy.

40 mins: Mr. Roberts finally approaches Omar. "Okay . Let's see . Omar . You guys ready again?" He positions himself between Omar and his partner and asks, "Okay . What's what?" Omar points to the piles and, referring to the handout in front of him, says "Igneous . Sedimentary." For "metamorphic," he turns to look at the board and Mr. Roberts assists him with the word. Mr. Roberts proceeds to evaluate each pile again. When he is done he straightens each pile and says, "Okay . So you have them right." Omar grins widely. "So . Igneous . Sedimentary . Metamorphic," Mr. Roberts says, point to each pile. He goes on to tell Omar and his partner how to fill in the handouts now that they have finished their pile placements. When he walks away, Omar and his partner look at each other and smile. They begin filling in numbers on the paper. Omar stops occasionally to rub his eyes as if he has grown tired from the activity. The bell rings and Mr. Roberts dismisses the class.

Life-Moment 4: The Job

Over the following summer, I paid a visit to Omar and his mother. I learned that he had liked his school year because he had made friends and had found his teachers helpful. He had no complaints about or suggestions for Mr. Roberts and regarded him as a good teacher. "*Nos ayuda mucho porque no nos presiona*/He helps us [Mexican newcomers] because he doesn't pressure us," he told me. When I asked him if he was planning on continuing school the following year, there was a pause and then an answer: "*Tal vez*. *Quizás me voy a trabjar*/Maybe. Maybe I'm going to work," he said. "Why?," I pressed. "*Para ayudar a mi mamá*/To help my mother," was his answer. Probing further, I wanted to know what kind of help she needed. "*Económica*/Economic," he replied.

The situation was that Omar's uncle had a found a position for him in his construction company. Since Omar did not know if they would need him next year, he was feeling he had to take advantage of the opportunity while it existed. He found school interesting and wanted to continue his studies *sin duda*/without a doubt, he assured me. At this point, his mother intercepted the conversation and explained that Omar felt badly about going to school. "*Se siente mal porque quiere apoyar a otra gente y no a él mismo. Y la realidad es que es poco lo que gana mi esposo y es mucho que pagamos . Los biles. sabes*/He feels badly because he wants to help other people and not just himself. And the reality is that my husband makes little and we pay a lot. The bills . you know." About when exactly he would make the decision to enroll in the fall or not, Omar had told his mother that she should decide; she had countered by saying that the decision was his.

“Could he work *and* go to school?,” I inquired. “*Sí*/Yes” he replied. “*Si tienes papeles*/If you have papers.” The kinds of jobs that would allow that, Omar explained, “*son para la gente de aquí*/are for the people from here.”

Omar did not enroll for his junior year at CHS. He now does drywall, which, as it turns out, is made of gypsum rock. The industry is notorious for hiring (undocumented) Mexican workers. And for abusing them through inadequate (or sometimes no) pay, benefits, and leave. Because it is a cash business, owners make out big with unclaimed social security, income taxes, and worker’s compensation. Omar, it seems, traded in one possibility for exploitative work in Captainville—work at the plant—for another.

Rewriting the Social Warrant

“Home Is Where the Hatred Is” (Lipsitz 2006a) is a fitting name for a piece that details the systematic oppression Mexican immigrants face, oppression only made possible, as all oppression is, by systemic societal not-caring. Hatred towards this segment of the U.S. population has become part of a “social warrant.” A social warrant, as Lipsitz (2006b) explains, is “a widely shared and generally understood definition of what is permitted and forbidden in society. It is rarely written down but draws it power from the diffuse authority of collective ideas and actions” (p. 454). The ideas and actions that have construed a social warrant of not caring against Mexican immigrant communities are, at their root, Lipsitz continues, those of accumulation and consumption. Capitalism requires a populace that hungers forever more goods and services. To (create and) meet the demand, it produces and provides goods and services at the cheapest rate possible. In striving to cut overhead and ensure the bargain that consumers (have been made to) expect, owners come to not care about the conditions of their workers. As labor conditions worsen, the characteristics of the work force change. The bottom-line becomes finding those who will work (better) for less and do so with complacency.

Enter Omar’s family and hundreds of others who make the trip from impoverished rural communities in Mexico to Captainville, not because they want to but because they must to survive. They fit the bill perfectly. Desperate by want of life’s basic needs, defenseless by lack of legal documentation, and different by virtue of race and language, Mexican immigrants are easy to not care about. They deserve their exploitation because, after all, life is better for them in the US than it would be in Mexico and most are “criminals” anyway. Industries, like meatpacking and drywall, take advantage of many Americans’ rationalizing justifications. Capitalism counts, in this way, on people caring more about their next ham sandwich and home addition than they do about the very people who make their (insatiable) lifestyles possible to begin with. Divesting science education of its possessive investment in this social warrant means caring about the students and communities it leaves behind.

An ethics-of-care approach with Mexican newcomer youth would mean attending to the dynamics of glocalization that arise out of the phenomenon of globalization. Here I use the word glocalizing in two senses: first, to refer to the way in which, with globalizing movements of human capital to new social and geographic spaces, local cultural meanings and practices (both of the diasporic and host communities) necessarily (and usually unconsciously) undergo re-signification and reform; second, to refer to the work of (consciously) attending to such changes in order to understand and meet the needs of the emergent context. The life moments I have shared from Omar's larger life story are useful in helping us think through what glocalizing science education, in Captainville or another demographically-transitioning setting, would mean for three aspects of student learning: artifact, agency, and activity. For each element, attending to the dynamics of glocalization reveals Omar's experience in the science classroom as haunted by ghosts of past, present, and future injustices in a way that, I argue, has practical relevance for his teaching and learning.

Artifact

With respect to artifact, Omar's stories make clear that the tools we ask students to interact with in science classrooms position them differently vis-à-vis the larger social structure. They are not neutral objects. In Omar's house story, we can read off his interaction with rocks the poverty from which he came. As a young child, he helped his mother build their home, using rocks from the local environment, because that's what was available (free) to them. In his crossing story, the reading of poverty continues (for that is what necessitated the crossing) but onto it is added the layer of "criminality." Rocks are what hide Omar, his brother, and his aunt from *la migra* so they evade (a second round) of detention. Finally, in his job story, the rock-derived material of drywall provides Omar with an opportunity for much-needed economic amelioration. With it we more clearly see how his crossing ("criminality") served as the bridge from poverty to opportunity. This is *the* story behind the majority of Mexican immigration to the US today. This particular configuration of poverty-crossing-opportunity rock stories is unique to Mexican immigrants (and to Central and South American immigrants that use Mexico as their corridor). Their White peers (even those living in poverty) will not share the experiences these rock stories connote. Therefore, in doing an activity like the mineral identification activity, Mexican immigrant students are positioned substantially differently than their peers with respect to the central artifact of instruction—rocks—and in a way in which the difference underscores deep social and economic disparities between, locally, the student populations and, globally, the national populations. The global forces of economic injustice, then, haunt this local classroom activity in ways that, as hauntings do, routinely go unseen.

Agency

Whereas hauntings may not be seen, they are often felt. Clues from Omar's rock stories help us imagine how he felt during the mineral identification activity in ways that, again, allow us to discern a shadow of the ghost in his classroom. In the house story, we hear about a very young Omar helping his mother build their new home. He carried large rocks to construct its walls and, when the structure was finished, took extra care to make it look as nice as possible by sweeping and making the beds. The Omar we hear about in this story is, beyond his years, strong and determined, conscientious, and caring. In the crossing story, we can see Omar's strength and determination again. Those qualities bore him through an experience of terror, wading, sometimes swimming, through the *canales/*canals of human remains that signified what his fate would be if he did not persevere. We see his cunning as he hides behind desert rocks from *la migra/*border patrol. We see his pain as his hands bleed from the scramble to escape. And, again, we see conscientiousness—his mother is waiting for him so he must make the trip—and caring. Imagine the kind of love that supports a child in the making of a trip like this.

Building one's home. Saving one's life. Both go straight to the core of what agency essentially is—taking action in the world for one's self-interest and, in this case, preservation. Even the job story is agentive in this sense. Omar, as we know, feels deep responsibility for his mother. She is ill and, ever since he was a child, he has wanted to help her. The dream of being a doctor to cure her has, with the crossing, given way to other means of assistance. He can at least work and ease her financial worries. He takes the drywall job for this explicit purpose, even though he would rather continue his studies. Although driven by concern for her, the decision is his. He owns it. It is, ultimately, in his self-interest and for his self-preservation that he chooses to put his mother's needs above his own.

Among Omar's agency-rich house, crossing, and job stories, is the lesson story. Now, my argument is not that Omar is non-agentive during this lesson. In fact, given the fact that he speaks little to none of the language of instruction and therefore can neither follow the basic science content (Mr. Roberts' explication of the igneous, sedimentary, metamorphic distinction) nor follow routine classroom procedural requests, Omar shows striking resourcefulness and perseverance in successfully completing the mineral identification activity. He does this by actively drawing on the supports that do exist in the classroom environment—his peers, Mr. Roberts, his notes, his textbook, the whiteboard drawings. Omar uses all of these to make his way through. He seems tired at the lesson's end and he should be after all the meaning negotiation he has done. So, yes, he shows remarkable agency here too. But it is a different kind of agency, borne, ultimately, as I argue, out of alienated activity.

Whereas Omar is certainly acting in his self-interest (he wants to get successfully through the lesson), we see how his life is not, as it was in the house and crossing stories, hanging in the balance. Instead of purpose, there is, instead, pretense. Omar plays the part of a student by (keenly) watching other students. He fakes his way to the end. If we take this as a metaphor for his experience in school, we can even more fully understand the temptation to let school fall away. Whereas drywall work is itself alienated labor, a sense of genuine purpose is derived from the activity when such activity feeds and clothes much-loved family members. As a Mexican immigrant, Omar's life, in the end, has no room for "playing" school. And, as he points out, for such play there is, at least for him, no payoff. Without legal documentation, his options for work are not improved by a high school degree. Surely some of his White peers experience alienation and, the poorer ones, economic necessity as well. But for Omar and the majority of Mexican immigrant students like him at Captainville High, the experience is not the exception but the rule. And White students have one thing that Omar does not and perhaps will never have—U.S. citizenship and its paths to opportunity (which they likely take for granted). It is in "feeling" his choice to stay or fall away, a choice I imagine plagued him more severely the more alienated and alienating he found school (and which, given economic constraints, was not much of a choice anyway) that Omar, again, greeted his ghosts.

Activity

Agency and activity go hand in hand. It is through activity processes that human beings experience their selves as agentive (what I have previously described as self-interested and -preserving). Agency may also be considered in terms of generating change (Stetsenko and Arievitch 2004). These two views are reconcilable. If one finds that one's current situation is not in one's best interest and, in fact, is self-destructive, one will seek to alter the situation through change. Through the cumulative effect of these change-based activities, humans, molded as they are by the world, in turn mold the world: "they are created by history but also create their own history" (p. 492). Read against this understanding, Omar's agency in the four life moments takes on deeper meaning. Building a home (for physical protection), and crossing the border and working in drywall (for economic protection) are all activities by which Omar can create change for himself and, through him, his family. Participating in a science lesson, for him, reaps far less substantial rewards. This is, in fact, the very reverse of the premise upon which recruitment efforts in science fields rely—that studying science opens up opportunities for socio-economic advancement. This can be true, of course, but only for students whose needs for food, clothing, and shelter are already met and who can participate freely in the economic system by virtue of a little nine-digit detail called a social security number. Omar's presence in the science classroom upsets this tidy logic. He reveals the gap that exists between the ideal of science for all and the reality of science for some. And he, as many others, votes with his feet. In mass, their individual efforts at meaningful and feasible self-change through low-skilled employment have impact on the collective: They are (re)creating a segmented labor force in which Mexican immigrants are at the bottom. In this way, the globalizing movement of human capital across national borders, spurred on as it is by the social and economic disparity deeply entrenched in hundreds of years of systematic and systemic not caring, has marched right into (and out of) Mr. Roberts' classroom.

Omar's activities, as a young child building a home of rocks in rural Mexico, as an adolescent hiding behind rocks on the Mexico-US border, as a high school student studying mineral classification in the US, and as an undocumented drywall worker in the US, are grounded in his material reality of economic injustice. These activities are neither just (underdetermined) elements of his background knowledge nor are they overdetermining elements of his destiny. They construe his habitus, the "socially constituted system of cognitive and motivating structures, and the socially structured situation in which [his] *interests* are defined" (Bourdieu 1977, p. 76, original emphasis). Without taking account of how not only his economic condition, but also his interest in changing it is immediate to his cognition and affect, we will not understand his science learning experience. That experience is part of the process of engaging in what Bourdieu referred to as a "practical evaluation of the likelihood of success of a given action in a given situation" (p. 77). Just as Bourdieu points out that someone who has no money for travel, has no need, that is, "no real and self-realizing need" to travel (p. 77), someone, who practically evaluating the likelihood of their science learning to ameliorate their economic condition, may find they have no real and self-realizing need for a science education; he may discontinue that learning in search of activity with a more favorable evaluation.

This is exactly what Omar did. His decision to leave school is the result of him acting in accordance with the principal of human development central to self as leading activity. In leaving school to work in construction Omar assessed he had a much higher chance of "*changing something in and about the world* (including in oneself as part of the world" (Stetsenko and Arievitch 2004, p. 494) than he did if he stayed in school. This assessment is a profound statement about the way that, in his life, his "needs, desires, and motives" (p. 486) reflected an environment of economic injustice. This statement is important because of its very practical relevance for understanding his science learning experience as activity through which Omar is continuing to do the work of world- and self-change. It is in this way that conceptual change as an approach to guiding teaching and learning, in its psychological or sociocultural derivations, is inherently limited; as long as the concept leads in science education, it will obscure the leading activity of the self. A promising pathway for the re-visioning of both approaches in science education and for the articulation of their points of reconciliation would be to take the necessarily transformative project of the self as the point of departure. What cascade of changes would result from this new starting point? Here's just one: science educators and researchers would come to heightened level of awareness about how, if Omar is to find in science activity the tools for change that he wants and needs, he must find supporting social structures where he can meaningfully and gainfully apply those tools.

Teaching Science as if Selves Were at Stake

"Ultimately, what it is that the person is positioned by his or her activities to change in the world and oneself as part of the world—what kind of an objective in the world she or he contributes to—is the pivotal question, the answer to which reveals the uniqueness and integrity of each individual, that is, her or his 'self'" (p. Stetsenko and Arievitch 2004, p. 495). What if we took the goal of science education to be that of giving students a tool by which they could discover their uniqueness and integrity, their potential and possibility? What if we divested ourselves of the whitewashed possessive investment in science? What if we let self-change, not conceptual change, drive our approach to curriculum and instruction? What if students who are now on the margins found representation and recognition through science education? How might this re-constitute science's center? Could we redistribute knowledge activity and authority in this way?

It is true that economic necessity is a pressing concern for many students from non-dominant cultural and linguistic communities. It is particularly so for Mexican immigrant students whose families may arrive in the US with nothing else but the clothes on their backs. They are not just poor; they are starting from scratch. Work in the low-skilled industries (meatpacking, drywall) that attract them holds a promise for a better life but, in return, it extracts a significant price—the alienation of the self from the laboring body and the work it performs. The laborer can have an expert understanding of the content and purpose of her work, yet view it depreciatively because of its wage value and effect on the material conditions of her life (Duarte 2006, p. 226). The trade-off made between subsistence, which wage labor provides, and the "fulfillment of the individual as someone representing the human species" (p. 236), which it erases, is, for him, unacceptable extortion. At the moment in which one sees that what should be only a means (subsistence) has become an end in itself one has been notified of a time for change. Responding to such notice is pro-adaptive because it is only human nature to resist under such circumstances of self-erasure. Can science classrooms, for Mexican immigrant and, indeed, all students, be sites of such a response?

I have witnessed Mexican immigrant students resisting and transforming science instruction, trying to throw off the impediments their glocation has placed on their true humanity. I urge science educators and researchers to *acercarse*/get closer to these communities of practice because it is from these students that we will learn about the already-existing alternative cultural forms that will lead us in a different direction, cultural forms wherein world- and self-change already is the leading activity. We need to learn from these students as if lives were in the balance (because they are). To do so will mean some throwing-off work of our own, namely of haunted constructs, such as conceptual change, which, continue to re-focus science's myopic gaze. Such construct(ion)s are obstruct(ion)s that occlude from view each learner's unique and integral nature because they enable selective attention to only certain aspects of her developmental processes. *Este yo. Y no el yo del otro.* This me. Not your me. But this me. Hear me? Here, me!

To get closer is harder. To get closer is to grapple with ghosts. To get closer means feeling your way nearer and nearer "*until you do feel what is at stake*" (Gordon 1997, p. 134, original emphasis). May the life-moment stories that I have shared here be touch*stones* that illuminate the "luminous" while seemingly invisible presence of the lingering past and hastening future. And may they also light the way for points of human connection. Rocks (and rock stories) can build a bridge. Many Mexican newcomers are in U.S. classrooms because the adults around them had to take action on which their lives depended. Science educators and researchers would do well to teach and study with similar rock-hard determination. What we do and the tools we use to do it *matter*.

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Chapter 18

Concept Development in Urban Classroom Spaces Dialectical Relationships, Power, and Identity

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Conceptual development in science has been studied for decades with learners of all ages and for a variety of science topics, ideas, and concepts. Increasingly, scholars have presented differing views regarding what it is important to be studying about conceptual development and conceptual change, how teaching practice is/should be influencing and be influenced by research in this domain, the extent to which cognition, social interactions, and affect/emotions (could) shape conceptual development and change, the extent to which language and other modes of communication influence, or possibly constitute, concept development/ change, and whether, and the degree to which (from zero to a high degree), a variety of theoretical frameworks can be used together and inform research in this domain.

Our work begins in practice, proceeds to research, and returns back to practice. This iterative process shapes our thinking and doing of both the teaching and the researching that we attempt to do. We practice and research in primary-grade classrooms in urban elementary schools with students of a variety of ethnic, racial, linguistic, ability, socioeconomic, and cultural backgrounds, African American children, Latino/as in bilingual classrooms, children who receive special education services, children growing up in challenging urban neighborhoods, children living in poverty. We collaborate with teachers to develop integrated science-literacy curricular and instructional units, and as they bring them in classrooms with young children, we study how children together with their peers and their teacher come to experience, learn, and engage in science and its literacy practices. Our team (of university-based and elementary-school-based teachers and researchers) therefore has a natural tendency to gravitate towards research questions and methodological approaches that address, capture, and explore the complexities of classroom teaching. In a classroom of, for example, 29 third-graders or 30 first-graders, we

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attempt to make sense of scientific concepts in the moment-to-moment classroom interactions that pile up from day to day over the whole school year they are together.

Furthermore, what we know from conceptual change research relates mostly to what individual learners know and think about concepts and how concepts change or not in their own minds. What we do not know much about is how these concepts come to be shaped or not shaped by others (adults, peers, teachers, friends, etc.) around them, as they interact with each other in various settings, including classrooms. We also know mostly about conceptual development of learners who are members of the middle class who attend non-struggling schools. What we do not know much about is how learners in impoverished areas of big cities in US schools, which are stigmatized by low performance and, thus, feel the pressure and heat to improve, think about ideas, build upon them, use their experiences in and out of the classroom to change ideas, concepts, understandings.

Researchers have acknowledged that conceptual change happens in, and it is influenced by, broader social contexts, but the social context has not been given primacy in studies; it has remained secondary, a by-the-way idea. As Smardon (2004) claims, social context has been treated as a theoretical appendage. We need to unpack how social context comes to shape and is shaped by concept development, not only in its static form at particular benchmarks of students' learning experiences, but also in its dynamic form, as the learning experiences unfold in the midst of others at particular places and in particular ways that are governed by particular expectations, assumptions, rules.

With this study we aim at contributing to this goal, by integrating theoretical constructs that help us think and talk about social context as a unit of analysis of similar importance to that of concept development, and by examining socio-contextual, conceptual development as it unfolds in a classroom with African American young, elementary-school children and their teacher at an urban public school in a low-income neighborhood of a large city. We examine concept development as it evolves with various classroom community participants who get involved, thereby going against an emphasis, prevalent so far in the literature, on how concept development (change) is owned by individuals independent of the process with which it came to be.

Jennifer's Third Grade Classroom: Spaces as Learnerhoods

Jennifer had been teaching for 7 years, and all in this school, a neighborhood school where 98% of the students receive free lunch. All the children in the school are Black, but Jennifer is White. There were 20 children in her classroom in the year of the study who had looped with her from second grade. During that year Jennifer was using with her children a curricular and instructional approach—Integrated Science-Literacy Enactments (ISLE)—that she had helped shape. She was part of a group of teachers and university-based educators and researchers who had developed two units (*Matter* and *Forest*) that are consistent with inquiry-based, argumentation-rich teaching and learning, and aim at fostering open-ended conversations in whole-class and small-group settings that celebrate explanations and reasoning rather than just the correct answer. She encouraged her children to negotiate ideas, thereby privileging the sharing of power and authority between them and her, so that all classroom participants' agendas could be considered important. Knowledge in her classroom was tentative, open to revision and transformation—knowledge that emerged from the interaction of voices through collaborative transactions.

Although Jennifer was the teacher in that classroom, Justine, the second author of this chapter was also there whenever the ISLE units were taught (a total of 63 approximately 1-h lessons throughout the year). Justine practically lived in Jennifer's classroom for a year, taking field notes, and interacting with the children, as an ethnographer of their lives during the ISLE units. Her observation of participation in Jennifer's classroom and her extensive conversations with Jennifer throughout the year helped appreciate and articulate the dynamic nature of the construct of space and how it affects concept development.

Jennifer and her children engaged with science ideas in classroom *spaces* that they co-constructed together, spaces that they created with each other and attempted to share with each other. These spaces were intersections of symbolic and physical dimensions, where issues of power, hegemony, agency, structure, control, and knowledge defined boundaries that had varying degrees of flexibility and permeability. Spaces were constructed, they did not simply exist; they were not containers to be filled with contents. They were the milieu in which relationships, meanings, and identities were lived, perceived, and conceived or imagined. It was within spaces that dialectical relationships among knowledge and understanding, interactions and transactions, emotions and moods were performed and constructed.

Children, as members of Jennifer's classroom community, were sometimes inside spaces, and at other times outside spaces. At times, they penetrated spaces that had been created by others; other times, they were allowed entrance; or on other occasions, they left the spaces at particular moments only to be a part of them later. Spaces were stretched and expanded in various dimensions and they also shrank as competing spaces took over. These classroom spaces that were the hubs of interactions among the classroom participants were like *learnerhoods*, neighborhoods of learners who influenced each other in various ways as they learned to live together in the classroom, sharing resources, at times competing for resources, engaging with ideas, concepts, practices with the goal of learning to be better thinkers, doers, helpers, listeners. Learnerhoods, as a term, encourages us to be considering the whole person as we think about and explore learning. Learning science is about learner and scientist identities, about racial and gender identities, about emotions, about interactions with others, about engagement with ideas and reasoning, about cultural norms of the practice of science, about people coming together to practice their craft, negotiate their responsibilities, use various tools, and aim towards certain goals.

However, we cannot fully understand Jennifer's class if we view it as one learnerhood, but rather if we study the ecology of learnerhoods, the ecosystem of interacting learnerhoods, that came to be defined as interacting learners co-constructed spaces and inhabited them at the same time. Science classrooms are places where learners with various ways of acting, thinking, doing, and feeling come together, interacting with each other and various materials and texts, to make sense of scientific phenomena, ideas, concepts, and processes. Engagement with ideas and concept development happens within ecologies of learnerhoods, which are governed by certain rules and characteristics that regulate participation and in which learning unfolds and evolves. And they happen in the company of others—peers with their own experiences and ways of making sense and a teacher with her/his understanding of science and pedagogy.

As we further conceptualized spaces and learnerhoods in Jennifer's class, we came to appreciate that some classroom spaces were accessible for some children and other spaces were forbidden territories or undesirable destinations for others. Some children were socially positioned as marginal, outsiders to the learnerhoods that their peers, with or without their teacher, had created, and other children flourished in their learnerhoods. The texture of spaces, their dynamics, is critical in understanding the knowledge production that goes on in these learnerhoods. An important dimension of the dialectical relationships that shaped these learnerhoods was the arguing, explaining, challenging, wondering, debating, echoing, transforming of ideas that took place. In this sense, the learnerhoods were spaces like the ancient Greeks' agoras, the public spaces where citizens argued out their ideas (Massey 1994). It was this argumentation that was a distinguishing characteristic of agoras. And it was the exchanging, reasoning, connecting, analyzing, and all the critical habits of mind in the science practice that constituted the learnerhoods where concept development happened in Jennifer's science class.

In the rest of the chapter, we present how these young African American children's sciencing and concept development shaped and were shaped by classroom spaces, learnerhoods that Jennifer and the children created together, and the social capital of these spaces. We focus on a classroom of Black children who live in a low-income under-resourced community on the west side of a big city, because we believe that the U.S. science education scholarship has been severely lopsided—most of what we know about how children learn, think, talk, make sense of, and develop scientific knowledge, concepts, ideas come from middle-class children who attend schools either predominately White or racially and ethno-linguistically mixed. We do not put our research efforts on Black, low-income children because we try to uncover specific links between on one hand their experiences, ways of life, resources, and on the other, their concept development in the science class. We take the position that their out-of-classroom life experiences have shaped their identities, their ways of thinking of themselves, the ways others are thinking of them, the ways they act, think, talk, relate, feel—a relationship that we believe exists for any group of people. Acknowledging such relationship, though, implies that as a research community we need to expand our efforts and enrich our understandings by not limiting ourselves to studying particular groups with certain ways of life and certain capital and not others. If we continue this practice, we will miss out on the opportunities to know what is possible with underserved and underprivileged groups, what forms learning takes, what issues emerge as students engage with each other, with their teacher, with ideas, and with artifacts. As a field, we need studies that help us capture and unpack these children's ways of engaging in and learning science in school, as well as studies that help us understand how school learning and engagement relates to children's life experiences, cultural affiliation, and life outside the classroom.

Competing Spaces: Fantasy or Science?

Jennifer and her children were engaged in the *Matter* unit, exploring the three states of matter (solids, liquids, gases)—their characteristics and examples of everyday substances in each of these states, changes of states, such as freezing, melting, evaporation, and condensation, and the water cycle. Several instructional tools were used to support children's engagement with these ideas. The unit includes read-alouds of seven children's literature information books that were read in the following order: *What's the Weather Today?* (Fowler 1991), *What Do You See in a Cloud?* (Fowler 1996), *When a Storm Comes Up* (Fowler 1995), *It Could Still Be Water* (Fowler 1992), *What Is the World Made Of? All about Solids, Liquids, and Gases* (Zoehfeld 1998), *Air Is All Around You* (Branley 1986), and *Down Comes the Rain* (Branley 1983). In between read-alouds, children engaged in various hands-on explorations, including observing and measuring water evaporation from a cylinder (evaporation experiment); sorting objects into solids, liquids, and gases (sorting activity); stuffing a napkin or piece of paper towel at the bottom of a cup and submerging the cup upside down, straight in one case and slanted in another, in a bowl with colored water ("existence" of air activity); melting an ice cube in a baggie, and in cups with warm and cold water (ice cube activities); wetting three paper towels and leaving one hanging straight, one laying flat on the table, and one laying on a table crumpled up in a ball (drying up of paper towel activity); a water bottle taken out of a freezer that "sweats" (water bottle condensation activity); droplets being formed on a cold cookie sheet that was placed above a pot of boiling water (steam and cold cookie sheet activity); and letting a drop of food coloring fall in cups of clear water at different temperatures (colored-water activities). In addition, children wrote and drew in their own science journals throughout the unit; wrote and drew the day's weather over several weeks on a weather chart; participated in a drama activity in which they acted out molecular behavior of solids, liquids, and gases; engaged in small-group literature circles (using additional information books); created a class mural of their evolving ideas about matter; kept track of their ideas on an on-going class semantic map; conducted a home project, from which findings were shared with the class; and at the end of the unit, created their own illustrated information book on a topic of their choice. See Figure 18.1 for a unit timeline.

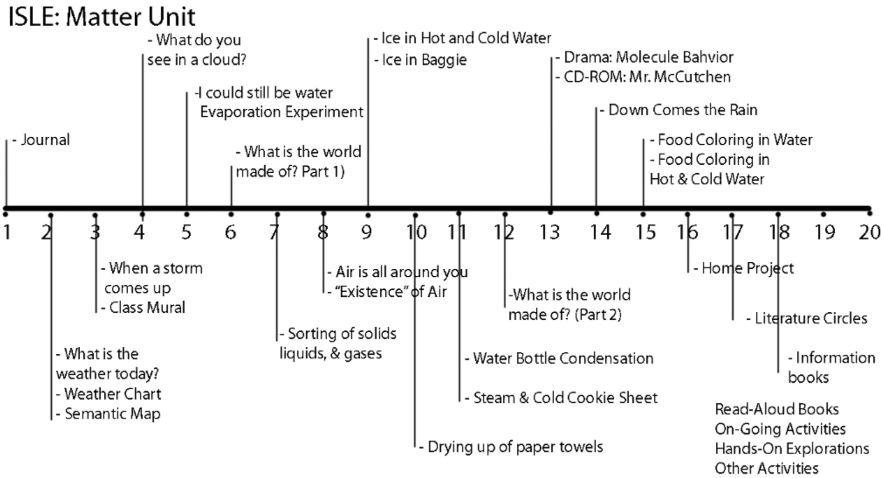

Figure 18.1. *Matter* unit timeline with 20 lessons that took 29 days to be enacted in Jennifer's classroom.

Lesson 3 was mostly devoted to the read-aloud of the book *When A Storm Comes Up*. While Jennifer was reading the book, Corey (all children's names are pseudonyms) wanted to share a question he had.

Excerpt 1

98	Ms. Hankes:	Let's finish our book. A LITTLE HEAVIER RAIN IS A SHOWER. AND IF IT'S REALLY POURING, THAT'S #A RAINSTORM.#
99	Cs:	#A RAINSTORM.#
100	Ms. Hankes:	Yes, Corey.
101	Corey:	(***)
102	Ms. Hankes:	Can't hear you, honey. You got to talk real loud.
103	Corey:	When it rain don't some people be thinking that it gonna make them taller and taller and taller?
104	Ms. Hankes:	And why do some people think that rain's going to make them taller?
105	Corey:	That's what makes grass grow.
106	Ms. Hankes:	Oh, so you're saying the // the grass becomes taller because the grass is growing? Are you saying people think they will become taller?
107	Corey:	Yeah, people be thinking they gonna get taller with water.
108	Cs:	[Giggle.]
109	Ms. Hankes:	Rain doesn't make people become taller unless it is a fantasy story that we're reading.
110	Mary:	It's a fantasy story.
111	Ms. Hankes:	Gianna.
112	Gianna:	We could add "shower" to our // our word wall.
113	Ms. Hankes:	We could // we could add this word "shower" and also "rainstorm," couldn't we? [Writes those two words down on a sticky note.] Good thinking.
114	Tamara:	We could write that in our ~ thing.
115	Ms. Hankes:	And we could write it in our journal, but for right now, today, we're gonna use just our word wall. Yes, Mary, I see you patiently raising your hand now.
116	Mary:	Uh, I think that when he [Corey] trying to say // and he // he talking bout them people think they // it's a book and he got that in there and when they

		thunderstorms, they think they gonna get taller and taller and taller [raises her [left-hand] forefinger pointing vertically upward, then points the right-hand forefinger horizontally toward the tip of her left forefinger and raises it upward as she says "taller"].
117	Ms. Hankes:	Yeah and we talked about that is kind of more of a fantasy story. We are talking about non-fiction now. Things that are true. Uh, let's go to Yvonne. [Motions for Chantrelle put her hand down and whispers to Chantrelle] save it.
118	Yvonne:	My mama used the expression saying the rain can make you grow taller, but she saying you get smarter.
119	Ms. Hankes:	You get smarter?
120	Yvonne:	[Nods affirmatively].
121	Ms. Hankes:	Again, that is like a // more like a wise tale. Okay? Let's stick to // let's stick to facts about science right now. Okay?

In this excerpt, Corey initiates an idea that is obviously unscientific and several of his classmates know it. A couple of them try to help explain where Corey's idea originates from, perhaps to make him seem less nonsensical, and the result is a friendlier space for Corey. We do not know if Corey thought this idea was real or not, but we do know that he asked the question in the midst of a science class. Students bring to science learning ideas from fictional literature, expressions they have heard, or simply what was told to them by others. The teacher does not always know if students believe these ideas or not, but the way teachers engage with such questions can both help them understand the conceptions that students bring to science learning and help students transform non-scientific everyday-life ideas into accepted scientific understandings.

In this excerpt, Jennifer attempts to create a space in which students can hear and discuss real science ideas. She establishes a boundary that excludes ideas she considers fantasy and only takes up ideas that she considers real science. We do not know if Corey cannot not tell the difference between real science and fantasy when he asks if rain will make people taller (unit 103), but we have two pieces of evidence that suggest that his question is genuine. He does not laugh along with his classmates, and he offers reasoning when Jennifer asks him why (units 105 & 107). Perhaps Jennifer assumes that her students will just know that some things are fantasy and others are true. However, a teacher's attempts to introduce scientific ideas may be met with questions or ideas that although they seem out of touch with science, they may in fact be imbued with sense-making that children, as newcomers and novices to the ways scientists think and do their work, have to be doing. Furthermore, let us consider for a moment Jennifer's goal to differentiate fantasy from science in the context of the larger ISLE project of which she was a part. In ISLE, there is an emphasis on the distinction between the two, especially as it relates to children's books used in the units. We have had repeated conversations in our team about the significance of using informational text as part of the science units that supports children's scientific thinking and reasoning, and that models for them scientific language. For Jennifer, the science space she is trying to develop in Excerpt 1 is crucial and based on her understanding of what she is trying to accomplish with her students.

Jennifer's students express power and agency in this space as well, and, in doing so, create multiple and competing spaces. In some ways, Corey is an insider to the space that he and Jennifer are trying to construct around his question. Jennifer privileges his question, tries to understand it (units 104 & 106), and finds her reason for his idea, namely, that it is fantasy (unit 109). Mary and Yvonne, however, do not allow Corey's idea to be lost and, in following up on it, affirm Corey's insider status. Mary attempts to explain where Corey's idea may have originated from (unit 116) and Yvonne cites an expression that her mother uses that parallels Corey's idea (unit 118). In making these comments, both girls thwart Jennifer's attempt to affix a real science boundary to the space and press on allowing a different voice to be validated. At the same time, Corey is positioned as an outsider to the science space that Jennifer and other children are trying to create. Because his idea is not real science, some students giggle when he brings it up (unit 108). Gianna changes the subject altogether when she mentions "our word wall" (unit 112). This draws attention away from Corey's question and aligns Gianna with the teacher's ways of thinking about learning and about science. However, we also see students who are willing to challenge Jennifer's notion of what is permitted in classroom spaces and to define spaces for themselves as well as for a classmate. In this way, they challenge Jennifer's notion of what can exist within the space.

The kids who enter the space where Corey is at that moment do so for reasons we cannot ever be sure about and for which we can only speculate. We do not know whether they do it to support Corey as a friend, a peer, one of their own, whether his idea seemed plausible and sensible to them, or whether it evoked contexts that they have experienced, stories they have read or expressions they have heard. Maybe one of these reasons is the first, the motivation to get to that space, but other(s) may eventually emerge. At the same time, some students distance themselves from Corey's idea and from him by giggling or changing the direction of the conversation. They are creating a competing space affiliating themselves closely with the teacher's response and canonical science. The interplay between these two spaces that unfold at particular moments nuances the children's engagement with, and understanding of, the concept of growth—what it means, what it is, how it is manifested—and what different living beings need to grow. In the various spaces that are constructed and inhabited, children's identities are also enacted and constructed.

Who children see themselves being, who others see them being, and their actions, or, in other words, the children's identities shape and are shaped by membership in these classroom spaces. Their identities also shape and are shaped by participation, engagement, membership, and activity within various communities, practices, groups, institutions, and affiliations that they a part of. Identity is not something people are born with or have. "Identities are representations of kinds of people engaged in kinds of social practices over periods of time … identities … [are] the *accumulations* of the daily stories and positionings that result from our daily interactions with others, and change as we gain new experiences" (Tucker-Raymond et al., p. 561, original emphasis). Thus, identities that children enact and develop in classrooms very much speak of the spaces that they have been a part of in and out of the classroom, and influence the spaces wherein they will be in the future.

Lawrence's Learnerhood: Who Is Allowed in?

During the steam and cold cookie sheet activity in Lesson 11, Lawrence asked Jennifer a question about how heat can make bubbles while he was writing in his journal and Jennifer was nearby. Jennifer told Lawrence that the answer involved molecules and that they would be discussing molecules in later lessons so he should ask his question again during those lessons. Lawrence returned to his question several times, but Jennifer continued to postpone answering it. In Lesson 13, Jennifer and her students listened to, and discussed, information on a CD-ROM entitled *States of Matter* that includes ideas about how molecules look like in solids, liquids, and gases, and what happens at the molecular level during state of matter changes. Lawrence asked again for permission to ask his questions. While the whole class was assembled, Jennifer let him ask his questions and, thus, she made a critical move towards the construction of a space where Lawrence may be able to find answers. His first question was "How does heat make bubbles?" The class attended to this question, and Jennifer and her students engaged in a lively discussion about how water molecules move faster when they are heated. Tasha thought molecules, "kinda lose control," and then "pop off" the top of the water as they turned into water vapor. Then Jennifer asked Lawrence to share his second question that was offered in the form of a statement—"I think water is a liquid and a gas because that makes water move." Jennifer responded to this idea by describing how water had different names in different states, but that it was still water—which did not clearly address Lawrence's point. The discussion continued for a few more minutes and then the class participated in the drama activity in which they acted out molecules of water in different states.

Early in Lesson 14, as Jennifer was reading the book *Down Comes the Rain*, Lawrence came back to his questions.

Excerpt 2

36	Ms. Hankes:	They are thinking the same. You saw the little thinking bubbles, didn't you [pointing to the dialogue bubbles in the picture]? WATER VAPOR IS MADE WHEN WATER EVAPORATES. {IT} MEANS THE WATER CHANGES FROM A LIQUID TO A GAS. [Pointing to the dialogue bubbles] IN THE MORNING, PUT A TEASPOON OF WATER IN A SAUCER…[moves book back and forth so all students can see pictures] BY THAT NIGHT, IT MAY HAVE EVAPORATED INTO THE AIR! Lawrence.
37	Lawrence:	Ain't that like my question?
38	Ms. Hankes:	Hmm?
39	Lawrence:	That just like my question|
40	Ms. Hankes:	Kind of like your question about which one?
41	Lawrence:	Um, that there // um // a um that liquid is a um gas or something.

42	Ms. Hankes:	And do we know um // and is liquid and a gas the same thing?
43	Lawrence:	[Looks away from Jennifer.]
44	Ms. Hankes:	How can a liquid turn into a gas, Lawrence? By doing what?
45	Lawrence:	Drying up.
46	Ms. Hankes:	By drying up. And when // that drying up // what's the scientific word we learned for that?
47	Lawrence:	[Does not respond.]
48	Ms. Hankes:	What is the scientific word that starts|
49	Lawrence:	Mmm, molecule?
50	Ms. Hankes:	Okay, so what makes the molecules turn from a liquid to a gas?
51	Lawrence:	Gas // [shakes his head] I mean um steam?
52	Ms. Hankes:	Okay, well eventually // you're right // it can eventually become steam. But what is happening to the water. Help him out Gianna.
53	Gianna:	#Water vapor#
54	Lawrence:	#Water vapor#
55	Ms. Hankes:	It turns into water vapor when it evaporates. Okay, I see you [talking to students waving their arms in the back]. You do not have to wave at me for me to call on you, okay? Joe.
56	Joe:	<What?>
57	Ms. Hankes:	You had your hand raised.
58	Joe:	I was trying to say the word.
59	Ms. Hankes:	You were trying to say the word "evaporate," okay. Now here in these little bubbles here [pointing to the dialogue bubbles] I am going to read what they're saying // these conversation bubbles. WHEN WET CLOTHES HANG ON THE CLOTHES LINE, THE WATER IN THEM EVAPORATES. THE HEAT FROM THE SUN CHANGES THE WATER DROPS AND DROPLETS INTO WATER VAPOR.

Lawrence is a person who asks a lot of questions. In fact, he describes his identity as a scientist by highlighting his role as a questioner in the science class. Jennifer is aware of the importance of questions for Lawrence and often privileges them within classroom spaces. In this instance (Excerpt 2), Jennifer engages with Lawrence's question that connects the book text to his previous question. Lawrence somehow demands the space from his teacher and class, as he reminds them that he had a question before. From his words, we do not know whether he sees this text as an answer to his question, or whether this is still a question in his mind that he wants addressed.

Lawrence is unsure as he restates his idea and Jennifer uses his words to transform his idea into accepted scientific understandings. When Jennifer asks Lawrence another question, he turns his head away and does not respond (unit 44). Perhaps he hopes that Jennifer will turn her attention to someone else, but she persists and asks Lawrence how a liquid can turn into a gas, thereby transforming his question into a scientific idea (unit 45). Lawrence looks back toward Jennifer and answers her question. Again Jennifer uses his phrase, "drying up" (unit 47), to transform his ideas into a scientific understanding. Then Jennifer asks him a question to which he does not respond (units 47 & 48). It seems as though Lawrence is resisting the space that Jennifer is trying to construct for him and with him for the rest of the class. Again she persists, repeating her question and giving him a clue, "the scientific word that starts with" (unit 49). However, Lawrence interrupts her and guesses "molecule," not evaporation (unit 50). His answer may make him sound clueless, but we have to think more deeply about the situation. Jennifer asked him what the "scientific word" was, and because Lawrence interrupted her and she did not have a chance to share the first letter of that word with the class, he quickly guessed "molecule." In Lesson 11, Jennifer had told Lawrence that his question then involved molecules and that is why he had to wait to ask it again after a couple of lessons. Lawrence may have kept in his mind Jennifer's answer. After all, "molecule" is definitely a "scientific word."

Jennifer knows that Lawrence is interested in science and she uses his answer to draw him toward the idea of evaporation. In this way, we see Jennifer privileging Lawrence's learnerhood, using her interaction with him to discuss evaporation with the whole class. When Lawrence responds with the unexpected "molecule," she says, "Okay, so what makes the molecules turn from a liquid to a gas?" (unit 53). When he responds "steam" (unit 52), she follows that "eventually it can become stream, but what is happening to the water?" (unit 53). She asks Gianna to help Lawrence out. Gianna brings up the idea of water vapor (unit 54), which Jennifer transforms into a more articulate statement saying, "It turns into water vapor when it evaporates" (unit 56).

Meanwhile, other students in the class are enthusiastically raising their hands to enter the conversation. Jennifer chooses to ignore them and to privilege Lawrence's ideas and questions. There is frustration in her voice when she reprimands the students for waving their arms too enthusiastically (unit 56). She tries to protect the boundaries of the space she has been developing with Lawrence, but there have been several bids from other children to enter this space and possibly alter it, pushing Lawrence out of it. When she finally calls on Joe, we learn that it is the word "evaporation" that he wanted to share (unit 59), but has put his hand down because Jennifer had said the word responding to her own question (unit 56). This frustration signals the tension that teachers and students often experience in classroom spaces. Jennifer chooses to privilege Lawrence in order to draw him into the conversation even though other, more knowledgeable students are bidding to enter. In their moment-to-moment construction of spaces, teachers make such decisions to privilege some students and exclude others. In this case, Jennifer chose to privilege Lawrence because she knew him to be very interested in science, but also a student who struggled with scientific understandings. By crafting a particular learnerhood for him, she could both lead him to deeper understanding as well as allow him to perform himself as a person who knows science. Perhaps her frustration was not only due to having to silence many other eager students keeping them out of Lawrence's learnerhood, but also due to considering that, despite her efforts, in the end, Lawrence might still be unsure of evaporation.

How Can People, Ideas, and Rules Shape Fuzzy Boundaries?

As the read-aloud of the book *Down Comes the Rain* continued in Lesson 14, a different student, Yvonne, wondered about the "little cloud" that forms when people exhale on a cold day. Yvonne wanted to understand if those “little clouds” rise up into the sky to become larger clouds. One impetus for this question may have been the picture in the read-aloud book which showed four children, one on a horse, and a dog outside on a winter day with “little clouds” next to their mouths, and the text of the book page which read, “On a cold day, the water vapor changes to droplets and makes little clouds you can see” (Branley 1983, p. 13). Another impetus may have been Yvonne’s experience of this common phenomenon that she was attempting to connect with the book text.

Excerpt 3

121	Yvonne:	[Places her right hand in front of her mouth] do the clouds then come out of your mouth [raises her right hand to the side of her head with palm up] and then go up to the sky and get on clouds [moves her hand back in front of her mouth]?
122	Ms. Hankes:	Does the what? [Jennifer takes Yvonne’s hand away from her mouth so she can hear her better].
123	Yvonne:	The cloud that comes out of your mouth, do it go up to the sky and make|
124	Ms. Hankes:	[m…] So you are saying when you breathe out what ends up happening to that little cloud? Does it go up to the sky or does it stay there? What do you guys think about that?
125	Tasha:	It go up?
126	Ms. Hankes:	Think about when you go outside and you // on a cold day and you go [exhales loudly]. What happens|
127	C1:	<Molecules comes out.>
128	Ms. Hankes:	It doesn’t stay there forever it doesn’t follow you around.
129	Lawrence:	It moves|
130	Ms. Hankes:	See, your [pointing to Lawrence] hand is not up // your hand’s up but I did not call on you. What happens to that little cloud? Chantrelle.
131	Chantrelle:	It // it go [long pause, looking like she’s thinking, and doesn’t finish her sentence].
132	Ms. Hankes:	Do you want some think time?
133	Chantrelle:	[Nods head affirmatively].
134	Ms. Hankes:	Joe. Is your hand up?
135	Joe:	[Nods negatively].
136	Ms. Hankes:	I want you [Joe] to participate in our conversation. Come on // come closer.
137	Joe:	[Moves closer].
138	Ms. Hankes:	Tamara.
139	Tamara:	It moves into molecules.
140	Ms. Hankes:	Okay, so we know that it’s made up of molecules and so the molecules are moving. So let’s think about what happens to it. Does it follow you around? Does it stay like this [holds both hands in front of her body with fingers spread out, palms and fingers facing each other] and follow you around?
141	C2:	Ooh, it go to|
142	C3:	No.
143	Ms. Hankes:	Tasha.
144	Tasha:	It um go in the sky.
145	Ms. Hankes:	Do // do you see it moving up? [Raises right hand up to signify the cloud going up in the air].
146	Yvonne:	No! [Shakes head negatively].
147	Tasha:	But you know with the steam what you made with that thing it went all the way up there [points to ceiling] when you was doing that experiment.
148	Ms. Hankes:	So the steam went all the way up. So you are making a connection with something that you saw in the classroom with a cloud that you made. I want you to try that. What I want you guys to do in the next cold morning.

		Hopefully, we will have a cold morning in a couple of days, I want you to go out and I want you to breathe in the air and then I want you to see your little cloud that you formed and then I want you to stand and watch it. Watch what happens to it. Okay?
149	Terrence:	It disappears very quick.
150	Ms. Hankes:	[Puts her finger up to her lips to quiet the student.] We'll come back to that. Guys, we have a lot more of this book to read. Okay? Good conversations, though. YOU CAN MAKE WATER VAPOR CHANGE {^BACK} TO WATER. PUT A LOT OF ICE {IN} A GLASS OF WATER. AS THE GLASS GETS COLDER, THE OUTSIDE OF THE GLASS GETS #WET.#

In this excerpt, Jennifer and the children engage with Yvonne's question. Jennifer brings the question to the whole group by asking what the students think. Jennifer does not acknowledge the picture in the book, but she assumes that every student has had this experience. Several students call out responses or comments, but Jennifer ignores them. Perhaps she is frustrated or is simply interested in maintaining a particular kind of participant structure to the group, namely, for students to raise their hands before they answer. Tasha offers that it goes up to the sky (unit 125). Jennifer does not respond to Tasha and suggests that students think about their experiences and recall what they might have seen happen. An unidentified student calls out, "Molecules comes out" (unit 128), but Jennifer does not take up that comment either. Lawrence suggests that the "little clouds" move, and Jennifer reprimands him for not waiting to be called upon. It is not clear why Jennifer is frustrated at this particular moment, but it may have originated when Leigh, who was seated in the center of the group, left the classroom. When Leigh re-entered during the discussion, she attempted to regain her seat in the center of the group prompting Jennifer to ask her to sit on the edge, which she did.

Jennifer then asks Chantrelle for her ideas, but Chantrelle cannot think of what to say or perhaps she changes her mind about offering an idea. Chantrelle is very quiet and often over-run by her louder, bolder classmates. Jennifer usually accommodates Chantrelle's quietness by waiting for her. Eventually, Jennifer gives Chantrelle some think time. Joe usually sits in the back of the group and speaks infrequently. Jennifer invites him into the space both by participating and physically moving closer to the group. Several students wait with their hands raised to answer Jennifer's question, but no one continues to call out answers. Tamara suggests that a little cloud "moves into molecules" (unit 139). We are not sure what Tamara means by this, however Jennifer gleans from Tamara's comment helpful information to move the conversation forward. "Okay, so we know that it's [cloud] made of molecules and so molecules are moving. So let's think about what happens to it. Does it follow you around? Does it stay like this and follow you around?" (unit 140). In this way, Jennifer lends credibility to Tamara's idea, as well as gives direction to the conversation.

Two students enthusiastically respond to Jennifer's questions. Tasha offers that "it um go in the sky" (unit 144). Jennifer follows up her question with another, "Do you see it moving up?" (unit 145). Yvonne asserts that you cannot see the cloud moving up into the sky (unit 146). Tasha, however, does not drop her argument that the cloud must rise into the air. She calls out a follow-up that compares the "little cloud" to steam rising, which she experienced during a hands-on exploration the class had done in a previous lesson (unit 147). In that hands-on exploration, students observed boiling water forming steam which rose up into the air as it escaped from a small, hot pot. At this moment, Jennifer does not reprimand Tasha for calling out a response, rather she affirms the connection that Tasha makes between Yvonne's question and the hands-on exploration, and uses it as an opportunity to challenge students to observe what happens on the next cold day. Terrence then calls out a prediction that the cloud will quickly disappear (unit 149), but Jennifer silences him with her finger (unit 150) to return to the read-aloud and suggests that they will return to this same topic on another day. "Good conversations, though," she says.

In this excerpt, we see Jennifer balancing the needs of individuals, Chantrelle and Leigh, with those of the group. We see Jennifer patiently waiting for Chantrelle's reply and the tension Leigh's interruption creates for Jennifer as well as its effect on her willingness to accept subsequently called-out responses. Once the issue with Leigh is resolved, however, Jennifer is able to return to the topic at hand. Jennifer occasionally tightens the boundaries around the spaces she creates with the children. Sometimes she accepts called-out responses, and other times she does not. Her students seem to adjust to her loosening and tightening of the boundaries. Here the children cease to call out responses after she reprimands them, but then continue to do so later.

Furthermore, it seems like this discussion involves several ideas that do not get differentiated as the creation of multiple spaces is attempted. As Yvonne, like Lawrence in Excerpt 2, asked a question, Jennifer tried to create a space that fulfilled various goals—one being answering Yvonne's question. Jennifer was creating with Yvonne and the rest of the class a learnerhood in a dialogic way, where the children had a voice, not only the teacher. She created and used this learnerhood to clarify points, give the class an opportunity to hone in particular ideas, make connections, and develop extensions. These are quite diverse goals that may not all be compatible at the same time, and may lead to fuzzier boundaries of spaces in terms of both ideas and people that define them.

Yvonne's question (unit 121) contained two ideas about the "mouth clouds"—they go up to the sky and get on clouds. It is not clear what part(s) Yvonne's question was about. Was she asking whether they do both? Was she telling that they go up in the sky, but was asking whether they join or "make" clouds? Jennifer understood and transformed it for the rest of the class as a question as to whether clouds go up and stay up there, and in the conversation that took place afterwards, other children eventually commented about mouth clouds going up in the sky (Tasha) and moving (Lawrence). However, Yvonne eventually said that these clouds are not moving up, to which Tasha objected bringing up a connection with an exploration they had watched before where boiling water was producing steam that was rising up. As we study Yvonne's answer more carefully, we do not know whether she meant that clouds do not move up, or that we cannot see the clouds moving up. And the distinction is important as she was responding to a question by Jennifer that was about seeing (unit 145). Distinctions between seeing, existing but not seeing, moving, moving all the way up in the sky, and so forth, were missed in the space that Jennifer and the children were creating. In fact, Terrence's contribution (unit 149), which was put aside for the sake of continuing with the book, is relevant to such distinctions. And these distinctions involved important concepts, ideas, discussed and developed in the *Matter* unit that invited children to think about different states of matter and the visibility property of the various states.

Clashing Authorities: How Can Spaces Be Shaped by Texts?

As soon as Jennifer returned to reading from the *Down Comes the Rain* book as indicated at the end of Excerpt 3, Lawrence interjected asking a question that addressed the main idea of condensation, one of the changes of states of matter explored in the *Matter* unit. Condensation and evaporation are more difficult changes for young children to grasp than freezing and melting, partly because of the invisibility feature of water vapor. Jennifer's students had previously explored condensation in an exploration, water bottle condensation, a set-up very similar to the one portrayed on the page of the book Jennifer was reading to the class. In the water bottle condensation activity, each group of children had a sealed, frozen water bottle. They observed what happened over the class period and tried to explain why water began to appear on the outside of the bottle. During the conversation after the activity, Jennifer and her students agreed that the water bottle was sealed so that the water on the outside was not escaping from the inside, that the water was coming from the water vapor around the bottle, and that the change was caused by the cold temperature of the bottle. The picture in the read-aloud book showed a glass filled with water and ice cubes and covered with condensation.

Excerpt 4

156	Lawrence:	Um, how does the um the ice make the water drip out of um outside the cup?
157	Ms. Hankes:	What makes the ice cause [pointing to the picture of a glass filled with ice and condensation on the outside of it] the water vapor to turn into water? If you have another question, put your hand down because we are looking at Lawrence's question. What about the ice makes the water vapor [pointing again and again to picture of a glass with ice cubes in it and condensation on the outside] turn into liquid water? Think about what we talked about with those arrows. The blue arrows and the red arrows. Changes of state of matter. Alice.
158	Alice:	I think ~ evaporate.
159	Ms. Hankes:	[Frowning.] So the water is evaporating when you see that?
160	Alice:	No! It's // it's melting.
161	Ms. Hankes:	But the ice is not pouring out of the container [pointing to the glass again]. That ice is still in there.
162	Alice:	The water vapor is taking it out of the glass.
163	Ms. Hankes:	Okay, but the water vapor is not coming down the side here [pointing to the side of the glass filled with ice] this is water vapor around the glass [pointing to the red arrows signifying water vapor] that is then turning to a

liquid and forming on the outside. What about the ice is making it do that? [pointing again and again to the ice in a glass picture] Gianna.

164 Gianna: Condensing.

165 Ms. Hankes: It's condensing. Why is it condensing? What temperature change is happening?

166 Gianna: Cold.

167 Yvonne: The heat.

168 Ms. Hankes: This glass of water with ice on it is // has heat?

169 Yvonne: No // no, I mean the air.

170 Ms. Hankes: Okay, the air. The air around here becomes what from the ice?

171 Yvonne: Cold.

172 Ms. Hankes: Becomes cold! We know that heat speeds things up and cold makes things slower. Okay, I'm gonna wait till everyone's sitting up. Latessa, sit up, please. Joe.

173 Joe: How come // how come they make the glass water, but not the refrigerator // I mean real cold?

174 Ms. Hankes: Hmm! Very good question. Why does the outside of a refrigerator not become wet because the refrigerator is cold? Well Joe, if you go home and you feel your refrigerator, don't open it up, just feel the side of it|

175 Amber: It is hot.

176 Ms. Hankes: Well I want you to go home tonight and just kind of feel the refrigerator in front and kind of feel how the temperature feels because refrigerators when they make them // if they make them so they weren't really tight and they weren't sealed really well. All of that cold air would escape, right. And then our food wouldn't stay cold.

177 Amber: Ms. Hankes?

178 Ms. Hankes: [Motions Amber to put her hand down]. So they seal those refrigerators pretty tight. So Joe, when you go home tonight just kind of put your hand on [extends her arm out to show Joe what to do] the side of the refrigerator and I want you to feel the temperature. Excellent question. Tasha.

179 Tasha: It made the heat in the water and the water vapor make it come out.

180 Ms. Hankes: [Pointing to the ice in the glass]. So this is heat?

181 Tasha: Heat and air in the water vapor.

182 Ms. Hankes: Okay, there is water vapor [pointing her finger all over the picture with ice in a glass]. But when I am looking at this picture, I am not seeing anything with heat. I am knowing when I have ice, it is what? [rubbing her thumb with her index finger]

183 Cs: Cold.

184 Tasha: Sometimes it be um slippery.

185 Ms. Hankes: Cold. And it does // it can feel slippery because it's becoming a liquid. But|

186 Jamilia: [To the person sitting next to her] dang, y'all squishing. Ms. Hankes.

187 Ms. Hankes: It's the cold|

188 Tasha: At the bottom of the glass.

189 Ms. Hankes: When gas changes to a liquid it's because it cools down.

190 Tasha: And the dog [in the picture] drinking it. Look|

191 Ms. Hankes: It's slowing down.

192 Tasha: [Gets out of her seat to point to the book.] The dog's right here drinking the water.

193 Ms. Hankes: Terrence.

194 Terrence: [Goes up and points to picture of glass with ice.] Um why // why does that right there when she um puts that //no // when she put the ice in that // is that water vapor that just splashed out the cup?

195 Ms. Hankes: Oh, that is a good question. What is that that splashed out of the cup?

196 C1: Water.

197 Ms. Hankes: Water from where?

198 Tasha: Ice.

199	C2:	Water vapor.
200	Ms. Hankes:	[Making a motion like she is dropping an ice cube in a cup]. It's when she dropped the water in there it splashed a little bit.
201	Corey:	It be happening to me when|
202	Ms. Hankes:	Okay, we are going to move on to the next page.

The picture in the book may have prompted Lawrence's question and, perhaps because it directly relates to an important concept in the *Matter* unit, Jennifer privileges it. She tells all the students with other questions that she will address only Lawrence's question at that moment (unit 157). Or perhaps, Jennifer continues to privilege Lawrence, constructing with him a learnerhood, where other children may have access too, for reasons similar to those we discussed related to Excerpt 2. Jennifer draws children's attention to the picture in the read-aloud book. The text says, "Water vapor in the air is condensing on the glass" (Branley 1983, p. 15). She also asks the students to think about the semantic map they created in Lesson 12 to summarize changes in states of matter, where red and blue arrows depicting the addition (red) or subtraction (blue) of heat to cause such changes are included (Figure 18.2).

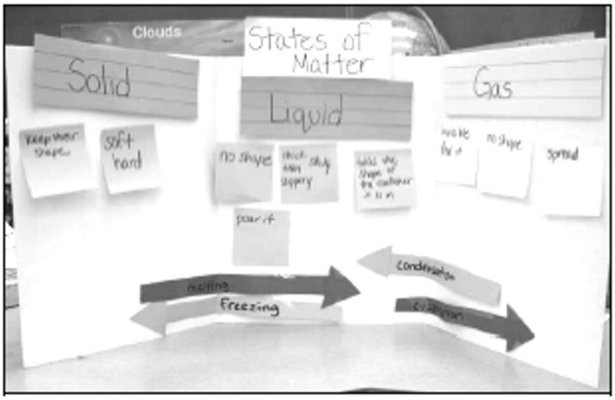

Figure 18.2. "States of Matter" semantic map in Jennifer's classroom.

In his question, Lawrence asks how the ice makes the water drip outside of the glass, and Jennifer repeats the question focusing on the ice as a cause of the process. As Jennifer uses Lawrence's question to create a space where he and his peers will discuss condensation ideas again, she summarizes for the class what condensation is (unit 157) and asks what role the ice plays in the process. Because Jennifer does not label the process as condensation, in response, some students try to name the process. Alice suggests evaporation (unit 158) and then melting (unit 160) after receiving a disapproving cue from Jennifer. As she interacts more with Jennifer, Alice brings up water vapor, and Jennifer repeats again what happens in condensation and focuses on temperature by asking again about the role of the ice. After that, Gianna suggests that the process is condensation (unit 164). It seems like there is a dissonance between Jennifer's and the students' questions and responses. The children seem to be responding to a different question than the one Jennifer is asking, and Jennifer seems to be asking different questions than the one Lawrence asked in the first place.

At times teachers make assumptions about what students mean, and it shows even if they ask their students to clarify their point. When Jennifer asks what change is happening and Yvonne suggests heat, Jennifer, assuming that Yvonne is referring to the glass, asks her to say how the glass "has heat." Yvonne strongly denies that, clarifying that she "mean[s] the air" (unit 169). It is a bumpy road as Jennifer and the children try to develop a space where common understandings unfold and support each other, and ideas get connected and articulated. Still after Yvonne clarifies her idea and Jennifer accepts it, Jennifer continues to challenge it—"the air around here becomes what from the ice?" (unit 170). Jennifer has an agenda; she wants the children to realize that what causes condensation is that the relative warmer air with the water vapor in it hits the cold surface of the glass and turns into water. She uses "becomes," not "has" in her question, which Yvonne answers "cold" (unit 171). Jennifer's agenda shapes the space she is trying to create with the children, a space that till now has only a few students in it.

However, Joe finds a way to get in that space, making a very interesting connection between the water on a cold glass and the lack of water on a cold refrigerator. And he receives Jennifer's praise (unit 174) and attention. As the boundaries of the space Jennifer is trying to develop around Lawrence's condensation question expand, "problematic" ideas (like Amber's "it is hot") prompt Jennifer to suggest to the class to feel their refrigerators at home and to also explain to them the difference between the glass and the refrigerator. Joe's entering the space that others have been creating diversifies the contexts within which ideas are explored. As discourse participants cross boundaries and enter spaces, they change these spaces in various ways. Spaces are fluid and dynamic sites of dialectics and relationships among people, materials, and ideas.

Then, Tasha brings the class back to the conversation around the book page again focusing on "heat" (unit 179), suggesting that the glass has "heat and air in the water vapor" (unit 181). Jennifer asks her to explain where the heat is located in the picture. As Tasha explains how heat is present in the picture, Jennifer focuses on the cold. The fact that Tasha points out that the dog in the picture is drinking the water that drips from the glass (unit 190) may indicate that Tasha associates heat with this process maybe because she believes that the ice is melting inside the cup and leaks to the outside. This does require the addition of heat according to Jennifer's semantic map. Tasha even rises from her seat to point to the picture of the dog in case Jennifer and her classmates do not know what she is referring to. Thus, she uses the text to try to convince Jennifer about her argument. Furthermore, the text contains red arrows around the glass that reinforce the children's focus on heat, and not the cold glass surface.

Terrence then focuses on the fact that the picture on the book indicates that the girl dropped ice cubes into the glass of water. He wonders whether the water splashed onto the outside of the glass. Jennifer acknowledges that it did "splash a bit" (unit 200), and Terrence suggests that this has happened to him before (unit

201). Terrence's observation on the book picture further strained the learnerhood Jennifer was trying to develop with her class around the idea of condensation. Jennifer decides to move on to read the next page as she and the children are struggling to see with a condensation lens the situation depicted on the book page.

Resources and artifacts that teachers bring into their classrooms, and specifically texts as in this case, come to shape the spaces developed. Furthermore, images in texts are quite important and powerful and draw children's attention. Images may encourage children to focus on different ideas than the ones the teacher aims for and the words of the text communicate. Pictures in children's illustrated information books are depictions of real-life situations where science ideas are involved. As we know, real-life events, scenarios, and situations, do not come in a simplified form, stripped from the many various dimensions, details, nuances, complexities that they may have. As much as such real-life connections enable children to relate with, engage in, think about, and debate scientific ideas, they also offer children plenty of opportunities to divert from the teacher's agenda and a science space she tries to develop with them. Thus, boundaries of this science space get stretched and pulled, sometimes making room for some children to come in and for others to stay out. At times the authority of the text clashes with the authority of the science that the teacher heads for. Concepts evolve within this clashing of authorities, within the tensions that emerge between the ways in which ideas make sense to children as opposed to their teachers. As participants in classroom discourse articulate, re-articulate, paraphrase, re-structure their and others' contributions, more, but not necessarily canonical, ideas emerge that need to be negotiated within the spaces that have been co-constructed.

Sociological Perspectives and Concept Development

In this study we used the construct of spaces and learnerhoods as a unit of analysis of the social context within which development of concepts unfolds and evolves in a classroom. As Jennifer and her students came together in their class to engage with ideas, to develop concepts, to learn science, they interacted with each other, with materials, and with ideas and negotiated ways of developing concepts as individuals in the midst of others. What was talked about, how, by whom, and when were all determined by the social spaces that the children and Jennifer co-constructed and participated in. Over the period of the year that Jennifer and the children worked on science, a myriad of spaces were created, dismantled, faded away, reconstituted, or re-emerged. Sometimes only two classroom members inhabited spaces; other times by more. In some ways, these were what Lefebvre (1991) called "lived spaces," embodied and symbolic spaces where production of knowledge took place, filled with elements of children's perceived life in the classroom and Jennifer's imagined, ideal, hoped-for and aimed-at configurations. These were historicized spaces, as both Jennifer and the children were bringing every day into the classroom their own histories composed both inside and outside of the classroom. Every space that was being created was related to spaces that preceded it. Thus, based on the children's perceptions of what had happened before, spaces were experienced and understood differently by different children. Although, in Excerpt 1, Jennifer's way with words was encouraging her students to stay out of one space and into, some did and others did not. Gianna and Tamara understood spaces that Jennifer constructed differently from Mary and Yvonne.

The children who argued their way into the space Jennifer did not want them to be in, did so by making connections to their interpretations of artifacts and connections to their own experiences with authority figures in their lives outside the school. The children who became part of the *fantasy* space relied upon what was perceived as an authority with power and status to argue their position. In addition to the symbolic dimensions that spaces have, their physical dimensions are important, too. In Excerpt 3, Jennifer invited Joe to come closer to the group so he could participate. It is the sense of closeness that brings at times people and ideas together, especially as Jennifer conducted her read-alouds with children sitting on the floor around her and she was sitting, too, and therefore no one was supposed to be moving around. Joe was brought in away from the margin and closer to the center, physically and symbolically. In Excerpt 3, Leigh's going in and out of the classroom disturbed Jennifer and the class, and Jennifer was much more persistent in calling only on students who raised their hand. Entering the space that Jennifer was creating with some students was temporarily denied to those who did not raise their hand—a widespread rule, of course, in classrooms of all ages, and especially of young children who should learn to do so for the rest of their schooling. We find yet another example of the importance of the physical dimension of spaces in Excerpt 4, when Terrence got up, went close to the book that Jennifer was holding and showing to the class, and pointed to the water that had splashed out of the cup when the ice cube was dropped in. Terrence was probably juggling several ideas and was attempting to understand how his peers and Jennifer were trying to explain why the cup was wet. He had heard several times that it was water vapor that made the cup wet. But, Terrence knew that water vapor looked different than water. He had contributed at the end of Excerpt 3 that a mouth cloud disappears. He also knew from experience that water splashed when something was dropped in it. Corey even said "it be happening to me." So, Terrence had to go up and show Jennifer and the class the picture in the book, so he could make his point stronger and maybe clear up his confusion.

In the excerpts we present, we see the tension between individuality and collectivity. At times, Jennifer firmed up the boundaries she was setting around a space where she and a child were pursuing an idea in order to make this space as productive as possible for this child. At times, though, other children's agency, or her own sense of responsibility to all her students' engagement and learning made spaces expand bringing or letting in more people and ideas. As Jennifer was orchestrating a class of 20 third graders—some eager to participate and show their knowledge and thinking, some looking intently but silently at the book, some squirming around as they were sitting on the floor, some looking away from the book—she was facing a perennial and constant dilemma teachers face at any moment of their teaching, the dilemma between pushing, enabling, and strengthening a particular student's thinking, or orchestrating the thinking of multiple learners.

This is, in fact, one of the fundamental tensions in an ecology of learnerhoods, where various learners' needs and strengths, or their different ways of making sense, may compete. As different learners produce their own understandings of ideas while lessons unfold, they may need their peers and their teacher to stand by them, for an extended period of time, to help them get deeper into a contribution they made, or a situation they brought up. Lawrence in Excerpt 2 needed to ask all his questions that Jennifer had asked him to hold on to for a while. Learners may need particular spaces, learnerhoods that encourage them to articulate their ideas, or to differentiate various ideas that may all be included in a scenario they are thinking about. In Excerpt 4, Lawrence, again, drew such attention from Jennifer. As such spaces are created, though, they may leave out some, or many, or most of the children in the classroom. A teacher with a heightened sense of duty for all her students tries to correct for this at other class times, where other children need to be privileged in some ways, having access to spaces created with them. The immense challenge, however, is that ideas addressed in the new spaces with the children left out from other spaces, may be quite different. It is impossible to develop spaces where every learner in the classroom is given an opportunity to engage with and share developing understandings of all the ideas. Thus, a goal may be to facilitate learnerhoods that overlap in people and ideas over longer periods of time, so that chances for common meaning making are maximized.

With this line of research we attempt to problematize what we know so far about concept development by putting the spotlight on how it is constructed in a classroom community of learners in urban schools, rather than on how individual students own it. Infusing sociological perspectives into how we understand the development of individual students' concepts is critical. Along with cognitive processes and emotions, the complex dynamics of membership in social spaces, populated with people, ideas, materials, goals, and rules shape concept development in classroom communities. In this study, we use a few vignettes from the yearlong data we have collected in Jennifer's class to illustrate dimensions of the theoretical constructs of spaces and learnerhoods that we have been working on. We have written elsewhere (Kane et al. 2008) about the ebb and flow of concept development of two concepts in Jennifer's class, and two other classes. It will be a daunting analysis to link spatiality and space development in a classroom with the ebb and flow of concept development, since there are a myriad of spaces that were created over a year. An interesting next step for us is to identify ways of capturing the ebb and flow of spatiality in broader strokes.

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Appendix: Transcription Conventions

Unit:	Usually corresponds to an independent clause with all dependent clauses related to it (complex clause or T-unit). Sometimes includes another independent clause if there is no drop of tone and was added without any pausing. Units here are punctuated as sentences.
Turn:	Includes all of a speaker's utterances/units.
Key for Speakers:	Ms. [last name] is the classroom teacher. C, C1, C2, and so forth are noted for individual children. C is used if a child's voice cannot be identified; Cn is used to identify particular children (but not by name) in particular section of the transcript (so that C1 or C2, etc., is not necessarily the same child throughout the whole transcript). Cs represents many children speaking simultaneously.
//	Repetitions or false starts or abandoned language replaced by new language structures.
~	Small/short pause within unit.
~ ~	Longer pause within unit.
|	Breaking off of a speaker's turn due to the next speaker's turn.
==	A speaker's pause at the end of uncompleted utterance, seemingly to encourage another speaker to talk.
< >	Uncertain words.

(***)	One word that is inaudible or impossible to transcribe.
(*** ***)	Longer stretches of language that are inaudible and impossible to transcribe.
Underscore:	Emphasis.
# #	Overlapping language spoken by two or more speakers at a time.
CAPS	Actual reading of a book or someone's writing.
{ }	Teacher's (or student's) miscue or modification of a text read:
	Substitutions—Word(s) substituted for word(s) in text {SUBSTITUTED WORD(S)}
	Insertions—Word(s) inserted, not in text {^INSERTED WORD(S)}
	Omissions—Word(s) omitted from text {<omitted word(s)}
	Reversals—Words reversed in order from text {>REVERSED WORDS}
[ ]	Identifies what is being referred to or gestured and other nonverbal contextual information.
…	Part of a transcript has been omitted.
[m …]	Part of transcript that involved classroom management has been omitted.

Chapter 19

Science as Context and Tool The Role of Place in Science Learning Among Urban Middle School Youth

Edna Tan, Angela Calabrese Barton, Miyoun Lim*

The students in Mr. Nader's environmental statistics class were involved in the "pigeon project." The pigeon project, inspired by Cornell University's Pigeon Watch Project was a 3-week investigation focused on two goals: To support students in learning to recognize the different color morphs of pigeons and pigeon behaviors; and to use this information to learn how to classify animals as well as to produce simple environmental statistics. It was precisely because he wanted his students to connect to the content of environmental statistics that the teacher selected the pigeon unit. Students in large urban centers, like New York City, are frequently around pigeons and thus have a great deal of experiential knowledge about them that can be tapped to support them in connecting with environmental statistics. By standard measures, the pigeon project was a success in Mr. Nader's classroom. The students demonstrated their learning about pigeon morphs, classification, and graphing through their coursework and at the end of the unit KWL (Know, Want to Know, Learn) activity. For example, in the initial class KWL discussion of what students knew about pigeons and what they wanted to know, students talked about how pigeons were dirty, carriers of disease, and "rats with wings." At the end of the unit, the "What we have learned" column was populated with comments like they "follow each other, there are many types or morphs, the majority of pigeons [in our neighborhood] are blue bars and checkers, they get along together although they are different types, and pigeons do not attack (are not aggressive)."

Yet, interviews with students after the unit revealed, surprisingly to us, that their ideas about the pigeons themselves did not change, and several students in the class did not see the purpose or importance of the project. Take, for example, what Jameer, a student who performed quite well in the unit had to say about the project:

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Researcher: What did you think about the pigeon study?
Jameer: It was stupid.
Researcher: Why?
Jameer: I don't know why I would want to learn about pigeons.
Researcher: What would you change about it?
Jameer: I wouldn't have studied pigeons in the first place.
Researcher: What would you study instead?
Jameer: Neighborhoods or something, not pigeons. It doesn't affect, what we are we going to do, change the way pigeons look or something. It really didn't help me with anything. I didn't really like it.
Researcher: How much do you remember about it? Do you remember what we did?
Jameer: We went to the Cathedral and we looked at pigeons, and we wrote down how they looked. I didn't really see the point. I don't know why.

Jameer was not satisfied with the purpose of the pigeon project and challenged it critically in her interview with us. She thought the pigeon study was stupid and she wondered why her teacher thought she would want to learn about pigeons. Her reasoning was clear: studying pigeons did not help her with anything. There was nothing she felt she could change with that information. Instead she suggests that they study their neighborhood, which she points out below is full of rats and garbage and something in need of change:

Jameer: I would choose a rat or a mouse or mice because there's a lot of them.
Researcher: Really. Where do you see them?
Jameer: On the way to school they be running across the street, you see dead rats on the street.
Researcher: So you'd rather study mice than pigeons?
Jameer: Yep. There's a lot of information about mice. You see them on train tracks; you do not see pigeons on train tracks.
Researcher: Why would you choose rats?
Jameer: Because rats are everywhere, they're in people houses. I'm dead serious. I'd choose garbage. It don't even have to be an animal because you see garbage all over the street on Amsterdam like they don't pick up the garbage or something, and then on Broadway it's just not there.
Researcher: That's true I never see garbage (on Broadway). If we had more time to study pigeons how would you like to continue the pigeon study?
Jameer: I would go to other neighborhoods, not just where we are. Let's say to a cleaner neighborhood to see how many are there because pigeons don't really do anything they just eat and that's it. To see where pigeons like to live, in dirty neighborhoods or clean neighborhoods.

Again, in this transcript above, Jameer directs her comments towards "change." She suggests that a study of pigeons could be revised to include an investigation of whether the cleaner neighborhoods have fewer pigeons. This comment by Jameer has to be understood within the context of how she views her neighborhood. She believes her neighborhood to be filthy, as is evident in how she talks about the rats and mice in the streets. Yet, she views "Broadway," where gentrification begins and the cost of living vastly increases, as a less filthy neighborhood. Why does it matter what Jameer believes about her neighborhood and how it is situated by class, race, cleanliness, and other issues in the larger city? Should this be the "content" of a science class meant to teach youth about taxonomy, one of the driving science ideas behind the original pigeon unit? We believe that Jameer's interview suggests that she had a deep awareness of how learning science in class might make a difference in her life. Jameer indicates that she has a strong desire to use science as a tool to make better sense of her neighborhood and perhaps to even make some changes within her community. While she could talk about what she learned about pigeons, she did not claim any connection to or ownership over her learning.

Learning science in the pigeon study involved many different practices—epistemological, investigative, and communicative practices. As these brief descriptions indicate, the students' practices were indeed local. For example, all of the environmental statistics the students prepared for the pigeon project emerged from their class-built data set. However, the point of the pigeon unit was to use these practices towards the goal of science learning, without consideration of how student goals might be more encompassing than that. We noted a critical juncture in which the students' sense of place and science as goal worked against shared goals and movement towards learning. The focus of the unit was on "where" students lived—that is, they lived around pigeons and would therefore be interested in them—but not on how pigeons might matter to students. As the teacher made decisions about the unit, "how" students lived in the city did not matter as much as the fact that they lived in the city.

We begin our manuscript with Jameer's story because it raises two questions: (a) In what ways do urban youth engage in learning science in place-based ways? And (b) What is the relationship between place-based science practices and meaningful participation in science class?

Conceptual Framework

Sense of Place

Although place has been a popular topic of inquiry in diverse disciplines such as philosophy, psychology, architecture, and urban-planning, it has not been a part of education discourse until recent years. Yet we know it is all too common for standard school practices to "teach students that their relationship with their place is marginal, uninteresting, and unimportant and the quality of the environment demonstrates this marginalization" (Sanger 1998, p. 5). Indeed, the current western education system exhibits a disproportionate emphasis on accountability and standardization, leaving little room for diversification of educational concerns or discourses including a concern for a sense of place. For example, today's education follows an "anywhere and anytime" general approach by establishing national (if not globalized) standards and subsequently developing curricula which can be applicable anywhere and anytime, thereby disregarding local histories, knowledge, stories, and languages in favor of the powerful national ones. The idea of focusing on and including local places and its attributes in education is radical

> because current educational discourses seek to standardize the experience of students from diverse geographical and cultural places so that they may compete in the global economy. Such a goal essentially dismisses the idea of place as a primary experiential or educational context, displaces it with traditional disciplinary content and technological skills, and abandons place to the workings of the global market. (Gruenewald 2003, p. 7)

Therefore, the importance and values of learning local knowledge and skills have been nearly eliminated in the current education system.

We value a sense of place framework in our work from cultural-historical perspectives because of how it helps us to understand the importance of the relationship between the local and the global. Thus,

> [a] central idea in linking individual trajectories and broader social structures is that of history. We have access to sets of roles and resources that are necessarily constrained (though not defined) by the history of individual in practice within these contexts. Sociocultural theories view these histories as critical to understanding how the sociopolitical arrangements of power and access in which individuals were situated came to pervade the practices they established. This is not to imply that contexts are static or handed down, but that things within them (practices, values, identities, beliefs, artifacts, etc.) are constantly indexing their own development. (Nasir and Hand 2006, p. 465)

In other words, part of understanding how roles and rules are mediated culturally and developing historically, is to understand how structures and trajectories interact in place-based ways.

We believe that marginalizing place removes practice from the cultural—historical realm, reducing culture to a static set of attributes and activity only through subject—object terms. Several studies have shown that utilizing student's social and cultural experiences promotes engagement in science among urban youth. Research with Hmong-American families has shown how family members whose cultural practices were once understood as different from school knowledge at best, and scientifically wrong or detrimental at worst, have helped to transform an elementary science curriculum when that curriculum critically emerged from their lived experiences (Hammond 2001). The result was that students and their family members were much more highly involved in school science. These issues regarding place-based education are global in nature. The centralized and standardized national education policy has damaged a sense of place education in much of the developing world. For example, in Kenya, since the beginning of European influence and control of education system through colonial exploitation, indigenous African knowledge in natural science and mathematics in Kenya has been ignored, underestimated, depreciated and held in contempt (Thomson 2003). National standardized curricula and tests that are insensitive to local knowledge have desensitized students' knowledge and value of their immediate local environment.

In short, science education has deprioritized the importance of place and its relationship to culturally mediated trajectories of practice to accommodate the push towards standardization and universalization of what students need to know and how they can best demonstrate that knowledge. The result is that whether a child lives in a rain forest in South America, in a hardwood forest in North America, in an island in Japan, or in West Harlem in Manhattan, children tend to get similar education which stereotypes places for example pollution in urban environment, deforestation in rainforest ecosystems and endangered species in Africa. In many cases, education seems to have lost its intimate and unique connection with the local community (Sobel 1996). "Here and now" seem to hardly matter in science education. However, even as place has been silenced in the current education climate, it does not mean that children's sense of place is absent in classrooms. Since children's sense of place is an important part of children's identity, affecting who they are and how they learn, it would be logical to expect that children leverage their sense of place when they learn at school. The question to ask is then, how does a sense of place play a role in a child's science learning?

Cultural-Historical Perspectives

Making sense of the role of place in children's learning, we believe, demands that we attend to the culturally and socially situated dimensions of learning. To do so, we draw upon a definition of learning as changes in participation and the ways in which such participation is culturally mediated and historically developing, involving cultural practices and tools (Rogoff 2003). Central to her thesis is that idea that culture is dynamic and activity-based. Such an activity-oriented understanding of learning suggests that culture can only be understood through its context development, and never as a set of definable, measurable traits.

We are drawn to cultural-historical approaches to understand the role of place in learning precisely because of its focus on social/cultural practices. Sociocultural theories, broadly speaking, have pointed out how classrooms are replete with a multitude of practices which are culturally grounded, and which foster many microcultures. These theories also point towards how changes in forms of participation are the products of both shifting cognitive and social functions. Cultural-historical approaches point towards how such education practices "are constituted through the junction of cultural artifacts, beliefs, values and normative routines known as activity systems" (Gutiérrez 2002, p. 1). Equally as important this framework intertwines the role and importance of cognitive, social and emotional processes in sense-making.

To make sense of activity from cultural-historical perspectives, we draw specifically from cultural-historical activity theory, which underscores the importance of the norms for talk, artifacts, the goals and social/cognitive resources of participants, the roles assumed, that all together interact to constitute the activity (Engeström and Miettinen 1999). Their model of mediated action (Figure 19.1) is based on Vygotsky's foundational work, which highlights that human agency and actions are mediated by cultural tools, signs, and signals. Cultural-historical activity theory (CHAT) has since been refined to reflect three levels of interactions as shown in Figure 19.1. In this model, the subject refers to the individual or group whose point of view is taken in the analysis of the activity. The object (or motive) is the target of the activity. Tools or instruments refer to both internal and external mediating artifacts that can be utilized to achieve the outcomes of the activity. The community is comprised of people who share the objective with the subject. Rules regulate actions and interactions within the activity system. The roles, or division of labor, describes how tasks are divided horizontally between community members as well as alludes to any vertical division of power and status. Learning is conceived of as a process occurring within on-going activity and not divided into separate characteristics of individuals and contexts. Cultural-historical approaches are particularly helpful in moving researchers beyond cultural regularities and the assumption that general traits of individuals are attributable categorically to ethnic group membership, by paying attention to variations in individuals and groups histories of engagement in cultural practices.

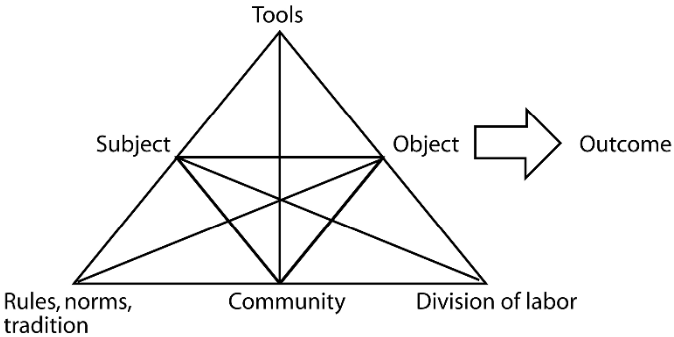

Figure 19.1. Model of mediated action.

Cultural-historical perspectives can powerfully support research into learning and participation among students of color. Let us look for a moment at Carol Lee's work on cultural modeling (Lee 2002). She argues that more work needs to be done that focuses on race and ethnicity in order to keep attention on the regularities of cultural practices by groups that tend to get buried through normalizing discourses and to uncover the ways in which meanings of practices are constructed and demonized by others. In her theory of cultural modeling she draws upon these regularities to support the design and enactment of curriculum that draws upon the social and cultural strengths that students bring from their home and community experiences while also recognizing how these practices develop in context driven ways. We believe these points about how cultural practices intersect with knowing, doing, and talking the academic subjects call attention to just how we frame questions of equity and learning in school settings. Indeed such a stance argues for us to consider how culture, power, and science literacy development shape each other at both the local and global levels.

The centrality of race and culture within a cultural-historical activity theory makes it a particularly productive framework for understanding the place in learning science. For example, we know that high school students from migrant farm worker backgrounds often use language practices from school and community in sense-making activities designed to promote critical reflection about their course subject matter as well as about their life experiences as migrants (Gutiérrez 2002). Thus, as Figure 19.2 suggests, bringing CHAT to bear on the role and importance of sense of place in learning calls attention to how the community of practice in question expands to be inclusive of non-science school based places such as the students' neighborhoods, the school neighborhood, or any other salient figured worlds important to students' lifeworlds, and their attending discourses. When students draw from personal experiences that are related to science to frame their participation in school science, the figured worlds that are recruited in school science expand to become more inclusive of communities outside of school science, impacting not only what science is learned but how the knowledge, discourses and resources from out of school communities can transform the subject and object of science learning and the rules and roles for participation within that community.

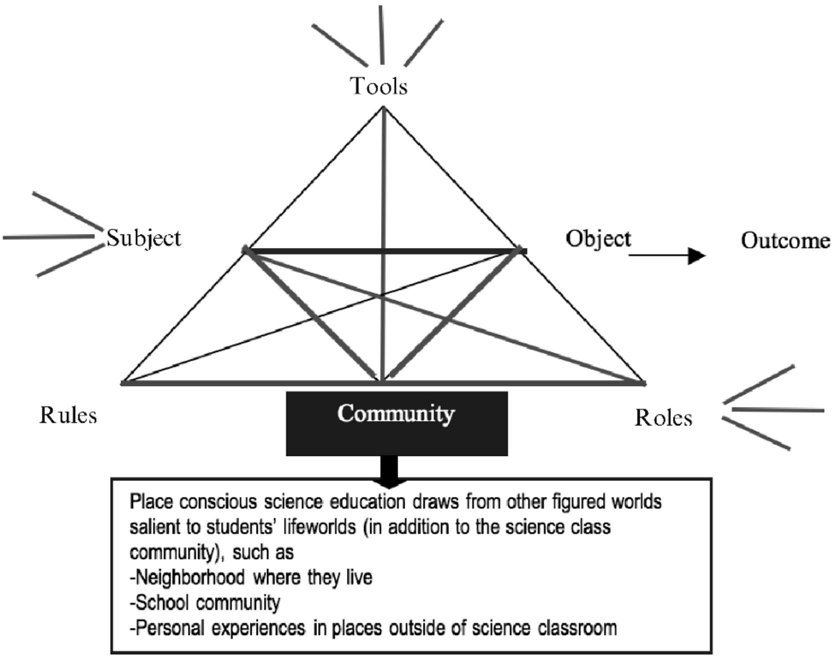

Figure 19.2. Place conscious science education expands the community of practice to be inclusive of out-of-school figured worlds salient to students' lives.

Making Sense of Place in Learning

As we sought to make sense of the role of place-based education in how students participate and learn in science class, we began to see the importance of how place framed not only what students learned but how and why they learned. Whereas

Jameer could talk about what she learned about pigeons, she did not engage beyond the acquisition of some content facts in the unit. As evidenced by her end of the unit interview, she did not claim any connection to or ownership over her learning. Jameer's experiences with the pigeon project, as described in the opening vignette, call attention to how school science traditionally has been framed as a goal, or in other words, the object of participating in science class is to be successful in only learning about science ideas. As Jameer's experiences illustrated, even in a science classroom where students' lived experiences are valued and integrated, science can still be framed mainly as a goal in the classroom when place matters only in what students learn and not how or why they learn. If we use activity theory to further unpack Jameer's experiences in her classroom, we can see how the explicit classroom emphasis in the pigeon project was on the subject-tools-object triangle, with the outcomes of learning focusing primarily on performance indicators of content mastery (Figure 19.2).

Whereas these learning outcomes are mediated by Jameer's classroom community and the rules and roles that shaped practice in the community, these dimensions were left uncontested within her classroom. Jameer's role as a member of her community and how that shaped her understanding of the value of studying pigeons was not considered in how she was expected to take up pigeons in her classroom. She was not asked about how pigeons connected to her place in her community or her views on her community, nor did she seem to have the unsolicited opportunity to bring these to bear on the task. As she stated in the interview shared at the beginning of this chapter, Jameer did not understand *why* she had to learn about pigeons because it was not going to help her make any changes that mattered to her. Instead, Jameer was expected to approach the pigeon activity strictly as a student of school science. She had to only use her school learning tools such as the KWL chart and school science skills such as observation and data recording to fulfill the teacher-stipulated objectives of the activity in understanding pigeon color morphs and behavior. The activity was a tightly scripted school activity where the students' particular and contextualized experiences with pigeons, their place-based pigeon encounters, had no role (Figure 19.3).

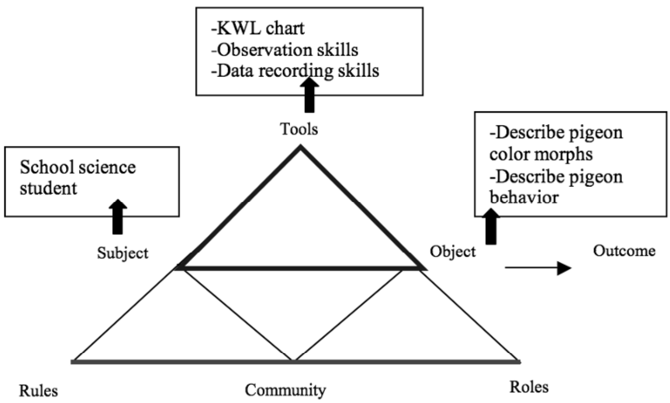

Figure 19.3. Jameer's pigeon activity as seen through the CHAT framework.

But what about those classroom events where the leveraging of place does more than shape the object-subject-tools triangle? What about those events where the community, rules, and roles which shaped practice in that community are contested along side the subject and object of learning science? In what follows, we share two vignettes that reveal classroom episodes where the rules, roles, and community shifted in unexpected and unpredicted ways and in so doing managed to support and transform student learning: Healthy Snacks and Anti-smoking Skit. We unpack each vignette to delve into how place helps to transform not only the rules and roles but also how these shifting rules and roles inform the larger activity framework.

Healthy Snacks

In a sixth-grade lesson following the "healthiest snack competition" where students worked in teams to buy the healthiest snack from a corner grocery store with two dollars, Mr. M., the teacher, wanted to review the students' choices and asked for each group to share why they thought their team had the healthiest snack. The conversation was slow and halting, with Mr. M. asking several probing questions to urge student discussion:

Mr. M:	Jess. Do you think your team was the best? Came up with the best snacks? For two dollars?
Jess:	No.
Mr. M:	You don't? Does anyone disagree with her? [one student to mr. m's side raises her hand, but he doesn't see her. Most students are quiet looking at mr m or looking around the classroom.] I don't know if we have all the time enough to share. I want to quickly review and move on.
Mr. M:	Jane do you think your team had the best snacks? Maybe not everyone there. Jane, what are your thoughts? Jane refresh our memories, what did you buy for two dollars?
Jane:	Cheese cracker and peanut butter. [Mr. M. Yup]. Cereal and orange juice.
Mr. M:	Cereal and orange juice. That all sounds pretty good. Jim what did your team get?
Jim:	Orange juice. Uhm and bananas.
Mr. M:	Bananas. Alright. Nadia. What did you team buy?
Silence	
Mr. M:	Nadya, do you remember?
Nadya:	Sun chips.
Mr. M:	Sun chips. What else was that?
Nadya:	*Inaudible *

Early in this conversation, Mr. M. is heavily directing the conversation. He is asking the questions. He is calling on students, for no one had their hands raised. While he starts with the question- do you think your team was the best- he reverts to asking students to simply report on what they purchased when he could not get any response. Student responses like Nadya's ("sunchips") or Jim's (Orange juice. Uhm and bananas) are simple. They report out what they purchased with no connection to previous statements or even to the overarching competitive nature of the activity that had seemed to greatly excite them the previous Friday.

In urging students to formulate a stance on their purchases, Mr. M. rephrases his question and asks the students to raise their hands if they thought their team had the best snack:

Mr. M:	Raise your hand if you thought your team definitely had the best snack. [a few students raise their hands] Jeff?
Mr. M:	Meli, read to us what you wrote for your homework. Tell us whether you agree or disagree, or your team will. If you could share with us.
Meli:	(reading) I wrote that I thought our snack was a good snack because
Mr. M:	stop right there. There is shuffling and it is distracting to what she is saying.
Meli:	I wrote that our groups snack was the healthiest because it had like less calories, and [inaudible].

Mr. M. draws upon the tools of the activity—the journal writing—to help the students engage more in his question on a health snack. When Meli reads from her notebook that her snack was a good snack because it has less calories, Mr. M. interrupts and then praises her and then uses it to ask the class how many calories are in a healthy snack. Once he gets an answer that he wants the class to recall, he repeats it and asks Meli to continue reading from her journal entry:

Mr. M:	OK, so calories is a factor. Good. How many calories should a snack be? In a day if you have two? Do you remember? Kitty?
Kitty:	*inaudible *
Mr. M:	Nope. Frank?
Frank:	200 calories per person?
Mr. M:	About 2–300 calories per person per snack. Good, (Meli) keep going.
Meli:	And … we didn't buy chips…
Mr. M:	Why didn't your team buy chips?
Meli:	Because, we thought that wouldn't be healthy.
Mr. M:	What about chips wouldn't be healthy? As a snack? Jane?
Jane:	'cause of the way its done? Like oil …
Mr. M:	So they're prepared in oil, which if you eat too much …
Student:	Not good for you.
Mr. M:	It's not good for you. Ok. You have another point Meli?
Meli:	*shakes her head while looking at notebook *

In the conversation Mr. M. draws upon two standard tools in the science classroom: a journal entry based on specific questions, and scientific definitions presented to the class earlier in the unit. The tools are familiar to the students; with some prodding, Mr. M. is able to string together a conversation about Meli's group's snack choices in the healthy snack competition. But the outcome falls short of what Mr. M. really wants, which is to engage his students in a lively, if not competitive debate, around whose snack was healthiest. In talking with Mr. M. prior to the lesson he imagined that the excitement he witnessed among his students picking out their snacks the previous Friday, and even their willingness to prepare journal entries on their choices, would translate into a debate on whose snack was healthiest. His science goal was to have the students use their scientific reasoning to support their arguments. After using these two traditional tools to get out the science ideas, Mr. M. makes another attempt at starting up a lively debate. He asks Franklin, who is normally quite talkative, if he agrees with Meli. Instead of a debate, however, he simply gets head nods:

Mr. M:	That's it? Franklin do you agree with her? [Franklin is on Meli's team]
Frank:	*nods *
Mr. M:	You have the same points? In your reflections? Carina?
Carina:	Yeah, the calories, and to see which would have the most sugar, and which would have no sugar … *writes in notebook *

At this point in the conversation, Mr. M. switched his focus from the school science assignment worksheet and asked if any of the students had gone back to the corner stores over the weekend. The students had learned, during the previous lesson on the healthiest snack competition, about the more nutritious options that the corner stores offer and that are within their budget. Mr. M. was hoping that the students would apply this knowledge when he asked for volunteers to share their latest snack choices from these stores. Many hands went up in the classroom at this question, and a lively discussion ensued:

Mr. M:	Raise your hands if you've gone back to either of those stores since Friday. Shernice, what did you get there?
Shernice:	I got … two bags of chips and a candy? *class laughs, including Mr. M*
Mr. M:	Ok, why?
Shernice:	Because I like to eat them.
Mr. M:	Because you like your junk food, ok. Now is that replacing a meal, or is that one of your two snacks? Was that going to be your lunch?
Shernice:	It was actually my breakfast. *class goes "wow"*
Mr. M:	For this morning? Okay … anyone else? Go back to those stores? I like the honesty and you're probably not alone. Mabel?

There is clear shift in the tenor of the conversation, and one that calls attention not only to what evidence and experiences matter but also to the framing of the question, did you buy a healthy snack. When Mr. M. calls on Shernice, he is met with a response that clearly he nor the rest of the class anticipated. When Shernice says she purchased two bags of chips and candy, the class along with Mr. M. laugh. We suspect the laugh reflects both students and teacher being caught off guard at the response, and to a possible nervousness among the students for listening to a peer so blatantly speak against the "science" they had learned in the activity. But Mr. M., instead of criticizing the choice, makes an interesting move. He asks her "why"? His tenor is sincere and his look somewhat quizzical. He genuinely appears to want to understand Shernice's choice. When Shernice replies that she likes them, and later that the chips were her breakfast, the class almost in unison loudly whispers words, such as "wow" and "oh my" and the like. We actually know that many of the students in class commonly purchase such items for breakfast and we therefore do not believe the students were surprised that this was Shernice's practice. What we think is going on is that Shernice trips up the narrative again. Not only has she gone to the bodega to purchase the chips, she eats the chips for breakfast rather than a snack. Mr. M. acknowledges her response by thanking her for her honesty but pushes on for other responses. And so we see here new tools being valued in the discourse already: personal experience, personal likes, and honesty, although we do not see Mr. M. placing these on the same plane as the content per se. Next, Mr. M. calls on Mabel, who was also raising her hand:

Mabel: I went back to the store, and I got two bags of chips and a lollipop. *class laughs again, but not so loudly this time*

Interestingly, Mabel repeats Shernice's narrative almost exactly. And, when Mr. M. again asks whether this was a meal or a snack, Mabel, like Shernice, reports it was a meal. But this time, Mr. M. seems ready to do more than just acknowledge the response. He asks Mabel what she bought on Friday during the class activity:

Mr. M: Was that a snack or was that a full meal?
Mabel: A meal. *some classmates go "Oh gosh"*
Mr. M: Mabel, what did you buy for two dollars last Friday, you and your team?
Mabel: We got granolas and some orange juice.

When Mabel reports on healthier options recorded in her journal, Mr. M. uses these as tools to challenge the developing narrative. However he is careful in how he did so by asking not why they did not choose healthy foods, but what their thought process was and if taste or cravings mattered more as factors one should consider, when choosing a snack:

Mr. M: Did you think about what you did on Friday when you went in there to buy those? What was your thought process? Why did you take what you learnt and make a different choice? Was it purely taste? That it was something you were craving?
Mabel: Yes…
Mr. M: Ok, that's honest … yes, Cindy?

Mabel only says yes but she is relieved from having to expand upon her answer by her friend Cindy who is using her entire body to get Mr. M.'s attention. Cindy had been waving, first with one hand, then with both, and half getting up from her seat the whole time Mr. M. was in conversation with Mabel:

Cindy: I only bought ONE bag of chips… but, I was going to buy more, I felt bad, so I just bought one.
Mr. M: Why didn't you buy more?
Cindy: Because, I know its not healthy …
Mr. M: Ok, what could you buy in place of another bag of chips? I'm OKAY with one bag of chips cause it's small enough for a nice little snack… but what could you add to that to get a balanced snack?
Cindy's teammate: *Whispers to her * orange juice!
Cindy: *nods at teammate * Yeah, a small container of orange juice. *two of Cindy's teammates, including the one who whispered to her, high fives *
Mr. M: Good.

In the last three transcripts we see the resources or tools that the students introduce to the classroom—a need to find their own breakfast, the importance of taste, and even peer culture—being acknowledged by Mr. M. However Mr. M. does not blend or merge these resources with the science story line he is trying to develop among his students. This last segment of transcript is the most interesting because Cindy strategically merges the resources her peers introduced into the conversation with Mr. M's content story line, showing how both can come together into a rational but culturally and youth friendly explanation. Mr. M. accepts this hybridization and reformulates the science content story line he wants his students to know when he states, "I'm OKAY with one bag of chips cause it's small enough for a nice little snack … but what could you add to that to get a balanced snack?"

The initial classroom discourse focused on using the healthy snacks competition to demonstrate knowledge gained about healthy snacks. The teacher, Mr. M. tried to make this conversation enjoyable and relevant by insisting that students compete with each other for having purchased the healthiest snack. Yet student participation followed a very traditional pattern and students were slow to participate. As Mr. M. later reports, he felt like he was "pulling teeth" to get the conversation started. However, after Mr. M. asked the students if they went to the store over the weekend, the focus of the discourse in the class shifted. In the latter half of this episode, we can see clear shifts in how students participated as well as their level of engagement. Mr. M. made the pedagogical move partway through the discussion to refocus the conversation on students activities and choices over the weekend, asking the same questions about what makes a healthy snack, but situating it in their weekend activities rather than in the class activity. Instead of teacher call and student response, students began calling out. They began talking to each other, offering suggestions for what to say, and commenting on each other's experiences and ideas. They were enthusiastic. They were laughing.

This transcript also reveals how the focus of the classroom discourse shifted to the student's personal accounts of healthy snacks. Instead of a recitation session where students were expected to offer correct but abstracted canonical responses, students began to offer complex personal accounts that drew upon scientific understandings along side the pragmatic realities of their lives. Their accounts, while deeply personal, were not devoid of scientific talk and thinking around the big ideas they had covered in the previous week. In fact, we argue, that their talk is more scientific as they raise questions and insights into the complexity of understanding healthy food choices and dynamic equilibrium in the human body. The students were quick to support their peers' wrong answers—their seemingly bad choice of snacks—by emphasizing their experiences in figured worlds outside of school science. For example, Shernice's snack choices are cast in more complex shades of a limited budget, undesirable school lunch and teenage preferences instead of a black and white application of a school science lesson to everyday decision making. In other words, what students were learning in science—what constitutes a healthy snack and why—became part of the larger mosaic for how students made sense of their choices. Cindy, who both supported her peers' choice of potato chips for snacks, did so while explaining that one bag of chips is better than two, and that when accompanied by orange juice might offer some nutritional value.

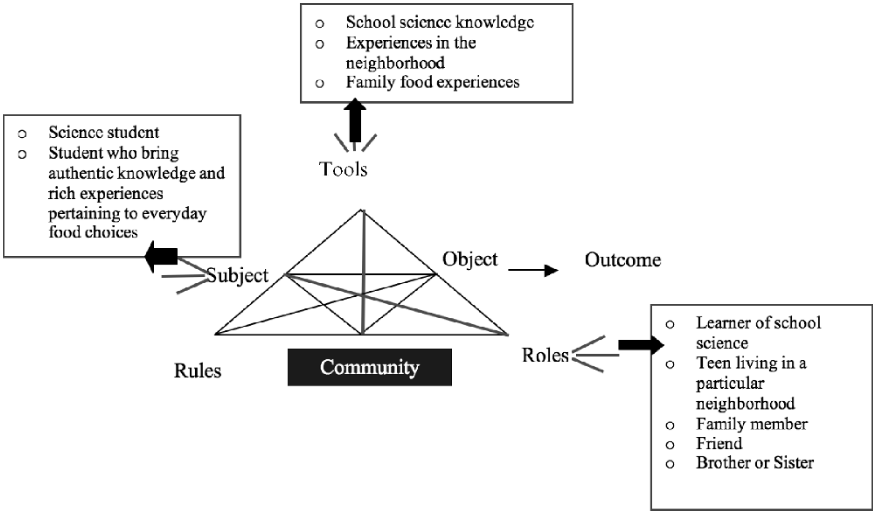

Figure 19.4. Expanding the subject, roles and tools in healthy snacks discussion by focusing on students' sense of place and personal experiences with food choices.

In this episode, we believe that the place-based experiences and relationships of the students mediated the purposes and nature of activity in class. The object of the activity was expanded to be more than a goal—that engaging deeply in the subject matter of healthy eating habits was fundamentally more than understanding what constitutes a healthy snack and why. We argue that when science is brought in as a context in addition to a goal, students have a wider base of resources to draw from and multiple roles with which to engage. As Mr. M. leveraged students' sense of place in a way that expanded the role of community, students had a wider repertoire of roles available from which they could participate in the healthy eating dialog and the connections between school science and lifeworlds are made bolder and more explicit (Figure 19.4).

Antismoking Skit

After teaching the students about the respiratory system, Mr. M. wanted to increase student participation by having each team write and enact a short skit with an Anti-Smoking theme. Mr. M. gave very specific instructions for the skits. The students needed to use what they learned about the respiratory system to prepare a presentation that would convince their peers not to smoke. Students were given a preparatory period to write the script and then a presentation period to perform their skit. Mr. M. was clear that everyone should contribute to writing the skit and that everyone should have a role in the skit. He told the students they could be as creative as they wanted but that they were required to incorporate the science that they learned.

All of the groups successfully completed skits, and after each skit, Mr. M. opened up a short dialog on the class' reaction. We focus on one skit by Chantelle's group. In planning this skit, Chantelle's group drew heavily from Chantelle's suggestions. Group member Tricia is the one everyone acknowledged as the "science student" whereas Chantelle, Lionel, and Tom were average to below average students. However, all four contributed actively to building the storyline of their skit, drawing both from personal experiences and science content. Chantelle's group's skit is like many of the other group's skits in that it positions good versus bad and peer pressure as central elements to the plot. However, we were intrigued by how the skit drew upon gestures and discourse patterns to centralize the place in how smoking was talked about in science. We were also compelled because by and large this was the favored skit among the class and served as a turning point in how talk about the respiratory system blended with the youth's lives.

To open the skit, Chantelle holds up a sign that says "In a corner" to set the scene. There are four actors in this skit, Chantelle, Tricia, Lionel and Tom.

Chantelle:	*saunters in holding imaginary newspapers* Newport! Newport! Newport! Who wants Newport??
Tricia:	*saunters up to C with enthusiasm and the two greet with elaborate hand shaking ritual* HEY CHANTELLE! How you doing GIRL?!!
Chantelle:	Whassup whassup whassup?! *while engaging in hand ritual with Tricia *

The gestures enacted by Tricia and Chantelle did more than set the place of the developing skit. They enacted them carefully and slowly as if to exaggerate their importance in the skit and in establishing their roles and dominance in the room.

Tricia:	* The boys enter the scene and stand next to Tricia, who introduces them to Chantelle* This is my friend, this is Lionel, that's Tom… *gestures to both boys*
Chantelle:	Whassup whassup whassup… *grips the hands of both boys in turn as if to arm wrestle * You guys wanna smoke? *holds up bunch of imaginary cigarettes *
Tricia:	Yeah!
Chantelle:	*hands out imaginary cigarette to Tricia, Lionel and Tom and mimes lighting each cigarette, Tom throws his cigarette to the floor *
Chantelle:	*to Tom * Why you don't wanna smoke? You a wussy?
Tricia:	You're a WUSSY!!!

On the one hand the developing scenario is typical: Three students choose to smoke and one thwarts peer pressure, throwing his cigarette to the ground. The response is thickly loaded with cultural intention. Both Chantelle and Tricia refer to Tom as a "wussy," a derogatory term among the youth meant to combine "wimp" and "pussy" and to saddle a boy with the image of being girly, nervous and weak. Besides challenging the teacher's authority to bring in derogatory terms to the classroom discourse, "wussy," the skit pushes onward with the remaining smokers nurturing each other through their smoking:

Chantelle: Get out of here, get out of here! *pushes Tom away* You're wasting my money, get out of here man!

Tricia: Yeah, we don't want you!

Tom tries to get Lionel and Tricia to leave with him but was unsuccessful. Tom leaves. Chantelle turns her attention to Lionel and Tricia as they continue "smoking".

Chantelle: Yeah yeah yeah, so whassup whassup whassup…

When Lionel starts to cough violently while "smoking" Chantelle comes back in to center stage, patting Lionel on the back with advice on how to smoke:

Chantelle: Yo yo yo!!! That's not how you do it yo, that's not how you do it! Slowly, softly, softly … *gestures to Lionel*

Chantelle's motions are more evocative than her words, and the class is captivated both by her knowledge of smoking and her resolve to be both so sensual and provocative in class. The skit ends, however, with Tom coming back and inviting everyone to his house where he shows them from the internet the biological consequences of smoking and the smokers all shocked and talking about "going into rehab"!

In the skit, community funds took center stage providing several plotlines. Street culture and ways of speech were also showcased in many skits and students' everyday lives in their neighborhood became the core content of a science class. The four students drew deeply from their personal experiences rooted in their sense of place. By having Chantelle appear as a newspaper girl, the students allude to having contact with working youth who occupy their world outside of school, who most likely have concerns very different from youth who are in school but who are no less important figures in the students' lives. The language and body gestures enacted also illustrated the unique code of conduct that is part of the street culture among youth in this specific neighborhood. Incessant attention was paid to the gestures that positioned the kids as either not in school or having active lives outside of school.

Peer pressure featured prominently in the skit along with the painful consequence of public humiliation with disparaging name-calling and outright rejection should a youth choose to go against the crowd. The four student actors convincingly showed the gritty side of urban living and the acute force of peer influence. As Chantelle's character alluded, taking up smoking from peers can be made desirable when a youth is faced with choosing between suffering immense social pressure and gaining acceptance through free cigarettes and guidance from the tutelage of expert friends who can coach one to inhale the first puffs of smoke "slowly" and "softly."

On first glance, this skit seemed to be more about "a day in the lives of urban youth" than a skit centered on scientific concepts. However, it is precisely because it is so grounded in the students' sense of place that a hybrid space was fostered both in its enactment and in the class discussion that ensued. Students' roles, tools and subject entry point expanded as a result (Figure 19.5). Enacting such a skit then is an example of the instantiation of a place-conscious education that "enlist[ed] teachers and students in the first hand experiences of local life and in the political process of understanding and shaping what happens there"

(Gruenewald 2003, p. 620). Science became a context in addition to being a goal, and this science context is powerful precisely because it is experienced as a reality in the students' everyday lives with the attendant identities germane to them.

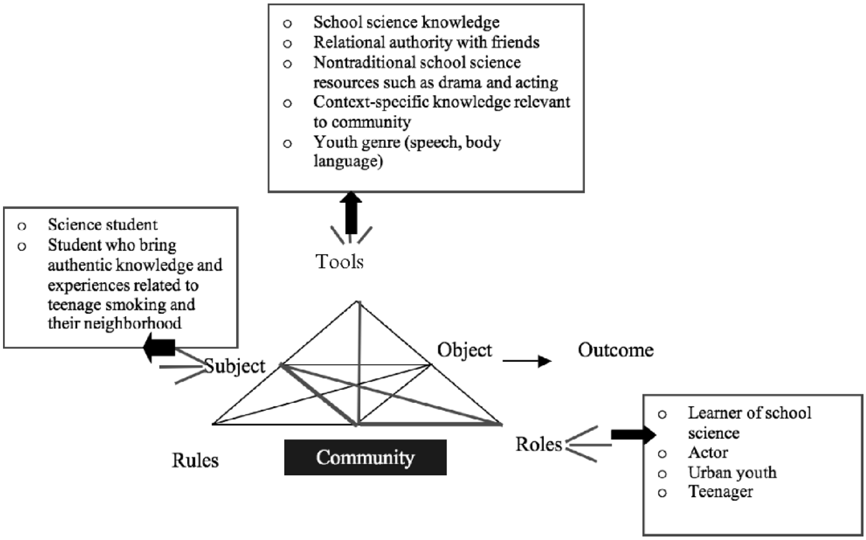

Figure 19.5. Expansion of subject entry points, tools and roles in Antismoking Skit when students' place-based communities are emphasized.

When science was taken up as a context, students recruited real life experiences grounded in their sense of place to be legitimate and important science content to be discussed in science class. Students' street discourse, with its attending valences of power, was dramatically woven into science classroom discourse. The audience gave these four actors riotous applause and showed their appreciation with calls of "that's hot, that's cool." They related to the skit throughout its enactment, laughing at Chantelle's antics but falling silent in those moments when Tom was ostracized, suggesting that they empathized with his situation despite of it being only an act. It was an act that mirrored personal experiences.

When the skit concluded, Mr. M. asked the audience for feedback and some students shared their own experiences in struggling against peer pressure. Another student pointed out a local grocery store that would not bat an eyelid selling cigarettes to minors. Instead of concentrating solely on emphysema and carcinogenic ingredients in cigarette smoke, the students told stories about how smoking is prevalent amongst their peers and discussed the options open to them. Mr. M. facilitated the discussion with sensitivity and thoughtfulness, reminding the students what they have learned to reinforce the message on the dangers of smoking, as well as suggesting ways students could deflect peer pressure. In so doing, Mr. M. made clear that the students community funds and discourse were welcomed in his classroom space and the 6th grade community-of-practice as a whole inhabited a hybrid space where a new classroom discourse is created through the integration of students' community funds and discourse with the disciplinary texts and discourse of school science. Place-conscious education took place with this example where students' lived experiences in their neighborhood were fore grounded in the science classroom and both teacher and students had the change to participate as engaged, informed citizens around the localized context of student experiences with the issue of smoking.

Science as Context

The classroom events we have described reveal instances where students seemed to deeply invest in science class where their participation appeared to be qualitatively different. In these instances students seemed to more deeply engage in classroom activity, when classroom practice placed value on the multiple communities in which they participated and the meanings these communities carried to doing science in the classroom. In these instances, the ways in which rules and roles mediate activity in the classroom and how these rules and roles are informed by both the learning community and the multiple figured worlds to which students belong, become points of contestation to traditional science discourse. Unlike the episode of Jameer and the pigeon project, students' place-based experiences mattered not just in what they learned but why and how they learned. These instances constitute science as context because such classroom practices frame engagement in science activity through the ways in which place-based experiences and relationships mediate the purposes and nature of activity. In science as context, science plays a deeply situated but supporting role to make sense of the place-based experiences of youth. Furthermore, when science emerges as a context, the ways in which rules and roles mediate activity in the classroom and how these rules and roles are informed by both the learning community and the multiple figured worlds to which students belong, become points of contestation to traditional science discourse. In science as context, therefore, the object of science is expanded to value the multiple communities in which students participate and the resources, roles and expertise that come along with those communities.

The idea of science as context draws significantly upon how participation in science is placed-based, meaning that how and when students enter into science activity, the expertise they share, and the tools they co-opt reflect both the science activity and their simultaneous inhabitation of multiple figured worlds, including figured worlds outside of school science (Figure 19.6). As these figures suggests, the community of practice in question expands to be inclusive of non-science school based communities such as the students' neighborhoods, the school neighborhood, or any other salient students' lifeworlds. When students draw from personal experiences that are related to science to frame their participation in school science, the figured worlds that are recruited in school science expand to become more inclusive of communities outside of school science. Out of school communities are grounded in the lived experiences, knowledge and ways of being students possess from being members of various figured worlds that matter to students, such as the neighborhood where they live as well as the school community. Science classrooms, by framing science as a context, can become spaces for connected science learning. The youth in our study used science to further their participation in their science learning community as well as the different figured worlds that make up their lives. When they, along with others be it their peers, teachers or family members, re-positioned what it means to know, do, and learn science from being only about a goal to also being a context and/or a tool, they were able to find multiple and meaningful ways to participate in their communities. Here we reflect on the implications that this study has for a science classroom that attempts to frame science as a context, and in so doing, provide connected and participatory science learning opportunities for students.

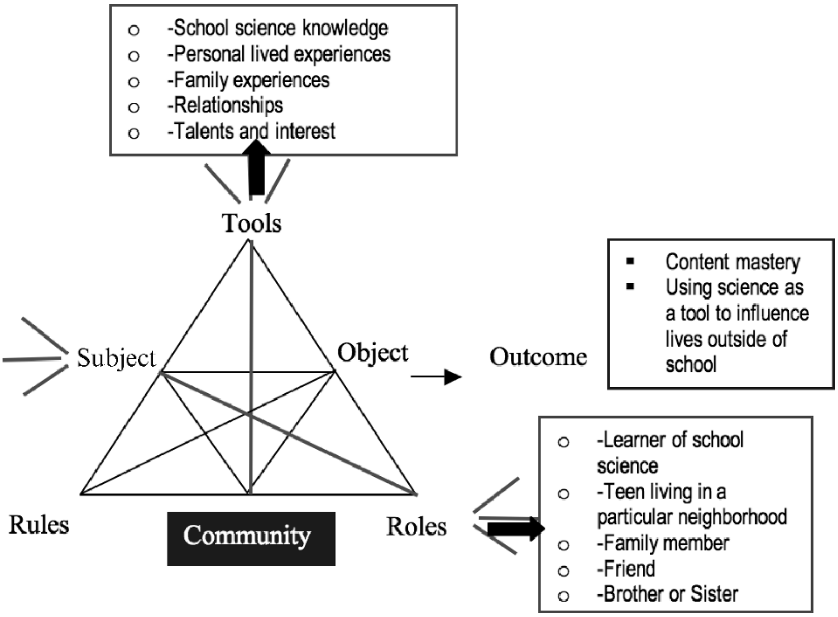

Figure 19.6. Expanded roles and tools that are recruited into science learning with place conscious science education.

Expanded Boundaries of Science Class Through Hybrid Spaces

Boundaries of science class can and will expand by framing science as context. We saw that when science was taken up as a context, the students were fostered in bringing in their multiple figured worlds to bear on learning science, thereby including and inviting multiple communities outside of traditional science class and expanding the rules and roles of students in their science learning community of practice. Science as context opens up science learning opportunities by expanding the communities that are welcomed in the science classroom, allowing new and disruptive third spaces to emerge. By including multiple communities in science class, students were allowed to take up multiple roles and utilize multiple tools or resources from the communities. In other words, as science became contextualized, the place of science became clear within the expanded context of science learning. Students were able to see how science connects to their figured worlds, thus it opened up multiple entry points for science learning in the class and students took up multiple roles and got engaged in science practices in class. These sorts of hybrid or third spaces in science classrooms can collapse the distinction between everyday and academic knowledge or literacies by showing how both can work together to support meaningful science learning. This is the basis of her more extended analysis of how youth draw upon their funds of knowledge to generate third spaces in support of scientific literacy learning.

Focusing on students' sense of place fosters hybrid accounts and brokers for a hybrid school science discourse that can transform student participation. A hybrid discourse gives multiple meanings to abstract ideas and allows students to see that there are real and meaningful connections between science concepts and their everyday lives. A hybrid discourse foregrounds the value of science as a contested practice and repositions students in a more powerful position to start to critically question and explore scientific ideas that will likely result in a more robust understanding of science when compared to mere rote learning of science as mere epistemic fact. Finally, a hybrid discourse emphasizes that meaningful participation in a community of practice is as much about practice/identity as it is about knowledge. These hybrid spaces are important because they bring together the different forms of knowledge, Discourses, contexts and relationships one encounters in ways that collapse binaries, allowing them to work together to generate new knowledge, discourses and identities (Moje et al. 2004). They disrupt normative rules, roles, and tools for mediating participation in a community of practice.

Shifting the Position of Science

When science is framed as a context, it not only expands the boundaries of science but it also shifts the position of science in a class. As science gets situated as a context, science then can take up multiple positions in science class. Due to this flexibility in the positioning of science, new hybrid spaces can be created in science class. As science steps aside and takes up a supporting yet deeply situated position, students' lived experiences and understandings of their figured worlds can become fore-grounded and valued as legitimate discourse in the science classroom. Thus hybridization between school science and students' lived experiences of their figured worlds can proceed. We note two aspects in which the shift in the position of science could lead to meaningful science learning. First, from an entry point (to science learning) perspective, the shift can encourage multiple entry points and furthermore foster deep engagement in science learning as we saw from the healthy snack story. Second, from an outcome/learning perspective, the shift can nurture connected science learning opportunities, that is, deeply situated and real understanding of the role of science in their communities. As we saw in both the healthy snack story and the anti-smoking skit story students encounter real world situations and problems in which they are encouraged to make sense of and try to make the best use out of science or scientific information that they have. When it is framed as a context, science is no longer an isolated goal of the learning attempt. Science is no longer wrapped in its own separated disciplinary world. Science is opened up and positioned within the complicated interconnected figured worlds of students. In real world situations, science is no longer the sole factor in making decisions. When students try to buy snacks, they not only have to consider what is a scientifically sound decision, but also what could satisfy their empty stomach or taste buds with given limited budget or given poor cafeteria food. When students try to keep away from smoking, they have to utilize scientific understanding of the harmful effect of smoking but also deal with the peer pressure coming from the youth community surrounding them. Science learning becomes more complicated yet real and thus connected and meaningful for students when they can see science in action in their everyday lives.

Repositioning of Science as a Tool

Lastly, when science is framed as a context and hybrid spaces are created, students can see and understand how science is connected to their figured worlds. Therefore, it is more likely to become visible or evident how science can be used as a tool for their meaningful participation. When science is a tool it highlights the relationship between object and subject. When science is both a tool and a context it allows participants to become more agential because they are highlighting the relationship between object, subject, rules, roles, and community. Just like Jameer wanted to refigure the pigeon project to help her critically analyze her own neighborhood, many youth we have worked with have often told us how they want to use science as a tool to participate in their communities. We often get amazed and surprised by the students' stories, especially by how agential they are and the possibilities they see in bringing science out of the classroom into their lives, whether or not such possibilities were taken up by the teacher. In the story of the anti-smoking skit, science was framed as a context and a tool and learning experiences were designed to foster students' deeper understanding, connection and participation in their community. What we also found from their stories is that how often their desires and agency gets truncated in school science. In the Jameer's story about pigeon study that we introduced at the beginning of this paper, we were amazed by her strong desire to use science as a tool to deeply and critically explore and understand her community and we shared her disappointment by the lost opportunity. After the unit on nutrition, the youth expressed their concern over their school cafeteria lunch. However their concerns and desire for change were stopped there. One of the reasons why science as a tool is often truncated in school science is that place or community is stripped away from the subject object relationship in science class. In other words, students' relationship with their place or community is often times undervalued in school science.

Coda

Valuing place is antithetical to the homogenizing culture of classrooms where individuality is not highly regarded. School place is all that matters. In the healthy snack example, place mattered in so far as it allowed the class to reconstruct how they thought about and applied the food guidelines. However, Mr. M. did not recognize the students' desire to reshape their participation in the classroom or their community through place. The value placed on sense of place was cursory in the sense that he acknowledged the students' point of views as side conversations but the school task was not reconfigured to fully include the students' discourse grounded in their sense of place, their experiences in this neighborhood grocery store. In other words, the kinds of ties the students had with their place were not drawn out or made to matter in how students moved forward with rethinking the food guidelines. Mr. M. returned to the standard guidelines and the students were not challenged to think through how their experiences and criticisms of the guidelines really matter in approaching healthy eating in their school or neighborhood. Through this study we witnessed that students are more agential when science is a context and when science is used as a tool. They have more reasons, more impetus to participate in science because more than just the world of school science is at stake. What is at stake is their place which is not merely condensed into a physical environment but rather, it includes their figured worlds including who they are and who they can and will become. Students exhibit more agency when they can inhabit more than the world of school science in the classroom, because when more roles and perspectives are valued, more kinds of knowledge are valued. Students therefore have more opportunities to act when they feel empowered as experts to act in pursuit of a particular outcome, be it voicing an opinion or applying scientific knowledge in an outside setting such as their out of school communities.

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Chapter 20

Becoming an Urban Science Teacher Teacher Learning as the Collective Performance of Conceptions

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This case study explores a teacher's learning within the contexts of her science methods course and field placement in two elementary dual language classrooms. Elena was a neuroscience major in her second semester of a pre-service teacher education program that also includes a science methods seminar attended by in-service and pre-service teachers. In the seminar, Elena partnered with two dual language teachers from a local, public, elementary school, Ms. Aron, a second-grade teacher, and Mrs. Hernandez, a fifth-grade teacher. She spent one period a week over 10 weeks observing and teaching in each classroom, and one period a week planning with her partner teachers, for a total of 30 h of fieldwork. The dual language model called for all science instruction to be conducted in Spanish. The analysis focuses on two pedagogical interventions employed in the seminar and explores linkages to Elena's classroom practices. Three questions frame this study: (a) In what way do changes in Elena's practices expand her schema regarding children's ideas about science? (b) What ideas do children bring about a unit topic and how does Elena use those ideas to shape instructional goals? (c) What are some of the linkages between Elena's developing schema and practices, her identity, and her enactment of a science lesson? In exploring these questions, I show the ways Elena's conceptions result from individual | collective activity, and thus draw on psychological and sociological frames to describe Elena's journey of becoming an urban science teacher.

Developing Schema, Resources, and Practices

Concepts possess a dual nature, as schema and resources (Sewell 1992). Schemas refer to how individuals structure knowledge in ways that allow connection of

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new knowledge to prior knowledge, recall, understanding, interpretation of sameness and difference, and transfer. Schemas include generalizable procedures for action that may be applied in a wide variety of situations, not always predictably. Schema may best be thought of as potentials, rather than discrete cognitive structures. Resources, such as knowledge, emotional commitments, and physical strength, may have multiple meanings and be employed in a variety of ways. Schemas and resources become evident through activity. Conceptions constitute individual | collective performances since activity require real or virtual others. A view of teacher learning as changes in schema, resources at hand, and practices, and an understanding that as researchers we cannot have full access to cognitive schema, necessitates a focus on what teachers do in the classroom, how they reflect on their experiences, and how they set goals and plan for subsequent science instruction. In the following sections, I describe two pedagogical interventions, or performances, embedded in the science methods seminar. The seminar represents collective activity organized around learning to teach science. Through her journal and other course assignments, Elena reports on the interventions, reflects on them, and evaluates their meaning for her practice. While removed from direct activity in the classroom, the reports embody the context of the school science curriculum, school policies and procedures, the configuration of the dual language program, students' cultures, Elena's culture and history, and her cooperating teachers' cultures and histories. Furthermore, the reports provide evidence for Elena's individual | collective performance of conceptions through instances of construction, elaboration, manipulation, and transformation.

Changing Practices and the Expansion of Schemas

At the beginning of semester, I ask participants to write about their beliefs about science and scientists and their purposes and goals for enrolling in the seminar. In response to the question, "What do you hope to learn from this seminar?" Elena wrote, "How to teach science classes in an engaging manner and not fall prey to the misconceptions of science education. I want to learn tactics and ideas for teaching that encourage all students to enjoy and participate in their science class." Across the data, we can look for ways Elena's developing schema, resources, and practices cohere, or not, with her stated long term goals. As part of the seminar, in-service and pre-service teachers engage in specific pedagogical interventions designed to expand their understanding of children's ideas about science and funds of knowledge and how those ideas might be used as resources in science teaching. Practicum assignments are specifically designed to bridge learning in the seminar with what in-service and pre-service teachers do in the classroom. The first practicum assignment is designed to elicit students' ideas about science and help pre-service and in-service teachers develop goals for challenging or expanding children's ideas about the nature of science. Rather than providing participants with set handouts for the students, the syllabus includes the following instructions:

> Ask students to write or draw a picture in response to the question: What is science? AND/OR Ask students to write about or draw a picture of a scientist. Analyze the class set as a whole. What patterns and/or anomalies do you find? Are any of these patterns related to gender, language, race, or culture? Write a summary of your whole class findings. Then, select two examples and write a reflection about why you chose the examples and what they helped you understand about students' ideas about science. Discuss instructional implications of students' ideas about science/scientists.

General instructions allow in-service and pre-service teacher teams to tailor the activity to different grade levels, students' writing or language abilities, as well as questions they may have about children's ideas about science. For the second grade dual language students, Elena and Ms. Aron developed a worksheet that included the following prompts in Spanish: (a) What is science? (b) What do scientists do? and (c) Draw a picture of a scientist. However, for the fifth-grade students, in addition to the prompts, "What is science? Draw a picture of a scientist," Elena and Ms. Hernandez asked students to write about what you have to do to be a scientist, then name a scientist and explain what the scientist had discovered. The actual performance of this pedagogical intervention in the two classrooms was shaped in part by instructions given in the syllabus, in part by the participants' beliefs about the ways second or fifth graders might represent their ideas about science, as well as by the teachers' particular questions about students' ideas about science. In this way, teaching and learning comprise individual | collective performances of conceptions. For example, the fifth grade activity illustrates the ways teaching and learning draw on individual resources, such as Ms. Hernandez' knowledge of her students' writing ability, and Elena's experiences with becoming a neuroscience major and her notions of the difficulties in becoming a scientist. Second, the activity draws on collective resources available to them through the seminar content. In designing the activity, Elena and Ms. Hernandez exercised agency as they mobilized their schema and resources to improvise a novel approach to the assignment. Finally, as the ensuing analysis will show, Elena's learning from the assignment also rests upon how students responded to the activity in class, how we debriefed the activity in the seminar, and cogenerative dialogues Elena had with her partner teachers about the students' responses.

In the following vignette, drawn from her practicum journal, Elena describes presenting the assignment to the second-graders and notes that a number of students did not seem to know how to answer the question, "What is science?"

> Some of her students were excited by the activity, but others were a bit lost as to the first question: What is science? They said they didn't know, but after probing them for a bit and letting them see it could be whatever they meant, they came to some interesting answers. They all came to the consensus that science deals with the natural world. Since they were studying leaves, a popular response was plants.

The practicum journal consists of weekly entries in which Elena recorded classroom events and reflected on the significance of those events for her teaching. In the above vignette, it is clear that after some discussion, many students made connections between science and their recent study of leaves. The entry shows the ways student performances are also individual | collective performances of conceptions. For students who were a bit lost, teacher probes allowed them to make connections between recent science performances, and how they might respond to the question, “What is science?” Furthermore, from the specific cases of students in the class, Elena drew the general conclusion that students formed a consensus that science deals with the natural world. In her report for the assignment, Elena’s analysis of the responses for Ms. Aron’s class explored issues of gender and science as a social activity. In this vignette, Elena first reveals what may have been her expectations about students’ ideas about science. She then explores the ways language may be used as a resource that reinforces or combats gender stereotypes.

> The students in Ms. Aron’s class did not depict scientists within the traditional stereotypes and generalizations. Only four of twenty students drew scientists with eyeglasses and there was a good mixture of female and male scientists. The presence of both sexes could be due to the way in which Ms. Aron and I presented the assignment and framed the questions. Ms. Aron and I gave the instructions in Spanish and as a result, when referring to scientists we used the female and male nouns, “cientificos o cientificas.” By referring to scientists as both males and females we automatically gave students the impression that men and women could both be scientists. … However, Ms. Aron and I were surprised that despite the balance between male and female scientists, the female scientists were all drawn by girls. Two of the girls even drew nurses, which I found to be interesting because I did not expect the students to relate science to a profession one would typically associate with women.

In this passage, Elena evaluates evidence from students’ drawings and concludes that students did not depict scientists within the traditional stereotypes and generalizations. She also constructs a hypothesis about why more students did not draw stereotypical male scientists. It is clear that Elena expected more students to portray scientists using traditional stereotypes. When students did not employ traditional stereotypes, she reflected on how the teachers presented the activity to students. Elena believed that because they used male and female nouns for scientist, “cientificos o cientificas,” in explaining the activity, students were primed to think of scientists as belonging to both genders. Yet, Elena’s use of the conditional language, “could be due to,” leaves her interpretation open to other explanations. For example, on the worksheet, the two questions were stated as follows: ¿Que hacen los scientificos? [What do scientists do?] Dibuje un retrato de un scientifico. [Draw a picture of a scientist]. The written questions used male forms of the noun for scientist and thus, did not reinforce the verbal distinctions Elena and Ms. Aron made regarding the gender of scientists when they said, “cientificos o cientificas.” In the seminar, across the different ages and responses of students, we noted that younger students (Grades 1–3) tended to draw pictures of scientists that looked like themselves. Girls tended to draw female scientists and boys tended to draw male scientists. Older students (Grades 4 and up), regardless of their gender, tended to draw more stereotypical drawings of scientists, males with glasses, lab coats, and traditional science equipment. Elena’s closing reflection explores perspectives, ranging from shared feelings of surprise to individual interest when students’ drawings did not confirm the teachers’ expectations.

In a second vignette, Elena explores patterns related to the nature of science as a solitary versus social endeavor:

> All of the students referred to science as an activity in which one explores and examines the natural world. Although there were a variety of drawings, the majority of students depicted science as a solitary profession. Sixteen of twenty drawings are of scientists alone surrounded by animals, plants, or unknown objects. … However, I should not jump to such a conclusion since the questions ask students to draw a scientist not several scientists. The four students that drew more than one scientist seemed to understand the need for social interaction in order to learn and conduct experiments.

Elena continues to evaluate evidence and draw conclusions. She recognized that most students drew a solitary scientist and noted that only four students conveyed the idea that science requires social interaction. By highlighting this idea, Elena distinguishes her views from the children's views. It is clear that Elena sees science as a social endeavor, while most children seemed to see science as a solitary profession. Once again, she considers an alternative explanation for the pattern she observed, since the question asked students to draw a scientist, not scientists. Nevertheless, she relates her understanding of children's ideas about science to her ideas about science.

In the following vignette, Elena explores overall patterns in the responses of the fifth grade students in Ms. Hernandez' class. In particular, her reflection focuses on students' responses to the question, "What do you have to do to become a scientist?"

> After reading the students' responses, Ms. Hernandez and I noticed that all of the students saw science professions as extremely difficult. When asked what is needed to be a scientist, the general consensus was, "uno tiene que trabajar muy duro" (one has to work very hard) and "tienes que saber muchos factos del mundo" (one has to know a lot of facts about the world). While in class Ms. Hernandez, Ms. Aron, and I discussed how these results indicate that as children get older they appear to have a more detached view of science, it becomes something strenuous and only for the very bright.

Elena evaluates evidence and concludes that the fifth-grade students considered becoming a scientist to be a difficult endeavor because a person had to work hard and know a lot of facts. She indicates that she and her cooperating teachers created a shared understanding of how children's ideas about science might change over time by comparing and contrasting the responses of the second and fifth-grade students. The teachers concluded that many of the older students were beginning to distance themselves from science because of the view that science is strenuous or only for the very bright. Had Elena only surveyed the fifth-grade students, she might have confirmed her belief that students hold traditional stereotypes as part of their beliefs about science. However, her experience with the second-grade students led her to take a more developmental perspective, that as students get older their attitudes towards science become more detached. The above vignette also illustrates the ways her learning about students' ideas about science occurred experientially and dialogically, through the individual | collective performance of the activity. Dialogue with Ms. Aron and Ms. Hernandez in seminar and in the classroom allowed the three teachers to cogenerate explanations for the patterns they observed in students' responses.

In the next two vignettes, Elena compares and contrasts two second-grade students' responses that were interesting to her. In these vignettes, Elena provides insights into how she made sense of the students' conceptions of science.

> I was impressed by this student's knowledge and ability to express her thought. Under her description of science she named different types of scientists such as archaeologist and entomologist. In her drawing, she drew what appears to be a female archaeologist and all the tools needed for an actual excavation. Gianna labeled all of her tools and even included a map, which shows she has a clear understanding of the activities performed by an archaeologist.
>
> I chose this student's assignment because he had a different outlook on science. His description of science was limited in comparison to Gianna's but his response was a concise and very accurate description. According to Taylor, science is "exploring things," and scientists "look at stuff." … I was also intrigued by his drawing because his scientist looks a little frightened and is face-to-face with a number of unknown items, which is often how scientists really do feel.

Her description of Gianna's responses notes the student's awareness of tools that archaeologists use, the range of activities archaeologists engage in, and other types of scientists. Elena notes Taylor's responses included a concise yet accurate description of science as exploring and looking at stuff. She especially noted how the scientist appeared frightened of the unknown objects. The two responses reveal that some students were able to express deep contextual knowledge of what science was, and others, like Taylor expressed more general ideas about science and conveyed the ways science was foreign or frightening. Through the students' examples, Elena illustrates key dimensions of the concept of children's ideas about science, ranging from a clear understanding of the range of activities and tools scientists' use to the more general idea that scientists explore and look at things. Elena interprets the second child's drawing as showing a frightened scientist and indicates that the child might hold the perspective that science can be frightening. Elena connects this aspect of the child's ideas about science to her idea that scientists do feel frightened in the face of the unknown.

The following vignette shares Elena's analysis of one of the fifth-grade students' responses.

> I chose this student's assignment because I was surprised that one of her responses was extremely conventional and depicts some of the misconceptions students have about science while one of her responses was extremely unconventional. Jenae described science as "something truthful" and "things in the real world." Science is not always about concrete facts and absolute truths. There is variability, questions, constant exploration. However, when asked to describe a scientist, Jenae chose to describe her science teacher. According to Jenae, her science teacher knows many things." It is possible that she chose her science teacher because she did not remember the name of a well-known scientist, but it shows that as teachers one has the ability to leave a lasting impression about a certain subject area.

In this example, Elena hones in on a clear contradiction between her views of science and the child's view. Elena firmly states that science is not always about concrete facts and absolute truths. Elena labels the child's conception as a misconception. As stated earlier, Elena hoped to learn how to teach in ways that "do not fall prey to common misconceptions about science." Thus, it is not surprising that Elena picks up on both the conventional misconception and the unconventional conception in Jenae's response. For Elena, some of the misconceptions about science include the idea that science is always about concrete facts and absolute truths. In addition, Elena is clearly somewhat surprised that Jenae identifies her teacher as a scientist. Conventionally, there is the sense that those who can do science, go on to become scientists and those that cannot, go into other lines of work. As a neuroscience major, Elena had to navigate her own sense and that of her peers and family that she was falling short of her potential by becoming a teacher. Thus, Jenae's response also seemed to resonate with Elena's desire as an aspiring teacher, "to leave a lasting impression."

Much of what Elena notices in the students' responses mirrors her own conceptions of the nature of science and scientists. In this way, her analysis of the students' responses includes her ability to recognize the roles or concepts students were playing. In her fast-write from the first day of the seminar, Elena responded to the question "What is science?" with a concise answer: "Exploration of one's environment and how the universe functions." In response to the question, do you consider yourself a scientist, Elena wrote, "Yes. On a daily basis I observe, examine, and make predictions about my environment and try to find solutions to problems through such things as trial and error or informed guessing." Across her analysis of the students' responses, she represents science as active exploration and observation of the natural world. Science involves the use of tools and exploration of the unknown, which at times can be frightening. Science does not always have definitive answers or Truths, instead science has questions and variability. Finally, Elena positions science as a social activity involving learning how to conduct experiments.

In addition to describing, analyzing class patterns, and exploring the responses of two students of interest, Elena was supposed to indicate the instructional implications of her findings. However, Elena did not include a reflection on the instructional implications in the written report. For example, with the second-grade class, although Elena noted that four students drew scientists with glasses, she did not indicate that this finding warranted any instructional intervention. Furthermore, Elena did not indicate that the students who drew nurses could potentially expand their notions to include a wider variety of scientific professions not typically associated with females. Her findings about the ways Spanish could promote gender equity were not explicitly taken up and utilized to articulate goals for using language more consistently to convey the idea that scientists can be male or female. With the fifth-grade students, Elena did not indicate how she might help students become less intimidated by science as a difficult endeavor and one that requires knowledge of many facts. In looking at Elena's practicum journal, her lesson plans, and field notes from observations of Elena teaching up to this point, it seems that Elena had not yet made the connection between students' ideas about the nature of science and possible instructional implications. Furthermore, Elena had not yet developed the sense that as a teacher she could establish class-wide as well as individualized goals for her students' learning about the nature of science.

Through this assignment, Elena practiced one method of eliciting students' ideas about science. In the process of reflecting on the students' responses she provides evidence that her schema and resources were expanding. She realized how differences between the Spanish and English languages might serve to combat or reinforce gender stereotypes in a science classroom. She expanded her notions about children's ideas about science and drew both comparisons and contrasts between her views of the nature of science and those of her students. In this way, students' responses became a resource that helped her articulate aspects of her own stance on the nature of science. Given that this was the first fieldwork assignment and the difficulties many teachers have incorporating the nature of science in their teaching, the assignment needed to more explicitly encourage Elena and the other course participants to set specific learning goals for the class as whole, and for specific students. Teachers also should have been asked to explicitly incorporate those goals into their planning and implementation of subsequent science lessons. Although changes in Elena's schema and resources might be inferred, linkages to changes in Elena's teaching practices as a result of this assignment were not explicitly reported in her journal, or observed in her teaching.

Children's Science Ideas and Teachers' Instructional Goals

In the second fieldwork assignment, Elena and her partner teachers developed interviews to explore students' ideas about an upcoming science unit. The interview questions included a combination of information-based, probing, convergent and divergent questions. Elena and her partner teachers interviewed six students in each class. This analysis will focus on the findings from the second grade class. Ms. Aron's students had already begun a unit on rocks that was going to continue for several weeks. The school uses kits from the Full Option Science System (FOSS). The second-grade students had completed the first investigation in the Pebbles, Sand, and Silt module. The following vignette, taken from Elena's report for this assignment outlines what activities students had already completed in the unit and some of the concepts they had discussed.

> The students in Ms. Aron's class are completing a unit on rocks. They have conducted several experiments on the different ways to analyze rocks. The students have used magnifying lenses to compare different types of rocks, rubbed rocks together and collected the smaller leftover pieces, and dipped rocks in water to observe changes in color and texture. The students work in pairs for these experiments, but complete independent charts and drawings of their observations. Ms. Aron has used these activities to introduce new Spanish vocabulary words, such as *lisa* (smooth), *babosa* (slimy), *aspera* (rough), and *brillante* (shiny).

The vignette primarily provides descriptive details outlining not only how students have explored rocks, but explaining how Ms. Aron structures experiments with students working in pairs, making observations, and recording their results independently. It is also clear that Ms. Aron was following the kit with a good deal of fidelity. Elena and Ms. Aron drafted six questions to explore students' ideas about rocks. Since science was taught in Spanish, the interview questions were given in Spanish. In the following vignette, drawn from Elena's written report, Elena opens with the claim that the questions were designed to assess what students may already have learned and explore ideas to be developed later in the unit.

> The interview questions we drafted could be used as an assessment of the knowledge already discussed in class and as a guide for the effectiveness of future activities. For the first question, "Describe *una piedra*," most of the students were not able to recall some of the vocabulary words in the chart Ms. Aron displayed. Only one student out of six mentioned the word *babosa* in her response. However, they all noted the differences in size, color, and textures among the rocks they have observed.

For future activities to be effective, Elena and the teachers wanted to know more about children's ideas about rocks, what they already had learned, where rocks were found, how they changed, and what they were used for. Based on the students' responses, Elena concluded that while students could not recall much of the new vocabulary about rocks, they could note differences in size, color, and texture among rocks. The context of the dual language classroom also aligned children's learning about science with Spanish ability. The teachers developed the interview questions in Spanish. Elena found that in order for English dominant students to participate, she had to translate many of the questions. Elena wrote the following:

> Today I finished conducting all the interviews for the second practicum assignment. This time instead of interviewing native Spanish speakers like Andres, I interviewed four students learning Spanish through this class. The four students I interviewed had difficulty understanding the questions, and I was forced to translate parts of the questions and for some, the entire question. I found this interesting because the students appear to follow Ms. Aron's instructions in Spanish with ease. I wondered if they were just used to a routine and were able to follow it despite the change in language. I asked the students to try their best to respond in Spanish. Some did a better job than others, but for the most part, they used a combination of Spanish and English.

One of the goals of the assignment is for teachers to gain a sense of the resources youth bring to learning. From her reflection, it is clear that Elena honed in on students' relative Spanish fluency and comprehension as a resource of high salience to their ability to learn science in their class. From observing students in class, she had gained a sense that their Spanish comprehension was good because they seemed to be able to follow Ms. Aron's instructions. However, in the interview, Elena found she had to translate most of the questions and that the ability of the native English-speaking students' to express their ideas in Spanish was more limited than she thought. For example, Gianna began to respond to the question, "Describe una piedra. ¿Cómo es?" in Spanish, but quickly switched over to English. She said, "Son diferentes, pero hay unas chicas que son pieces of asteroids that fell to the ground". [They are different, but there are small ones that are pieces of asteroids that fell to the ground.] Whereas, Andres, a native Spanish speaker, responded to the same question with, "Como las piedras estan una roca o piedra son fuertes, de diferente colores, grandes, pequeñas" [How the rocks are a rock or a stone they are strong, of different colors, big, small]. He was able to list a variety of ways rocks could differ. For Elena, language proficiency is a key resource students must draw upon to participate in learning science in the classroom, particularly since they taught science in Spanish.

In addition to assessing students' prior knowledge about rocks and gaining a sense of their Spanish comprehension and fluency, Elena reflected on how students were able to draw on prior knowledge to make inferences. She noted:

> Although the students have not taken any formal science classes, the interviews indicate that they are beginning to see how prior information can be used to make inferences about unknown objects and phenomena. For example, when asked, "*¿Qué es la arena?*" only two of the six students responded that sand is not a rock. The other four students described sand as a tiny rock, because as Katy explained, "Some sand sticks together to make a rock." Ms. Aron plans to do an activity with sand, but we were both surprised that some students already understand that sand is a rock. These four students were able to see that sand shares some of the characteristics they used to describe rocks and as a result must fall under the same category.

Making inferences is a central scientific reasoning skill, and it is clear that Elena was pleasantly surprised to see that four of the students were able to make inferences about sand. Part of Elena's surprise has to do with her lack of recent experience with second graders and how they think. In an earlier journal entry, she wrote, "After working with middle and high schools for so long, I have forgotten what it is like to be a second grader." Thus, Elena was able recognize concepts students were performing when they made inferences. She indicates that Ms. Aron was also surprised. It is possible that Ms. Aron was getting accustomed to what her students were capable of, since the interviews were conducted at the end of September. It is also possible that as a science major, Elena was able to recognize the role students were performing more readily than Ms. Aron, who had not majored in science as an undergraduate.

Following the interviews, Elena proposed a microscope activity as a way to follow up on the findings from the interviews. The following vignette describes Elena's purpose for proposing the activity and what she thought students should do.

> In order to further integrate students into scientific investigations and allow them to feel like scientists, I would recommend looking at the rocks and small pieces under the microscope. When beginning a new experiment, Ms. Aron refers to her students as "*cientificos*," so it would be interesting to see how they behave around actual tools for scientific inquiry. The microscopes [would] allow students to fully compare the differences in color, texture, and size between sand and the tiny pieces of rock.

Ms. Aron had just completed an activity in which students rubbed rocks together and collected the little pieces that fell off. Elena thought it would be good to have students use a scientific tool, the microscope, to compare and contrast the tiny pieces of rock to a sample of sand. This activity was not one of the investigations in the FOSS module. Furthermore, it is clear that one of Elena's goals was to "integrate students into scientific investigations and allow them to feel like scientists." Following the first practicum assignment, there was little evidence that what Elena may have learned from the assignment was impacting classroom instruction. Yet, here is a clear articulation of Elena's goals for students and how they might relate to science. As stated above, Elena and her cooperating teachers believed that as students got older they tended to distance themselves from science. By using actual tools for scientific inquiry, students would be positioned as scientists. At the beginning of the semester, Elena stated, “I want to learn tactics and ideas for teaching that encourage all students to enjoy and participate in their science class.” Whereas the goal of integrating students into scientific investigations and allowing them to feel like scientists is consistent with her goals stated at the beginning of the semester, Elena appears to have moved beyond students’ enjoyment and participation in science, to articulating a more agential positioning of students with respect to science, where they act and feel like scientists. In the following vignette, Elena describes how she and Ms. Aron would conduct the microscope investigation with the students:

> Microscopes may be a little difficult to use with such young children, but after observing the students for over three weeks they appear to be mature enough to handle the responsibility. Ms. Aron and I would first explain how students should handle the microscopes and then help them focus the lenses. Since Ms. Aron is using a combination of the play-debrief model and the scaling model, I would try to follow the same structure she has implemented in her rock experiments. It is important not to tell the students that sand is made of rocks, but help them to come to this conclusion through their interaction with the microscope and the materials available. The majority of students interviewed were able to come to this conclusion on their own and the microscope activity would help to test their hypothesis. To introduce some instruction into the activity, Ms. Aron and I could instruct students to record the similarities and differences between the sand and rocks and as a group, discuss the observations.

Several important indicators of what Elena has learned in the seminar and linkages to classroom practices are evident in this vignette. First, Elena is able to recognize Ms. Aron’s approach to teaching prior experiments as, “a combination of the play-debrief model and the scaling model.” Reading about both of these models formed the core of our seminar discussion over several weeks. In seminar, I modeled each approach and we discussed their pros and cons. The play-debrief-replay model focuses on open-ended student inquiry, whereas the scaling model attempts to scaffold student learning and foster language acquisition. Second, Elena identified Ms. Aron’s approach as one that she would model her lesson structure after. In the beginning of the field placement, pre-service teachers primarily observe and support the classroom teacher’s instruction. However, at this point in her placement, Elena was preparing to plan and lead science instruction in the classroom, and she had begun to think about how she will structure her lessons. Third, it is clear that Elena believed that an inquiry approach would allow students who did not realize that sand comes from rocks to make this discovery through their observations. She did not plan to tell the students, “sand is made of rocks,” instead she wants them to “come to this conclusion.” At the same time, students who already know that sand is made of rocks will have an opportunity to test their hypothesis. Having students use the tools of science, discover through observation, and test their hypotheses helps position students as scientists. This point is important because it shows Elena’s belief that she can address students’ positioning with respect to science instructionally, through what she says, how she structures their learning, and the tools, or resources, she provides. Finally, Elena was clear about how she wants students to record their results, in terms of similarities and differences between rocks and sand, and how they will debrief the results in their groups. Moreover, Elena's learning is revealed as an individual | collective performance of self in that language fluency and Elena's conceptions about the nature of science remain key lenses through which she makes sense of the conceptions others are performing in her field experiences.

Developing Schemas, Resources, and Practices

In reviewing the above sections for evidence of linkages between Elena's developing schema, resources, and practices, we can see how changing her practices promotes development of her pedagogical schema and her ability to discern available resources. We can also see that her developing schema have begun to influence how she makes sense of what she observes in the classroom, the goals she sets for students, and how she plans for instruction. In the following vignette, Elena writes about the inspiration for the first lesson she plans and leads.

> Today was my first lesson with Ms. Aron's class. After conducting our interviews, we both noticed that students had difficulty identifying the different ways rocks are used in our everyday life. One student replied that you use rocks to observe and study their shape and color. His response showed that he was aware that he was utilizing rocks in the classroom, but he could not see how they are used outside the classroom.

This lesson builds on Elena and Ms. Aron's shared understanding from the interviews, that most of the students interviewed had difficulty identifying the different ways rocks are used in everyday life. Elena developed a lesson to target this gap in students' understanding of rocks. Since Elena only interviewed six students, she could not claim that all students in the class were unaware of the role of rocks in everyday life. Nevertheless, it was reasonable to conclude that she and Ms. Aron should develop instruction targeting students' understanding of the role of rocks in everyday life. In the following vignette, Elena describes the lesson opening:

> To help students identify the many uses of rocks inside and outside the classroom, I brought in pictures of different items and structures, such as buildings, pyramids, sculptures, adobe houses, clay pots, etc. I began the lesson by playing a game with the pictures I printed. I asked the students to indicate whether the item in the picture was made from a rock.

To begin her first lesson, Elena designed a whole-class activity that involved showing the class pictures and having them guess whether they were made from rocks, or not. To implement her lesson, Elena created a visual resource, a set of pictures of buildings, pyramids, and household objects made from rock materials. Her decision to use a game is consistent with her goals for students to enjoy and actively participate in science learning. The game would facilitate generating students' enjoyment as resource for science learning. In the following vignette, Elena describes how the game worked:

> The students seemed to really enjoy the game, but they may have been a little too excited. I had to ask them to be quiet before I presented the next picture. Ms. Aron had to remind them to be quiet a few times, which was definitely helpful, but I wish I could have silenced them on my own. Then again, I need more practice in this area of teaching and Ms. Aron is their teacher so they respond to her comments faster than to the ones I might make.

As with many prospective teachers, Elena was concerned about how to position herself as an authority in the classroom, saying, “I wish I could have silenced them on my own.” She clearly recognized that she needed more practice in this area of teaching. Whereas the structure of the game positioned Elena as the authority, she determined when they moved on to the next picture. She led the discussion concerning the objects in the picture. But she still needed the support of Ms. Aron to get through the lesson. Thus, Elena still needed to develop authority. In the following vignette, Elena writes about a highlight in the game.

> The highlight of the game occurred when Tyrone, one of the non-native Spanish speakers explained how a clock could be made from rocks. I showed students a picture of a pocket watch and most responded, “No, it is not made from rocks.” However, Tyrone disagreed with his classmates. He replied, “Yes.” And when I asked why he said, “No and Si, because the glass is made of glass, and glass is made of sand, and sand is a rock.” Tyrone went on to explain how sand is compressed to make glass. I was impressed by his response and by the hand gestures he used to explain how the tiny particles of sand come together to form glass. Tyrone reached his hands outward and then clasped his hands together to illustrate how pressure transforms the sand particles into a piece of glass. I was not expecting any of the students to know that glass was made of sand or that sand was a type of rock. Tyrone’s explanation came at a perfect point in the lesson because the following picture contained three wine glasses and the students immediately replied, “Si.”

Elena identified the highlight of the game as the point at which Tyrone was able to bring in his prior knowledge of the relationships between rocks, sand, and glass. Elena believed students would not identify the watch as being made from rocks, and thus was surprised. Tyrone’s explanation and physical gestures became resources for the rest for the class to understand how rocks, sand, and glass are related. This vignette also shows that Elena was willing to provide students with the floor, and give them an opportunity to share their expertise. Elena shared her science authority with Tyrone. The students’ immediate recognition that wine glasses were made from rocks indicate their shared understanding. In the following vignette, Elena describes the second part of the lesson:

> After showing the pictures, I explained to students how they would now be creating their own pictures of the different things that are made from rocks. The items students drew were quite impressive. They drew necklaces, buildings, houses, a wall/fence made of boulders, the planet earth, and even Ms. Aron’s glasses. (I enjoyed that one the most.) Once students were done with their drawings, we returned to the rug and I showed them the different pictures they created.

This activity engaged students in illustrating some of what they had learned about how rocks were used in everyday life. Students drew necklaces, buildings, houses, and even their teacher’s glasses. By returning to the rug to share the pictures, students’ pictures became a resource to reinforce the teaching points of the lesson. Yet, Elena’s description of how she structured the sharing indicates that she collected the pictures and showed them to the class. Whereas time may have been a factor influencing her decisions, the lesson did not provide opportunities for students to articulate what they drew and why. In a dual language classroom, the goals of teaching both content and language, necessitate designing lessons that provide students with multiple opportunities to engage in speaking, writing, and reading science in the target language, which in this case was Spanish. In the following vignette it becomes clear that Elena believed to have met her goals. However, goals related to students' language development were not clearly articulated, planned for, or implemented.

> Overall the lesson was a success and the students seemed to grasp the multiple uses of rocks. I met my goal and the essential question I wanted students to be able to answer. However, I realized that I need to work on my presence in a classroom and giving more clear instructions about how I want students to interact during an activity. Instead of having students shout out the answers, I should have told them to raise their hand if they knew whether the item in the picture was made from rocks. I also realized that I need to practice my instructions in Spanish. I often spoke a bit quickly or stuttered with certain words. My difficulty with the language may have contributed to students' talking during my lesson.

Elena evaluated the lesson and concludes that it was successful, based on her impression that students seemed to grasp the multiple uses of rocks, the essential question driving the lesson. In her reflection, Elena recognized her need to practice giving instructions in Spanish. She believed her lack of fluency contributed to students' talking during her lesson. She also wanted to work on her presence. She realized that how she physically presented herself was a crucial resource for gaining and sustaining authority through the lesson.

The goal for the second assignment was for teachers to elicit and reflect upon what students know about a topic and to design lessons responsive to students' needs, interests, and capacities. In debriefing the interviewing activity in seminar, we discussed the feasibility of interviewing all students and recognized that although ideal, it would be virtually impossible to interview all students before teaching every unit. We then explored a variety of ways to assess students' knowledge, such as through KWL charts, wonder charts, free-writes, quizzes, and investigations, discussed the pros and cons of each, and concluded that interviewing would be one method that teachers could decide to use. We also concluded that the interview approach would be useful for students who might not be able to express themselves in writing. Elena's enactment of the lesson clearly built upon what she learned in terms of students' knowledge. The lesson specifically worked to expand students' understanding of how rocks are used in everyday life. Elena showed some improvisation, when she allowed Tyrone to take the floor and explain how glass is made from rocks. Nevertheless, the lesson did not explicitly address students' other learning needs, particularly with respect to language. In the design of this pedagogical intervention, incorporating prompts that help in-service and pre-service teachers articulated broader learning goals might ensure that science instruction more closely integrates other important learning goals, such as students' language development and oral and written communication.

Agency and Passivity in Individual | Collective Performance

Habitus, internalize social structures, links learning to the social context and the acquisition of rules for action (Bourdieu and Wacquant 1992). Expert teachers have acquired the rules for action in the classroom such that they are able to deliver instruction more effectively. Yet knowledge structuring cannot be standardized, fully predictable, or completely knowable. First, schema and resources structure and are structured by the everyday enactment of social life. At any given moment, teachers have a variety of schema and resources available to develop strategies of action. For example, the resources youth bring to the classroom and a teacher's ability or inability to take up those resources may have a profound impact on the strategies of action employed. Through a series of performances involving colearning, coplanning, and coteaching in seminar and classroom contexts, it is clear that Elena is internalizing strategies for action. Yet, Elena did not simply reproduce those strategies. Instead, her knowledge structuring and the performance of conceptions unfolds dynamically as an individual | collective enactment of self and social life. Agency involves the extension, transfer, reinterpretation or mobilization of schema and resources to new situations. Elena exhibited agency as she proposes ways to mobilize her developing schema and resources for science teaching in new situations. Elena also exhibited passivity in that much of what she learned was intentional. In the following sections, I elaborate on the role of agency and passivity in learning and propose additional frames for research on teacher learning.

One way to conceptualize teacher learning is changes in teachers' schema, resources, and practices, or their performance of conceptions. Agency plays a role in learning as teachers take up available resources and use cognitive schema to develop and enact strategies of action. In the process, the multiplicity of resources and the transposability of schema and resources from one situation to another, allows for new performances, transformation, changes, and thus, learning to occur. At the same time, to a certain extent, all people will necessarily undergo changes, most of which cannot be intended, just by their openness to the world through the senses, language, communication, and their activity in the world (Roth 2008). By focusing on two specific pedagogical interventions, I begin tracing some of the linkages, intended and unintended to Elena's developing strategies of action and practices. Yet, much of what she learned remains in the form of unarticulated and unconscious knowledge structures, strategies of action, and embodied practices. Knowledge production is embedded in and connected to the context. The journals and assignments are artifacts but are not analogous to the actual activities. In other words, there is no-one-to-one correspondence. Rather, the journal and assignments consist of selective interpretations. Yet, Elena's reflections are not possible without her experiences with the students and teachers in the classroom and without her experiences in the seminar. Elena's learning occurred at the nexus of her identity, the identity of her partner teachers, the students, the curriculum, the school culture, the activities she engaged in, and opportunities to reflect, plan, and act upon her plans.

Two modes of passivity are particularly salient to teacher learning as the performance of conceptions. First, "we are responsible beyond our intentions. It is impossible for the attention directing act to avoid inadvertent action" (Levinas 1998, p. 3). This mode of passivity provides a lens into all the ways despite what an individual intends, so much more is happening unintentionally. Passivity provides a clear argument for the role of reflection on both the intended and unintended outcomes for teachers to better organize learning for more flexible, improvisational use in the future. Furthermore, reflection that takes the form of discerning difference, how a given situation differs from prior situations, fosters transfer of learning to new situations. For example, Practicum Assignment I could focus on helping teachers discern differences, rather than overall patterns of sameness in students' responses to the query, "What is science?" Focusing on differences might help teachers develop differentiated learning goals based upon individual students' expressions of the nature of science. Discerning differences might help teachers note when inadvertent action, theirs, or their students, might become a resource for further learning. In a similar way, drawing on the results of her second assignment, Elena found it easy to develop a learning goal that would address most students' responses, wherein they did not seem to be aware of the role of rocks in everyday life. Yet, it is not apparent how she addressed individual differences, such as Gianna's statement about rocks, "the little ones are like rocks that grow from the ground." What did Gianna mean? Did she think rocks grow the way plants do? Did the word grow mean produce, develop, or mature? Gianna's response indicates a need to further explore her ideas about rocks, and perhaps design performances targeted to her learning needs.

A second mode of passivity is that "our consciousness, and our mastery of reality through consciousness, do not exhaust our relationship with reality" (Levinas 1998, pp. 3–4). What we say we know, or understand, at any given moment cannot capture all the interrelationships between thought, word, deed, and the other elements of the activity system. Rather, to a certain extent we are always engaged in multiple performances, such as presenting self, answering, remembering, explaining, considering, planning, and doing, with different roles taking precedence at any given moment. Since a multiplicity of performances occurs simultaneously, including conscious and unconscious, overt and obscure, verbal and nonverbal activities, transactions and interactions, remembering and forgetting, it is likely that for each individual, a unique multiplicity of conceptual developments in a variety of connected or parallel domains has occurred. Furthermore, some developments might align with a more incremental developmental process, whereas others might undergo a breakthrough or dramatic process. Finally, the ways identity mediates the processes of encoding and accessibility of memories, in terms of coherence and correspondence, ensure that a focus on a particular desired outcome or product, the verbal exchanges and gestures, or the overt activity, will at best provide an incomplete and partial description of the performance of conceptions and an individual's role in the performance. We may never have complete access to the cognitive dimension, or the mental models and conceptions of others, especially since they are always in a state of construction, deconstruction, and reconstruction. However, we do have access to the environmental and practice dimensions. If teachers utilize a variety of approaches to understand students' conceptualizations, including collaborative and individual performances, they can begin getting a sense of where teaching priorities might lie with respect to enhancing students' individual | collective performance of science conceptions.

Where Next?

Research has shown that science teachers bring | perform conceptions about science, science pedagogy, schools, and how children learn that may not be in harmony with reform-based teaching methods. Furthermore, teachers' performance of conceptions and beliefs may be firmly held and resistant to change. While sustained professional development has been shown to have an effect, those effects are by no means uniform, with much of the difference explained by differences between teachers and differences between teaching contexts. This study shows that regardless of my intentionality as a teacher educator so much more is happening and should happen because we are engaged in social life. As individuals we all engage in a dynamic process of becoming, and who we are becoming is a product of our inner thoughts, feelings, and memories, the actions we engage in, and the people and places that frame our lived experiences. Analysis of Elena's science lesson plans, her reflections about her teaching, and informal observations of Elena's science lessons illustrate both "gaps" and "elaborations" between intended science instruction and actual science instruction. One day we may have a better understanding of the possible forms conceptions take. We may also better understand the processes of correspondence and coherence that frame memory, learning, and identification. Until then, I believe it is appropriate to continue the search for a fuller understanding of the process of conceptual development, to explore multiple models for thinking about conceptual development as an individual | collective performance, to gradually draw the circle wider and include the biological, emotional, psychological, and social aspects of the change process, and to make salient to the lives of teachers and students, the outcomes of such research.

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Chapter 21

Science Agency and Structure Across a Lifespan A Dialogic Response

Jennifer D. Adams, Christina Siry, Koshi Dhingra, Gillian U. Bayne*

We are a group of science educators and researchers who are culturally diverse as well as diverse in our science teaching and learning experiences. We have worked with teachers and students from the elementary through the university level. In reading the four chapters in this Part C, we draw on our experiences of researching and teaching in various formal and informal settings to ask critical questions about the importance of making science education a multi-contextual, pan-cultural endeavor. What follows is a dialogic response that explores the major themes that emerged for us in the four chapters. We asked ourselves questions to deepen our understanding about science teaching and learning in different contexts such as, what is the goal of formal learning spaces? How can we bring to the forefront teachers' roles and agency in educational research? How can we use students' and teachers' individual life stories to create an inclusive learning community in the science classroom? What is the role of emotions in learning science? This writing approach allows us to share our individual perspectives while we build a collective understanding of connecting science teaching, learning and educational research across different contexts and lifeworlds.

The Goal of Formal Science Learning Spaces

Koshi: I begin with the question, "What is the goal and role of formal science education spaces (i.e., school science)?" I have suggested elsewhere (Dhingra 2008) that given the breadth of science (as context, tools for participation in an

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economy, a political society, a local community, etc.), it seems inappropriate to rely on the single institution of school to fulfill the task of providing children with science education opportunities to move forward in their journeys of becoming.

Jen: This is why it is important to consider both the formal and informal spaces where people learn science. For me, the notion of informal science education goes beyond learning in science-rich cultural institutions. Although people learn science in these spaces in a self-directed or “free-choice” (Falk 2001) manner, culturally they are still a part of the dominant western modern science discourse. I believe that we need to examine how people learn and understand science in their own communities and cultures in order to better relate classroom science to their lifeworlds. I also believe that peoples’ understanding of and interaction with science is deeply connected to their sense of place, as evident in Katherine Richardson Bruna and Edna Tan, Angela Calabrese Barton, and Miyoun Lim’s pieces. Jeff Malpas (1999) describes places as internally differentiated, interconnected and often nested and that this nesting is significant in place and memory. Richardson’s ethnography of Omar’s experiences with rocks in different places across his lifespan illustrates this point. Although Mr. Roberts did not explicitly make the connection between the science content and Omar’s life experiences, Omar was able to use the tools and resources (memory) he gained in his house building and border crossing to negotiate the geology activity in the classroom.

Koshi: Perhaps it is useful to think of the science classroom as a clearinghouse for the multiple stories/memories and identities created by learners and teachers in their diverse communities of practice. Maria Varelas, Justine Kane, and Christine Pappas seemed to speak of this clearinghouse function of school science when they state: “Jennifer and the children were bringing every day into the classroom their own histories composed both inside and outside of the classroom.” Here, these stories are exchanged, discussed, reflected upon and used as tools for further probing and application; they are foundation for shared activity that produces new meanings and identities for classroom community members, including the teacher. The classroom becomes a place where learning is validated, deepened, questioned, reflected upon and where classroom community members coauthor new life stories. Thus there is a value placed on the various contexts where science is experienced, such as the museum, the videogame, the television program, or family life.

Jen: The various contexts you mention makes me think of Richardson Bruna’s description of “society, schools, and selves as haunted spaces where not only can we encounter ‘the lingering past’ but we can also divine the hastening future.” This resonates with the notion of nested places and memory—the internally constituted places that students and teachers bring into science learning spaces and the futures that we wish to discover/uncover/create together. However, I would like to think of science learning spaces (both in the classroom and in informal science spaces) as cultural crossroads instead of clearinghouses since in clearinghouses, information is collected and distributed, implying that the information remains unchanged. At cultural crossroads however, different cultures meet and exchange information/ideas and leave the space created by this crossroads slightly changed if not transformed. I think that if we are to expand the notion of science—who has access to scientific knowledge and who feels like an insider to this culture or context we call science—we need to describe more of an expansive place that allots for the exchange of ideas in such a way that people can take ownership—in the sense of knowing and a cultural connection to the ideas—of the ideas generated in the space. Richardson Bruna mentions early on that creating spaces where science could be told from a different cultural story is an act of social justice. Tan et al. describe this as science as context—creating a space where students' sense of place includes the science that they know, understand and is relevant to their day-to-day experiences.

Chris: As this volume focuses on the role of conceptions in science, I see this discussion about the ownership of knowledge and personal connection to ideas as important and relevant to all four chapters in this section. In particular, Tan et al.'s work concludes, among other things, that "students are more agentic when science is a context" and the authors advocate shifting the position of science in classrooms to be framed as a context and as a tool. This can provide an approach to the expansion and possible transformation of knowledge and students' conceptions through cultural exchanges; and it is important to our exploration of the goal of formal learning spaces.

Koshi: I agree that the notion of transformation of self and others is an important one to include in a comprehensive vision of science learning spaces. I want to find a way to include the feel of randomness, however, which comes with use of clearinghouse. Multiple forces—frequently not acting in concert with each other—are at play in the classroom and school culture. Both children and adults enter the classroom with different interpretations of classroom goals and home cultures that shape those goals. Somehow, they are supposed to build a community in which they learn from each other and transform themselves and their environment. To me, it is helpful to acknowledge the chaos that often exists when diverse people attempt to build an effective learning community. In a community where all participants contribute to a shared knowledge culture in the classroom, it is necessary to understand and make public the personal stories that connect to the evolving classroom script. Most people have had experiences with school science that surreptitiously shape all other understandings of science that is an integral part of the memories and stories that people bring to a learning community. I want to find a language that is reflective of this chaos or "shaking up" of memories and stories—having all participants in the science education networks to revisit the structure and function of school science and its relationships with other social contexts in which science is experienced.

Gillian: Shaking up memories and understandings of school science is a challenging task. I feel that it requires stakeholders to take active roles in pursuing a more complex understanding of the many contexts within which science education takes place, and subsequently shapes individual and collective views and experiences. What comes to mind here is Joe Kincheloe's (2001) notion of a critical complex epistemology, which encourages the critical examination of forces that have mediated (and continue to mediate) science knowledge and understanding. We are urged to, "examine not only the popular domain, but the hidden rules that shape cultural production [science teaching and learning] in general" (p. 146). The ideas of building communities of solidarity and challenging assumptions about politics, culture, psychology, human potential, economics and the like, as they relate to the dynamics of science education, are essential to the construction, growth and metamorphosis of schools and school science that are rooted in truth and integrity.

Jen: Koshi, the randomness you describe reminds me of Antonio Benitez-Rojo's (1996) cultural application of Chaos theory, "where every repetition is a practice that necessarily entails a difference" (p. 3) or a repeating difference. In fields or nested/ing places there is a randomness of memory (haunting) and experience that is also repetitive, thus if one creates a learning space that capitalizes on this chaos there is the potential of generating new knowledge/ways of thinking/describing that includes the repetitive elements of the place-based memories that people bring to the learning space. Gillian, I am glad that you bring up the importance of critical examination of the generation of scientific knowledge and understanding. When the fruits of chaos are realized, we can move towards more cohesive and democratic science learning communities.

Encounters and Hybrid Spaces

Gillian: I like to describe science-learning spaces as fields where culture is produced and shared, reproduced and transformed. In thinking about and experiencing the dynamics of such a field, the challenge of protecting it and those who are engaging in it comes to mind. As I reflect upon Jennifer's (in Varelas et al., excerpt 2, line 55) encounters with students who eagerly wanted to participate in sharing their ideas and then didn't have the opportunity to do so, I am struck by the importance of students and teachers having opportunities to revisit and reflect on classroom experiences. Within my own lived experience as a science teacher, I have found that by using cogenerative dialogues to create an interstitial space with my students and other stakeholders, opportunities to learn from shared experiences help to make the unknown known. Video analysis of classroom experiences and cogenerative dialogues become important tools to use when revisiting encounters as the study of encounters involves not only a study of what has been said, but also emotional and prosodic qualities, gestures, individual motives and collective goals. I would guess that if Jennifer, Lawrence, and their classmates (Excerpt 2), as well as Justine and other researchers involved in the collection and interpretation of data, were able to revisit these qualities that characterize encounters together, many new stories of teaching and learning in this third-grade science field would emerge. Chris, I know that you have done some analysis on a variety of encounters that have occurred in your own classroom. What did your work entail and how did your findings help you to better understand classroom culture and/or make known what you had not already known?

Chris: Encounters are central to my examination of the emergence of solidarity within a classroom. Specifically, I am exploring the role that coteaching and cogenerative dialogue play in facilitating solidarity within a group of pre-service teachers. In my methods course, participants and I collaboratively develop and coteach science to children in elementary classrooms. In our analysis and interpretation of this work, I am continually struck by the layers of encounters that unfold in group interactions. By identifying and revisiting encounters together, we have been able to shed light on mesolevel and microlevel evidence of emotions, and have been working towards identifying implications for teacher education learning environments. Incorporating cogenerative dialogue in the analysis of these encounters has enabled us to enact culture that expands the agency of all participants in the group (myself included). Further, as we collectively revisit encounters that may have passed unnoticed to some of us individually, we are able to enact curricula so that we can improve the quality of teaching and learning in our class. Returning to our initial theme for this chapter, this can be considered to be one example of the many ways that we can reconfigure learning spaces in classrooms. When I think about my approach to researching encounters with my student-researchers (the pre-service teachers) I sometimes wonder how we can position this type of encounter analysis in classrooms in which the student-researchers are children. Gillian, I know some of you have had success in utilizing video-analysis with your students. Perhaps you can elaborate on this in relation to our discussion around cultural crossroads and creating hybrid classroom spaces?

Gillian: Over the course of 3 years, my ninth-grade biochemistry students and I did indeed create hybridized spaces by using cogenerative dialogues (Bayne 2007). We found these hybridized spaces to be extremely helpful, especially since they are grounded in inviting polysemic interpretations of the unfolding of social life and polyphonic opportunities for all participants. Some outcomes of using cogenerative dialogues were that my students and I were able to (a) learn a great deal about student identities, both inside and outside of the science classroom; (b) more clearly understand the nature of students' science content misunderstandings and address them in a mutually conducive manner; (c) transform pedagogical practices so that students became increasingly involved in the coteaching and coplanning of lessons and laboratory experiences; (d) create an environment that supported the management of classroom behavior in a distributed fashion, and (e) involve students in data interpretation for more deeply understand how they experienced their science learning environments.

In the four chapters we see many examples of hybridized identities of both teachers and students, as well the need to create and use diverse teaching styles. In Maria Rivera Maulucci's chapter the instruction of science required a dual-language approach in Spanish due to the student population. In one vignette, the student teacher Elena's recollection of students' responses to the question, "What is science?" clearly demonstrated a need for polysemy and polyphony for a collective definition to be generated. It would be interesting to learn how emotions, gestures, and body in addition to the spoken words mediated encounters amongst Elena, her students, Ms. Aron and Mrs. Hernandez.

Jen: These are good examples of the research methods that could be used to uncover the structures necessary to produce an inclusive learning community. The methods that you both discuss not only allow for researchers to learn more about creating a polysemic science-learning space, but also allow stakeholders to participate in creating such a space and the tools necessary to sustain a learning space that is truly a learning community.

Teacher's Roles and Agency

Koshi: Whereas student agency is a valuable concept and goal, I'd like to see more talk about teacher agency. In my work with many teachers, I hear their feelings of their dreams, hopes, and ambitions for their students. Although less important to consider, since the adult tends to be in positions of greater power than their students, I feel it is helpful for teachers to have the opportunity to consider their own agency in the classroom.

Jen: Given our discussion about creating expansive learning spaces I think the notion of teacher agency is a very important point of discussion. Whereas teachers may have agency over the content and pedagogy as we, as researchers, are encouraged to situate ourselves vis-à-vis our research, it is important for teachers to do the same vis-à-vis their students and their autobiographical selves. Rivera Maulucci touches on this in her study with Elena discussing her changing identity and conceptions about science based on her interactions students during student teaching. In her study, the lens clearly examines the teacher's role and changing self-identity as she reflects on different activities and interactions that she has with students and colleagues.

Gillian: My university students, especially those who are pursuing their degrees through alternative certification routes have spoken of teacher agency in a variety of ways. For example, many have noted that while they have extensive content knowledge, they often feel as though they cannot adequately transfer it into their urban science classrooms. Despite resource and administrative challenges, misalignment of student and oftentimes teacher cultures, my university students want desperately to be effective and happy teachers. They feel that if they could summon up the power to act in appropriate ways, they would feel more secure in their pedagogical practices, have a better sense of self-efficacy and self-confidence early in their teaching experience. Hence, the ripple effects of teacher agency would also increase science understanding and fluency in their classrooms.

Koshi: With this in mind, it is important to consider the teacher's role. Based on my work and readings I believe that the teacher's role must emphasize the following: (a) an understanding of developmentally appropriate pedagogies; (b) an understanding of (and participation in) the local community and existing relationships with other community structures—for example, museums or community-based organizations groups; (c) an understanding of own funds of knowledge, assumptions about community and students, and goals of science education for the particular students in the classroom (This is an area that the teachers in three of the four papers fell short. Clearly the focus on science as a goal vs. science as a tool and context represents a barrier for most of the teachers described in these chapters. The result of their overemphasis on learning science content as opposed to using science as a tool and context to expand student understandings of their own lived experiences, was that their students missed out on such possibilities); and (d) finding the wiggle room whether in a high-stakes testing oriented culture or in an ELL classroom with underserved children to address the above, for at least some units/spaces in the curriculum.

Jen: Research should further examine these roles that you outline. To often, the teacher is portrayed as the perennial outsider—always disconnected from the lives and cultures of the students. I know, as most of us who have been teachers and continue to work with teachers, that although this is the case in some instances, there are equally as many instances where the teacher is not an outsider, but an insider to the lives and cultures of the students but also struggling with her role as a science teacher when she has not quite reconciled her own understandings and beliefs regarding school/institution science versus her own cultural understandings of science. Where is the space that she can merge her own cultural understandings that are similar to that of her students with school science? Is her role that of a cultural broker/translator in this instance? What can outside educators learn from inside educators without subjugating or objectifying this intimate knowledge? This is what you allude to with your third point and I think this reflexive examination of one's own funds of knowledge is important in any instance but not only assumptions about the community, but assumptions about one's own situatedness vis-à-vis the community.

Chris: The way that researchers portray teachers in the writing of their research is an issue that is personally very important to me. Many of us are teachers or have been teachers, and it is critical that we take care to find ways to write about teachers' roles in classrooms without subjugating or denigrating others' forms of knowledge and experiences. Sometimes I feel that it is easy for people to find fault in teachers' actions without acknowledging the constraints that are placed on teachers. These questions that you raise are critical to consider before pointing fingers or placing blame. It is in researching with as opposed to on teachers that we can provide a polysemy that is often missing in research. Whereas I certainly recognize that there are a myriad of directions that writing can take, I believe in trying to find ways to embrace an approach to research that moves away from the authoritarianism of the researcher to include a multiplicity of perspectives. In doing so, we can seek to avoid a further deprofessionalization of teachers and acknowledge that teaching and learning are complex cultural enactments.

Koshi: Yes, I completely agree. I would love to hear the teachers' take on the descriptions of the classes we read about in these papers, for example. Whereas I recognize that, realistically, every study has to draw the line somewhere, wouldn't it have been useful and interesting to follow up with the teacher in some way so that research and classroom practice formed a tighter association? As you point out, if teaching is a complex cultural enactment as we know it to be, then should we not include teacher perspectives when we analyze the domain for which they are the key responsible adult?

Chris: Certainly every study has to draw the line somewhere; that is a good point. I contend that in adopting participatory approaches to our research we can include teachers as well as students in examining issues of teaching and learning and together we can decide on where that line can be. Joe Kincheloe and Kenneth Tobin (2006) have written that in order to take "the complexity of the lived world into account, we have to study the world 'in context'" (p. 5). More specifically, incorporating coteaching and cogenerative dialogue as context-specific methodological approaches to my research with teachers and students has supported us in providing differing perspectives in the research, as well as sharing responsibility for working towards our goal of improving learning. This approach has enabled us to go beyond having research and teaching practice have a mere association, but rather, teaching and research become intertwined and in many ways inseparable as we collaborate to create polysemic research.

Individual and Collective

Chris: In all four chapters I am struck by the importance of considering the dialectical relationship between individual and collective. Too often in my own work in urban elementary classrooms, I see individual knowledge seeking privileged far beyond collective experiences and shared knowledge construction. The role of students as members of communities is often overlooked as teachers and students work towards individually accountable success. This individualization of educational experiences is certainly an incredibly complex issue. But I wonder if an evident focus in our work with teachers on facilitating a greater appreciation of students' sense of place can lead towards a more holistic approach to exploring science not only in context but also as collectively relevant. Tan et al.'s chapter emphasizes the power of seeing science as context, and the possibilities for engaging students in locally legitimate approaches to learning science. Perhaps it is in seeing science as context and developing a communal view that can serve to facilitate a greater emphasis on classrooms as communities, and conceptions as collective constructions.

Koshi: This dichotomy goes hand in hand, in my mind, with the dichotomy of the perception of intelligence as a fixed trait as opposed to being seen as being changeable or correlated to effort invested—that is, an entity theory of intelligence as opposed to an incremental theory of intelligence, as described by Carol Dweck (2000). In my mind, an incremental theory of intelligence goes hand-in-hand with situated learning theories that underlie the spirit behind our discussion. An emphasis on an entity theory of intelligence makes individuals vulnerable to failure and needs to change. Further, we can imagine the effect of frequent evaluations, which are the hallmark of traditional classroom interactions with the teacher, when such evaluations interact with a student's vulnerability to the perception of failure. Classroom cultures in which frequent evaluations are part of the routine support an entity theory of intelligence; they do not support a mastery orientation in the participants but instead tend to lead to the helpless pattern as the key student response. To work toward the goal of supporting mastery orientations in student participants, learning communities need to be cognizant of the central roles played by student self-concept and the resulting psychological world a student creates for herself. In other words, intelligence becomes a label for and product of a wide set of prior student experiences, which include cultural positioning and access, all of which are continuously processed in the lifelong task of self-transformation.

Jen: To me, this resonates with our discussion of the science classroom as a cultural crossroads of sorts—creating a learning community that incorporates student and teacher understandings of sense of place—both the external and internally constituted notions as it relates to how students being-in-the-world shapes their understanding of the natural world and their world views of science. Creating learning communities that foster this type of cultural exchange is important in the type of work that we aim to do. I know that my research interests aims to explore more of how students' sense-of-place influences their ideas about their natural world, especially in urban environments, and how we can use this understanding to help students gain a broader knowledge of science and acquire the ability to understand and intelligently discuss science as it exists in their communities and in the broader global context.

Koshi: We all seem to agree with the authors of the papers we are discussing, that instead of seeing science content as the goal, it is more constructive to view science as a set of tools and as a context for certain experiences/activities. The former goal (science as content) has limited bandwidth and is frequently exclusive. We need to invite the whole student into the classroom, and continuously bridge the classroom experiences to other sets of experiences. As we invite students to be active participants in this bridging process, we should create a space where they could share their stories with the classroom community, thereby building a true community of practice.

The Role of Emotions in Science Learning

Koshi: In all four papers, there is emphasis on the notion that emotions of learners are important factors that shapes their experiences in different learning contexts. How we feel about our colleagues/peers, the power structures that exist in the various contexts that we work/live/learn in shapes our view of ourselves in that setting and the power we possess within that realm. How can a focus on science concepts as a goal allow space for teachers to figure out how students feel about themselves as learners in the classroom? Clearly, in Richardson Bruna, in Tan et al., and in Varelas et al.'s studies, the researchers found that teachers with a focus on attainment of science concepts as the primary goal were unable to effectively gauge students' feelings about themselves as science practitioners. Rivera Maulucci describes the importance of prior experiences on a teacher's identity-in-practice.

Yet, I fear that if I were to talk about the importance of figuring out how students feel, most school administrators and teachers would roll their eyes at me! We need to reveal practices that allow teachers insight into students' deep understandings, including personal relevance and opinions. For example, there maybe other ways of communicating with both the teacher and Omar about how Omar would have greatly benefited from some opportunity in the unit on rocks in the classroom to share his own experiences around rocks. Maybe validation of his funds of knowledge would have left him feeling that his experiences had worth in the classroom. It might not have solved the problems that led him to join the workforce instead of completing high school, but having a richer experience could have provided a richer personal development for him, that would always have been his to remember and to draw from.

Gillian: And from an emotional standpoint, what might students take from such environments—where teachers and school administrators might turn their backs and/or roll their eyes? I feel that central to the art of teaching are emotions. The materialization of emotions from human interactions takes place due to a variety of cues—text, body language, eye movement, prosody, and the like. One example of the materialization of emotions is provided in *Teaching to Learn* (Tobin and Roth 2006) where the authors present an example of interactions between Mirabelle (student) and Victoria (teacher). This analysis provides an example of how reexamining social life at the meso- and micro-levels can help to understand and predict the emotional content and the power dynamics that transpire as social reality in the science classroom gets enacted. To better understand and appreciate the challenges faced by an increasingly diverse and complex student population today, it is crucial to consider new pedagogical and theoretical lenses through which emotional considerations at macro-, meso-, and micro-levels can be studied.

Jen: Koshi has commented that when science and emotions are mentioned in the same sentence, eye rolling would be a response, and I would especially expect that from those who still view science as neutral and culturally objective. The notion of emotions in learning go beyond how student feel about themselves and the content, but also extends to their interactions with others in the science classroom. Having interactions that generate positive emotional energy are important in creating lasting memories about science and learning science as is connecting science to students lifeworlds—affording them the opportunities to feel positive about their own cultural knowledge/experiences with science that they bring into the classroom.

Chris: The emergence of emotional energy through interactions connects back to our earlier discussion about the importance of considering the relationships between individuals and the collective. Emotional energy and the production of emotions is an important consideration in working towards group solidarity (Collins 2004). Through this lens, successful interactions can lead to high levels of emotional energy, and sustained levels of high emotional energy can lead to solidarity among participants. I believe that a connection between roles, success, and emotions is highly relevant to work in our classrooms, especially in the teaching and learning of science. In particular, in seeking to successfully connect science to students' lifeworlds, finding approaches to generate positive emotions is a critical consideration towards students experiencing success.

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Part D

Epilogue

Chapter 22

Sociology | Psychology | . . . Toward a Science of Phenomena

Wolff-Michael Roth*

During the late 1980s, having done (neo-) Piagetian and information processing research before, I found radical constructivism and its individualist approach to theorize knowing and learning very fruitful. Soon thereafter, however, when analyzing classroom videotapes featuring students working together on problems, the limits of an individualist approach to thinking and learning became to be apparent to me. In 1992, I published what probably was the first science education paper on the social construction of knowledge in science classrooms (Roth and Roychoudhury 1992). Despite other work on the social construction of knowledge, however, science education remained in the grip of theories that focus on the individual (mind) as the unit of analysis. Even those scholars who used discourse analysis, cultural studies, and Bakhtin's dialogism as frameworks for understanding events in science classrooms continued to make attributions to individuals and therefore subordinated the new approaches to psychological (constructivist) ways of thinking about knowing.

Following an invitation by Ken Tobin, Yew Jin Lee, SungWon Hwang and I published a piece in which we show how conceptions are the result of complex processes that could not without many presuppositions attributed to individuals, though the current canon in science education does in fact make such attributions (Roth et al. 2008). I also published a review article, in which I show how one arrives at very different attributions for the origin of conceptions and conceptual change if one were to take a discursive psychological perspective (Roth 2008). Both of my articles took a cultural perspective as their starting point, asking at their outset questions that go something like "What does it take to develop a science of misconceptions given a starting point where there is no (psychological, sociological) science?" Yet, rather than leading to the rethinking of traditional positions, the two pieces caused some stomach upsets among those who have

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invested their lives' work in the development of conceptual change. It was Ken Tobin's idea to make the question of a reunification of sociological and psychological perspectives the focus of the *Second Springer Forum* held in New York at the Graduate Center of the City University of New York. The participants were invited to think about how to organize a reunification of the two very different approaches to knowing and learning in science.

The *Forum* and the present book are the result of this start of rethinking traditional approaches and of developing a new approach in which the two heretofore-oppositional approaches could somehow be brought together. In fact, the very idea of re-unification means that there had been times when researchers (and philosophers) took a more unified approach, an approach that has come undone, and an approach that we are now somehow attempting to recover in new and transformed ways. We do know that in some non-Western cultures, individuals see themselves through the lens of the collective, thereby explicitly understanding the Self through the Other, emphasizing the sociological and contextual aspects of everyday life over psychological aspects (e.g., Geertz 1983). Of course, there are questions in and to such a project. For example, one might ask, "At what cost is any reunification achieved?" (Just think about the costs that both sides in the reunification of the two Germanys have incurred, as we can take from the deep-seated mistrust and antipathies expressed in the East and West, respectively.) Is it possible to come up with a framework in which the particulars of each approach are, if not the same, though different and contradictory realizations of some underlying principle? I am thinking of what happened in physics at the beginning of the twentieth century when there existed a wave–particle dualism with respect to the nature of light. Subsequent work showed that the two perspectives were different realizations of an overarching phenomenon, that is, light, which came to the fore under different conditions of experimentation. Can science educators achieve something similar, that is, produce a theory in which psychological and sociological approaches and facts are but effects of one-sided nature?

This question oriented my writing of this epilogue, which I intended before actually sitting down to write to be precisely about the conditions that would have to be fulfilled to think sociologically | psychologically about knowing and learning in science education. In traditional dialectics, two opposites (thesis, anti-thesis) were sublated (*aufgehoben*) in the creation of a synthesis (Hegel 1979). The German verb *aufheben* exists both in the sense of to eliminate and to keep. Whereas synthesis traditionally was taken to mean an elimination of the contradiction of the opposite terms, my own emphasis, consistent with dialogism, lies with the keeping of difference. The Sheffer stroke "|" in the composite adjective psychological | sociological and adverb psychologically | sociologically allows us to understand each of the two perspectives as but realizations of a more general concept; and as in all such cases, the perspectives stand in a contradictory relationship that just may turn out to be exclusionary. But by the very fact that there is a higher-order concept, we are faced with the possibility of retaining (keeping) the two perspectives in a new perspective, where the mutually exclusive terms come to coexist. Neither term is reduced to the other, each having the right to exist all the while users recognize that the perspective (position) is but one among several, here two, but potentially many. The coexistence provides for the possibility of a dialogue, and it is precisely such dialogue that lies at the origin of continued development of ideas (Bakhtin 1984). (On this point see also Tobin's chapter 2.) And the new entity is, consistent with recent philosophical work on difference as such, heterogeneous, different within itself, involving a mêlée of irreducible ideas. Monological approaches—to which Bakhtin counts traditional science—have finalizing tendency, adhering to the fantasy of a Truth, whereas dialogical approaches inherently lead to continued development and non-finalization. This concept, non-finalization, leads us to learning; and it is precisely non-finalization that has allowed me personally to test many different theoretical frameworks in the course of my career, abandoning those that turned out not to be useful. I abandoned individualistic approaches, such as radical constructivism, information processing, and other related theories precisely because they had little explanatory power when it comes to understanding human interactions and the traces they leave in people.

Dialogue, and especially its tendency to develop ideas, has an effect that scholars rarely think about: erasure of past knowledge, which only remains in the form of a trace (Derrida 1967). Dialogical talking and writing, by the very fact that they lead to development, also lead to the erasure of past understandings. If it were not in this way, we would carry around all of our old understandings side by side with new understandings; and very soon in our development we—our minds—would crash under the burden of knowledge that had outlived its day. This forgotten knowledge constitutes the rubble on and out of which the new is built, but as in architecture, the cornerstone of a mosque no longer reveals its earlier life in a Greek temple or a Christian church.

At this point of the book, the contributors as a collective have covered a tremendous amount of ground, including very different perspectives on issues of knowing, learning, and identity in science education. I do not attempt a synthesis—which may lead to little more than fusion and confusion. Rather, before beginning to write this text I set myself the goal of articulating some fundamental conditions that we have to take on board when we study knowing and learning such that important aspects of the sociological and psychological dimensions do not get lost in our inquiry. Thus, in the past too much science education has been conducted that focused on knowing, conceptions, learning, and conceptual change without actually studying the conditions that lead to the reproduction of inequities along gender, race, culture, socioeconomic status, social class, and other lines. This is precisely the point that Chris Emdin (chapter 15) deplores concerning the lack of understanding for the learning and structural exclusion of African American students in urban settings; Kathryn Scantlebury and Sonya Martin ask a similar question with respect to gender and science achievement. Concerning my own context on the Canadian West Coast one might ask, "Why do so many First Nations students never finish high school let alone engage in scientific careers?" This is exactly one of the areas where we need to develop approaches that do not leave out of sight the conditions that work against individuals of different gender, race, culture, socioeconomic status, social class, and other dimensions all the while studying knowing and learning. What are some of the conditions that we need to fulfill so that important dimensions do not fall out of sight, outside of the clearing where we can see; and what are the conditions so that important phenomena do not fall precisely onto our blind spots, where, as in the first set of conditions, the important issues remain unseen. My a priori intent for writing this epilogue will have been to achieve the articulation of a position within which sociology and psychology are but one-sided realizations of more general approaches and principles.

In the following, I focus on three topics that may assist us in rethinking science education research and toward a reunification (or whatever) of sociological and psychological approaches. I begin with a discussion of the unit of analysis, which cannot be just the individual mind and which cannot be just the social conditions. There is more to learning science, which we will not see if the relevant phenomena fall outside the cone of our searchlights or if they fall onto the blind spots of our perceptual apparatus. Second, I sketch an approach that already includes the two ways of thinking about knowing and learning: cultural-historical activity theory, which most explicitly is used in chapter 19 (Tan et al.) though it also underlies the Stetsenko and Richardson Bruna chapters, is a societal-psychological approach that promises to be at least a good starting point for rethinking the basic tenets of science education research and theory. I emphasize the adjective societal, which includes inequities that exist in any society, but which fall outside our searchlights or onto our blind spots if we use the adjective social.[10] In the third section, I turn my attention to the question of building capacity. What can we do and what do we need to do to encourage and facilitate a reunification of psychological and sociological forms of thinking with respect to knowing, learning, and teaching in science education?

Unit (of) Analysis

The issue of the unit of analysis has already appeared in the discussion of several contributions, including the ones by Stetsenko, Smardon, Roth, Mortimer, Hsu, van Eijck, Maheux, and Varela and colleagues. It is likely one of the most central issues in the question of the relation of sociological and psychological work specifically and in social science generally. What research can discover depends on the chosen unit of analysis. Sociology and psychology have differed in the past in their units of analysis so that it is not surprising when the disciplines have focused on different phenomena and make very different claims about the reproduction and transformation of individual and social/societal life. Psychologist tend to think about life in terms of processes that occur in the mind and that control what human beings do when facing tasks or learning challenges. *Psykhè*, in Greek,

10. The Anglo-Saxon translations of Russian psychologists, for example, replace the adjective pertaining to society, societal, by the adjective social. In German translations, on the other hand, the distinctions are maintained giving to A.N. Leont'ev's (1978) *Activity, Consciousness, Personality* a different flavor in the two translations.

denotes something like our breath of life (spirit) that animates the body, which Plato already designates as the tomb of the soul. The Greek, therefore already, separated the body (*sôma*) and the mind/soul (*psykhè*), a separation that entered present-day metaphysics and psychology, the body (*sôma*) being but a tomb (*sêma*) and a sign (*sêma*) of life and spirit (Derrida 1972). The psychological unit of analysis is the individual mind abstracted from any thinkable situation. The purpose of such research is to find out about mental processes in and of themselves.

For sociologists, an aphorism pronounced by what became to be the father of sociology, Émile Durkheim (1894), has been the guiding circumscription of the relevant unit of analysis. Thus, sociology's fundamental principle is this: the objective reality of social facts. That is, whereas psychology aims at identifying and researching mental facts, sociology has been, since its beginning, in the business of identifying and researching social facts. When sociologists use the individual as the unit of analysis, then it is generally to study how these are affected by some social or societal fact. To work out some of the differences between the psychological and the sociological, let us return for a moment to the fragment featured in the first pages of this book. The interviewer and her participant Mary are comfortably seated on a couch generally oriented toward the camera but also looking at each other (Figure 22.1).

Figure 22.1. An interviewer (*left*) asks Mary (*right*) to explain the phenomenon of day and night.

We may gloss the moment of the fragment featured here in this way: The interviewer asks Mary about the reason for having the sun in a particular position of the sky (turn 01) and Mary, after ascertaining what the interviewer has asked (turn 03), answers the question by stating that it is day and that the sun is moving (turn 05). The gloss actually is evidence for a tremendous amount of social competence that research needs to take into account rather than merely brushing or keeping under the carpet. The transcription, too, is evidence of a lot of cultural competence, which is of the same kind as that underlying the interactional work that the interviewer and Mary produced.

```
01 I: um (0.48) and do you think why the sun is over there?
      (0.90) its in the sky?
02    (1.12)
03 M: why? the sun is in the sky?
      (0.19)
04 I: yea:
      (0.65)
05 M  because=a its=a ^moving ((hand gesture of movement against
      the horizon)) and a its a (0.44) now today- (.11) now is
      (0.13) ‘day↑time
      (0.23)
06 I: uh hm:
```

Psychologically oriented research in science education, going under such labels as conceptions and conceptual change research, however, will extract turn 05 and attribute its contents to the mind of Mary. Thus, a conceptual change researcher might say that Mary has a misconception about the reasons for having day and night because the words stating that the sun is moving and that one can presently see the sun because it is daytime have come out of her mouth. Making such a statement presupposes that the contents of Mary’s mind somehow are spilled into the open, by means of an utterance (turn 05). This, however, requires language to be a transparent medium or a medium whose transformative effects are known so that the contents of the mind can be recovered from the talk.[11] This, in many instances, truly is a recovery effort, because it is made although sound-words blend together, pauses stop the utterance, sentences are grammatically incomplete, questions are not marked as questions in a grammatical fashion, and so forth. But I am not aware of any efforts of deconvolution, which suggests that talk can be taken as a direct way of getting at mental phenomena. The methods section of conceptual change research does not specify how conceptions can be inferred from talk that is quite noisy and messy. Conceptual change researchers apparently take their cultural competence in understanding what is said, even in the face of apparent problems with ascribing a particular sentence to a particular state of the mind or mental framework. It is because this competence is shared with interviewees and readers of science education journals alike that the recovery of conceptions from noisy data goes without saying, that is, without actually describing how it is done.

Sociologically informed science educators, on the other hand, would point out that Mary does not just spill her mind. She participates in a social event, an

11. In the natural sciences, for example in physics, researchers tend to know how their instrument changes the sought-for original signal coming from the phenomenon. Mathematically, the signal from the phenomenon is changed producing a convolution of two mathematical functions (instrument, signal). To get the signal of the phenomenon back from the convoluted signal actually recorded, the scientists conduct a deconvolution of the known instrument function and the convolved function. Something similar should be done in the social sciences if the effect of language on some true phenomenon were known.

interview; more so, she is participating in a societal event, an interview that is part of a collectively motivated activity of increasing (improving) knowledge about knowing and learning. What she says and how she says it is oriented toward the realization of the societal event, which inherently has to be intelligible to both participants. Mary does not respond as if a child had asked her the question about day and night, because manners would require her to explain why she treats the interviewer as a child. But she does not likely respond in the way she might as a student in school, especially if she were a student worried about grades. In other parts of that interview, she explicitly states never having talked about the phenomena before and then engages in responding nevertheless. In a school situation, she might not have cared to respond because of a fear that the teacher might assess her in a negative manner. The societal situation therefore shapes both the semantics and syntax of the response.

But there are still other ways of thinking about the situation, shaping the way in which we would conduct research. For example, the philosopher Martin Heidegger (1985) says that it is language that speaks (*die Sprache spricht*). If this is the case, then the response is only a concrete realization of the linguistic possibilities of the English language. Saying that the sun moves across the sky is nothing strange, and even the most ardent and dogged astronomy professor may be able to admire a sunrise or sunset without every worrying that he or she is not consistent with the scientific canon in making the sun the agent of the movement. That is, although we hear Mary's voice when listening to the videotape, it is language that we hear rather than some solipsistic Mary caught within the confines of her mind, a prison that in Kantian and neo-Kantian constructivist theory à la Jean Piaget or Ernst von Glasersfeld is the result of her own construction. Moreover, Mary does not just spill her mind, but she is in a social situation with the interviewer, who has asks her a question. Mary responds, addressing the content and the interviewer simultaneously. What she says is presupposed to be intelligible; it has to be presupposed as intelligible, understandable not only by others like herself but precisely by individuals such as the interviewer interested in the production of scientific misconceptions. That is, science education researchers themselves, in and because of conducting misconceptions interviews, reproduce this form of talk about the Earth and sun, and therefore reproduce the misconception that some of them attempt to "eradicate." They do reproduce the misconception in the same way that television programs that blip out the utterance "fuck" or a newspaper that prints "f…" or "?x#$" reproduce and continue rather than eradicate the life of the four-letter word, which is kept alive in and through its negative, its absence.[12] This position is consistent with the approach taken by the members of the Bakhtin group, who emphasize, as do Vygotsky and Jacques Derrida, that a word, any word, always is a reality of two or more people because it is absolutely impossible

12. The impossibility of getting out of the dilemma is the same that does not allow us to get out of the opposition of psychological and sociological approaches if they are viewed as opposites on a scale, as a dualism. The Hegelian negation of a term still retains the term, even though it is in the form of the negation. This is also why M.M. Bakhtin rejects the Hegelian approach and favors dialogism, which retains differences as these are subsumed to a higher-order unit.

for one. The utterance of a misconception presupposes the hearing of a misconception; and the hearing of a misconception presupposes the understanding of a misconception.

This has, of course, tremendous implications for the unit of analysis that we have to choose when working with language. The unit of analysis cannot be just the sociological; the unit of analysis cannot be the psychological either. Each approach constitutes but one side of a multidimensional and multifaceted life–language coin. At a minimum, the two approaches operate simultaneously in apparent contradiction to each other. We can think of language as offering general cultural possibilities beyond what can actually be observed as linguistic behavior; there are more possibilities of speaking (discoursing) than are actually realized. However, actual analyses are confronted with the concrete realization of some of the existing possibilities. Much as in quantum physics, where there are many states possible in/for a system—for example, in E. Schrödinger's thought experiment about a cat inside box containing a quantum detonator, the state of the cat has to be modeled such that it exists as a mixture of dead and alive—one is realized in and through the concrete, singularizing act of observing the system. Linguistic possibilities are similarly collapsed into a single and singular state in the act of speaking; and this state has been denoted by the term *theme* (Bakhtin/Vološinov 1973). The most interesting addition to our understanding of the function of language by the Bakhtin group is that theorizes each act of speaking as changing the language as a whole, ever so minutely, but observable over relatively short timescales. Educators know from experience how much the language of students is changing within the lifetime of a teacher, but theories do not capture such changes of language at any scale. In this, my own chapter 9 differs from much of research. In the same way, my collaborators and I studied knowing and learning in a fish hatchery contextualized by the 35-year history of the institution, itself contextualized in 120 years of fish farming (Roth et al. 2008). In this approach, knowing and learning are never reduced but always understood in terms of the changes of local institutions (equivalent to schools and school boards) and in terms of cultural-historical changes in the system specifically and society generally.

This ever so brief analysis points us immediately to another important phenomenon implicit in learning but not implicit in the theories of learning: the different levels of time and temporality in human experience that mutually constitute each other. Thus, culture and cultural possibilities change over time, whereas much of educational research is conducted as if culture did not change and as if the sole purpose of education is to bring young people into a fixed culture. Some of the analyses presented in this book can be seen as disconnecting learning from the broader contexts, whereas others, such as K. Richardson Bruna (chapter 17), squarely locate their analysis in the societal political arena of the day. Moreover, individual students do not just learn as if taking up knowledge in an atemporal process. Students actually engage in and with the world, an engagement that is temporal and that produces time. Learning does not just mean changes at ontogenetic (individual) levels, but they are the result of microlevel second-by-second engagement with a world itself undergoing continual change. This means that an appropriate unit of analysis also has to address the dynamical nature of the world at all levels that one might care to look, including the society that was of such importance to Marx and subsequently to cultural-historical activity theory.

Associated with the lack of consideration in the educational literature for the temporal changes is a lack of attention to the cultural and societal phenomena that are reproduced and transformed in every single act. When Mary and the interviewer sit together on the couch talking about the reasons for having day and night, they are not just sitting in some box that we might denote by the label "interview," talking about some eternally fixed content. Rather, we can understand any cultural dynamic that we witness if we think of Mary and the interviewer as reproducing and transforming society and language (Bakhtin 1984). The professor teaching a course on thermodynamics (chapter 9) contributes, together with his students who listen during the fragments presented in this book, in the reproduction and transformation of society. If we do not include society as a pertinent dimension into our analysis, then we end up where much of science education research finds itself today: There are many studies and theories of learning that do not and cannot account for the reproduction of societal inequities in and by means of present-day schools. Whereas we know a little about how students engage with the science curricula that educators design and present them with, we do not know why, after 50 years of science education research since the Sputnik scare Americans experienced, students from African American and working class homes end up in the same situations of poverty or low income that characterizes their parents' home. That is, there is something that leads to the reproduction of inequities that has fallen outside the light cone of constructivist and conceptual change research or that is precisely at the blind spots of these approaches to science learning. Brief comments about teachers who allow or do not allow their students to use everyday language, or to link their in-school and out-of-school experiences are insufficient to theorize the structural reproduction of inequities. The analyses of school learning have to be conducted bringing to bear society on classroom interactions. In her recommendations for institutional ethnography, Dorothy E. Smith (2005) shows how such analyses can be conducted such that they bring macro-levels to bear on micro-level events.

Yet another aspect of being-in-the-world that is theorized inappropriately because it falls outside the chosen unit of analysis is emotion. At best, emotion is treated as a phenomenon in its own right, a phenomenon that then becomes only a factor mediating cognition from the outside. Generally the mediation is such that it decreases ideal performance (e.g., state and trait anxiety and fear diminish test performance). However, over 80 years ago, Vygotsky (1986) already charged traditional psychological research with inappropriately theorizing the relationship between affect and cognition. Thus, the separation of intellect and affect "as subjects of study is a major weakness of traditional psychology, since it makes the thought process appear as an autonomous flow of 'thoughts thinking themselves,' segregated from the fullness of life, from the personal needs and interests, the inclinations and impulses of the thinker" (p. 10). He then suggests that "*unit analysis* points to the solution of these vitally important problems. It demonstrates the existence of a dynamic system of meaning in which the affective and the intellectual unite" (p. 10, emphasis added). Already more than 200 years ago, Hegel (1979) whose work is the intellectual source of Marxism and Vygotsky's work—suggests that factors, because they are external to the thing/phenomenon cannot change the latter. Moreover, recent research falling into a discipline called sociology of emotion shows that rather than being something merely bodily, emotions constitute a sociological phenomenon that has to be used to account for social/societal facts (Collins 2004). It is precisely in interaction rituals—whether these produce interviews such as that featured in this chapter or in science lessons—that interaction participants make available affective aspects to each other by a variety of means, for example, prosody and body rhythms (e.g., Roth and Tobin in press). It turns out that rhythm and temporality are important aspects in the coordination and dis-coordination of interaction rituals involving African American as well as native students, such as those in the Pacific Northwest or on Hawai'i. Changing, for example, the way in which the temporal spacing between speakers is organized during story telling changes how and what students can learn, especially when the interaction rituals at school differ from those that these students experience at home with other family members and in the street with their friends. Cultural-historical activity theory is the only theory I am aware of that implements unit analysis to its fullest. It is this theory that offers the most potential for an integrative study of knowing and learning.

Cultural-Historical Activity Theory

The students and followers of Vygotsky, including especially Alexei N. Leont'ev (1978), developed, with cultural-historical activity theory, an approach that integrates over sociological and psychological approaches including the role of affect at the collective and individual levels (see also chapter 3). The theory distinguishes between three levels: collective, motive-oriented *activity*, individual goal-oriented *action*, and conditioned *operations*. In accordance with distinctions that the German and Russian developers of the theory make, activity (*Tätigkeit*, *deyatel'nost'*) does not mean being busy with some task, which would in these languages be denoted by the terms *Aktivität* and *aktivnost'*. Activity in the sense of *Tätigkeit* and *deyatel'nost'* implies the production of outcomes that serve the need of the collective, that is, society (e.g., food, tools, reproduction of cultural knowledge). These levels have to be used to analyze any instance of human behavior, insisting that we need to take into account not only goal-oriented actions but also, on the one end, the unconscious enactment of embodied skills, and, on the other end, the societal formation that mediates the choice of goals and most appropriate (i.e., intelligible and accountable) actions. To use an example, we cannot just look at students in a geometry lesson for second graders (chapter 14), in a science class with many Mexican immigrants (chapter 17), or in a water unit for third graders (chapter 18), but we have to understand what these students participate in: the production of grades that allow them to move up into other grades until the production of a high school leaving certificate. The Mexican immigrant Omar eventually moves away from school science precisely because it fails to provide a context within which his need-oriented actions make sense. Thus, providing for his mother becomes the most important goal, and it does not make sense or has a place within schooling. Richardson Bruna provides an excellent analysis of the shifting forms of participation, that is, the shifts in activity systems. Because motives and goals are mutually constitutive with respect to their sense, it comes not as a surprise that Omar would drop away from school.

Schools and schooling boil down to the production of grades. Teachers and entire schools, too, are oriented toward the production of grades and test scores, as shown in some U.S. jurisdictions where schools are taken over when the achievement mean targets are not met. Because the object motive of schooling are grades and grade reports, it comes as little surprise when students and teachers focus on passing exams rather than on understanding subject matter. The students in such schools still participate in the reproduction and transformation of knowledge, even though much of what they learn may not be science or mathematics but the kinds of social skills that get them jobs or survival skills that allow them to cope with structural or cyclical unemployment. In cultural-historical activity theory, the unit of analysis, therefore, because it attends to the societal-level and collectively motivated activity, includes the psychological and sociological, each of which constitutes only a one-sided expression of a more complex unit.

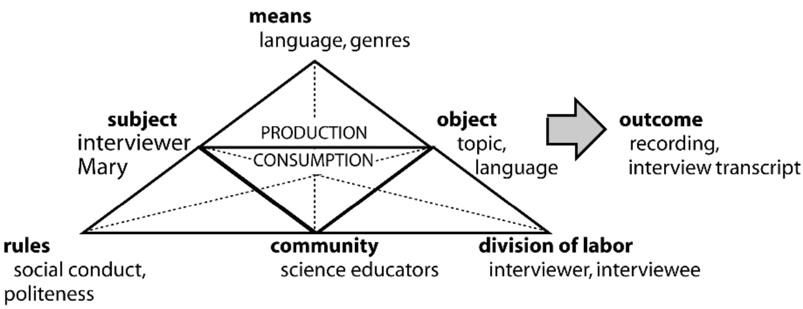

Figure 22.2. The structural dimensions of one version of cultural-historical activity theory are apparent in the emblematic mediational triangle.

Cultural-historical activity theory has become more widely known and accessible in the form of an almost iconic mediational triangle (Roth et al. 2009). This triangle highlights the structural dimensions of activity and actions, but makes invisible the agential dimensions that lead to the production of things that are subsequently used in the same or different activity systems, here exemplified in a model of the interview featured in this chapter (Figure 22.2). The different terms appearing in the triangle have to be understood as denoting irreducible moments rather than as denoting elements that can be used to build up the system (Roth and Lee 2007). It makes no sense, for example, to reflect on or research the subject of the activity independent of the activity generally and independent of all of the mediating relations that contextualize the subject. Moreover, the moments have to be understood as denoting both material and ideal dimensions, thereby integrating the distinctions other theories make between body and mind, person and setting, individual and collective, this and that side of some border, and so forth. In the concrete case of our present example, we understand what the interviewer and Mary do as the reproduction and transformation of an aspect of society, science education research that aims at producing knowledge about how people talk about natural phenomena (object-motive of activity). The *subject* here is a two-member group with a clear *division of labor* (interviewer, interviewee) aiming at the production of an interview text (*outcome*) that the researcher can subsequently use in the production of a research article. This article comes to be exchanged within the relevant *community*, here science educators. The topic and language are the *objects* (including materials) the two have available, and language is also the *means* they have for pulling off this production.[13] The two will not produce just any text, but, as Bakhtin (1986) points out, they will make use of topic-relevant genres that constitute cultural possibilities.[14] That is, both are oriented toward the production of anticipated outcomes, that is, outcomes that will be of use to the researcher although Mary cannot know whether what she does in fact helps the interviewer. She has to find any affirmation that what she does is appropriate for the purpose at hand in and through the interview itself. Asking whether her understanding of a question is the same as that of the questioning interviewer is one of the way in which Mary actively contributes to producing outcomes that the interviewer anticipates to be of use in and for her research project. Both act such that after the fact it can be said that they have followed the social *rules* that order interactions, for example, they have been polite interaction participants.

There is insufficient space to articulate the theory here. I point to but a few more possibilities that this theory offers. First, affect is built into the model at all three levels: Activity serves the needs of society, even if this is not immediately apparent because of the high degree of specialization due to division of labor; actions are oriented toward goals, the achievements of which are monitored and affect constituting an integral part of the monitoring process (positive valence is the desired outcome); and, finally, unconscious operations are mediated by affects, the sum total of different bodily systems and states, their immediate and constitutive context.

Second, learning itself is not a planned outcome in this theory—consistent with conceptual analyses that show that specific learning processes and outcomes cannot be planned ahead of time by administrations (Holzkamp 1992). Activity and actions are always oriented toward the production of something that is subsequently exchanged within the activity system itself or with the members of other activity

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13. On the nature of science language as contested terrain—that is, here object—and as tool-here means—see Roth and Barton (2004).

14. Because of this, there is no difference between biography and autobiography, because both make use of the same resources for constituting the life of a person and where persons writing their own biography are no closer to the truth of their lives than any other author. On the role of position on understanding, see the introduction to Part B of this volume.

systems. In the process of production, the body works and expends energy. This transforms the body, and with it, the consciousness. Learning is a consequence, or rather, a correlate and collateral of participation in activity. Participation, as Jean Lave says somewhere, *is* learning. This theory therefore radically differs from each of the two approaches that this book strives to reunite: sociology and psychology. The former discipline frequently focuses on the mechanisms by means of which society is reproduced, and the individual human being is little more than a dope performing according to and conforming to rules that lie outside of them. The latter discipline focuses our attention on processes within the individual, claiming, as seen in conceptual change research, that students actively construct knowledge, which therefore is seen as the outcome of students' mental actions. How learners can aim at and intend achieving something that they do not know—for example, canonical science—remains a question that psychologically oriented researchers do not (like to) look at. Cultural-historical activity theory transcends the two one-sided approaches in theorizing learning as a by-product of participation in societal activity, a participation that individuals always realize in concrete ways in the here and now of their respective situation.

Third, relevant for understanding what subjects (individuals, groups) do is not the world as it appears to the researcher outside of the activity itself—because the object and anticipated outcomes shape cognition, there are considerable differences between what a researcher sees within an activity system and what a participating subject dwelling in this system sees (Schutz 1996). Rather, what is relevant to the consciousness operative during productive activity are the lifeworlds of participants. This distinction is not generally made in science education research. Here, the term lifeworld denotes the world as it appears to the agent and in the way it appears to the agent—and this differs when the agent is a student, a teacher, or a researcher. To take a concrete example, the interviewer and Mary are conscious of the topic, and they exhibit this consciousness to each other as part of the conversation. Thus, we do not have to hypothesize about the intentions of Mary for doing what she does because she makes everything required available to the interviewer; the interviewer, in turn, makes every relevant intention available to Mary. We do not have to overlay intentions that we derive from interpreting what participants say. This is further visible, for example, in the fact that Mary asks a question designed to clarify the interviewer's question. On the other hand, neither the interviewer nor Mary gives any account of the couch as something salient in their consciousness. In fact, we know from everyday experience that we are not continually conscious of the chair in which we sit while having dinner with friends; we are not conscious of the clothing we wear other than while we dress for the dinner event and perhaps during isolated moments when the dress is relevant and salient in social interaction; and we are not even aware of the glasses that allow us to see the facial expressions of our friends. It is only during instances of breakdown—dust on the eye glasses, food on the shirt, a squeaking chair—that we become aware of these things and make them a topic of consciousness. This has consequences for the way in which we think about some issues, for example, about identity, for the words someone uses rarely are deliberated before use, so a researcher would be ill-advised making statements about the (conscious) production of identity because a student uses street language when in fact there is no choice and therefore no intentional constructive process occurring.

Fourth, each action and activity produces something and in this production consumes resources, energy, and materials (bodies, instruments). That is, cultural-historical activity theory embodies a theory of the world as a continually changing whole, always in the process converting existing structure into the production of new structure. Aspects of the world are disappearing at the very moment that new aspects are appearing—leaving intact some aspects of existing structure but also contributing new aspects. Bakhtin (1984) orients our attention to the continuous process of birth and death, the two being in fact constitutive moments of life. Accordingly, life can be understood only through the material bodily principle that also enables the ideal worlds—that is, consciousness—that parallel it in human existence. There is no life without birth as there is no life without death: Life presupposes birth and death. Evolution requires both processes simultaneously. Cultural-historical activity theory, when it makes thematic both agency (not clearly visible in diagrams such as Figure 22.2) and structure, captures this dynamic aspect of life generally and human society and its material contexts specifically.

Fifth, cultural-historical activity theory also handles an aspect of human productive engagement that clearly lies in the area of the blind spot of most researchers and theorists: passivity (Roth 2009a). The role of passivity in learning most clearly is articulated in the contributions by Maheux and colleagues (chapter 14), Rivera Maulucci (chapter 20), and my own (chapter 9); others, including Tobin (chapter 2) and Reis (chapter 16), also take passivity into account. Let us pursue why passivity may be integral rather than something attached to activity or something intended. As discussed, learning, for example, is a collateral of productive engagement and participation; it happens even and precisely when the person does not focus on learning as such. Children learn their mother tongue without having to intend learning it. By the time they make conscious decisions about what they want and do not want to do, they are already nearly competent speakers of their mother tongue. We are passive with respect to the experiences we can make, even though we intend to learn something. Take the experience of finding out the texture of a surface. We make touching the goal of our learning intention but then we have to open up, allowing ourselves to be affected by the unknown surface texture—a completely and radically passive aspect of the experience. We touch precisely because we do not know what we will feel, and this is why we are radically passive with respect to this experience. Using language and producing the context of interaction rituals similarly involve essential passive moments (Roth in press). Moreover, Mary cannot intend, that is, aim at and turn her attention to, the scientific explanation of the reason for day and night precisely because she does not know it. If she knew the scientific explanation, she would not have to intend learning it.

As a sixth point to consider, (science) educators have to ask them about the extent to which the subject in/of the activity system buys into the motives of the collective activity. For example, we know that working class and African American students often do not buy into the production of good grades and report cards. We know this to be a fact because it is difficult to threaten and control them using the you-will-get-a-poor-mark stick as a means of enforcement. Omar in Richardson Bruna's chapter does not buy into the motive of schooling, in part because it does not allow making sense of the things important in his life. Many students never finish high school, which, in my Canadian context, include large disparities between men and women, rural and suburban, aboriginals and non-aboriginals, and regions. Reasons for dropping out often include the desire to earn an income, which tends to be low precisely for those who have left school prior to completion. If students do not buy into the collective motive, they are not personally motivated either, as collective motives and individual goals are dialectically related. Associated with buy-in is affect, which tends to be low when a student participates without having bought into the activity of schooling. The same kinds of analysis hold for all other personal working within organizational contexts (e.g., Roth et al. 2005), where disengagement and dis-identification lead to alienation at the workplace.

The aforementioned dimensions make it clear that to understand the events in any type of situation we need two types of complementary and integrative analyses. On the one hand, we need to attend to the world as salient to the subjects in the activity system, their lifeworlds. We need to do lifeworld analyses, which allow us to identify why people do what they do, which we can because they make these reasons available to each other as part of social life. In the conduct of everyday interaction, people make available to each other relevant structures, thereby employing methods that produce the very social structures that researchers discover without acknowledging that they are already competent in these methods (Garfinkel 1996). At the same time, we need analyses that focus on the historical evolution of those structures that make an activity—including those of the means and objects—because these tend have determinate effects on action most frequently outside of the consciousness of individual subjects. Institutional ethnography (Smith 2005), an approach that complements ethnomethodological with structuralist Marxist analyses, has the potential to keep in focus everything required to prevent researchers in doing reductionist, one-sided forms of research. This is also the route that Regina Smardon suggests to us in the closing section of chapter 7.

An ethnomethodological approach to the interview fragment reproduced in this chapter focuses on what the two participants do to produce the interview as structured and structuring societal situation and therefore the interview transcript as protocol of the events that have unfolded in the concreteness of their experience. For example, the analysis would show how the two ascertain to be talking about the same thing, the same topic, by having the original question followed by a second question itself followed by an assertion and a response. In fact, turn 03 does double function, it both makes a statement that can be glossed as "So you are really asking me, 'Why is the sun in the sky?' when in fact you asked 'Why is the sun over there?'" It is both a statement and a question, and the interviewer confirms the correctness of the statement in the question by means of an affirmation "yea" (turn 04). That is, my analysis shows how the nature of the current topic is at once questioned, confirmed, and reconfirmed. More over, not only is the topic confirmed but also the interview process itself is reproduced and maintained. But what the analysis does not get us at is the language that the two use, which may be an important issue in its own right. Mary and the interviewer talk about the sun, the Earth, day, and night in a factual manner without asking about the historical nature of the terms and the phenomena they denote. This seems to be without trouble in this case. But, consider, for example, a single mother accepting the label of single-parent family and subject to the way in which the school her child attends typically interacts with single-parent families (e.g., Smith 1990). Her life is determined by a structure the origin of which lies outside of her consciousness and therefore is subjected to rather than controlling it. To change the situation, she will have to become aware of this origin, which means, she has to become aware of the processes that the term entails and engenders. Critique of one's lifeworld requires a position that lies outside this lifeworld, which is a move equivalent to the proverbial fish that would have to get out of the water to recognize the constitutive effect water has on its lifeworld. Critique would require science educators to do historical reconstructions of the conceptual terms they use; but even in this volume, we are seeing little of this required work.

Building Capacity

What do we have to do to build capacity for overcoming the polarization of sociological and psychological approaches currently observable in our field in the confrontation, for example, of conceptual change research and approaches rooted in the sociology of education? My sense of the situation is that we need to attempt to bring into focus large bodies of research that are not only disconnected between approaches but also disconnected within approaches. We can observe a proliferation of (qualitative) research studies that make no attempt to integrate what has been learned from studying knowing and learning across different sites. In the classical research literature using experimental and quasi-experimental research, there exists an approach for learning from the results of multiple studies, that is, to learn from learning, a process some have referred to as second-order learning (Bateson 1972). Meta-analyses are studies that attempt to summarize findings within some domain over a period of time and across contexts. The fundamental idea underlying this method is to find out, given the variations of statistical inferences, estimates of the true effect sizes involved in some phenomenon. Another approach in experimental work is to use Bayesian statistics, which takes into account prior knowledge and factors it into the expected probabilities of a particular observation (e.g., effectiveness of one drug over other forms of treatment). Studies that might show statistically detectable effects without accounting prior knowledge may turn out to exhibit no significant effects once prior knowledge is taken into account. Similar integrative processes do not exist in the type of research often referred to as qualitative. This is a detriment, because, with all the research efforts spent, we never come to find out whether what has been learned in one context might be useful in some other context. But in evaluating the usefulness of research and especially the varied contributions of sociological and psychological perspectives on some phenomenon, we do have to engage in some form of compilation, comparison, and integration.

Qualitative research frequently is held against quantitative research, members of one approach placing the other on the opposite end of a research continuum, with some researchers favoring multi-method approaches. But do these methods tell us more about social and psychological structure? Harold Garfinkel (1996) famously asks what more there is to social research. His response makes it quite clear that he does not see much difference between qualitative and quantitative research, as both modes investigate social (psychological) structures and compile a body of work (a corpus). There is little difference which method has been used because the studies all belong to the same corpus based on formal and formalistic, specially specified (research) methods. It is precisely on this point that Tobin (chapter 2) and I differ. I hold it with Garfinkel, who points out that human beings continuously make available to one another what is required in making society and social interaction an ordered phenomenon. The methods of the people (ethno-) are quite unremarkable, mundane, and generally invisible—though it is precisely these methods that produce the structures that quantitatively and qualitatively working social scientists "discover." In a response to the rhetorical question "What more?," I, following Garfinkel, propose to study the generally invisible methods that allow mundane activity to go unnoticed (Roth 2009b). These methods in fact underlie the possibility to discover structure, because they presuppose an understanding of the structure, which itself requires competence in the ethnomethods for producing them (Heidegger 1977). Thus, "the true principle of order has its own content matter, which is never discovered by means of ordering, but always is presupposed by it" (p. 52). Scientific identification of order by means of specified ordering (research) methods—making use of comparisons, categorization, typification etc.—presupposes the principles from which social order arises. These principles are precisely the non-visible ethnomethods that come to the fore only in situations of breakdown where their ordinary efficient functioning is (or has been) disrupted. Knowing ethnomethods, therefore, allows us to know the social structures (including those that are recognized as higher order cognitive functions [Vygotsky 1978]), whereas knowing social structures does not inherently allow us to know the methods that produce them. It is precisely for this reason that Garfinkel calls ethnomethodology a radically alternate and incommensurable approach.

Ethnomethodology and the conversation analytic procedures it tends to employ is of advantage because it highlights when pertinent issues invoke sociological or psychological principles, which then are used as part of producing social order that sociologically or psychologically oriented science educators would discover with their formal methods. A salient instance of this is available in a transcript fragment provided by Edna Tan and her associates (chapter 19).

Mr. M: Did you think about what you did on Friday when you went in there to buy those? What was your thought process? Why did you take what you learnt and make a different choice? Was it purely taste? That it was something you were craving?

Mabel: Yes…
Mr. M: Okay, that's honest … yes, Cindy?

In this situation, Mr. M. clearly draws on psychological principles when he asks Mabel about whether she has "thought about" what she did on Friday, what her "thought processes" were, and when he suggested that she might have had "cravings," which we can hear as standing opposite to the thought processes. Mabel affirms ("Yes"), an affirmation that the teacher describes as being "honest." Here, then we have the psychological issue of character trait, honesty, mobilized in a social situation of the classroom. Mr. M. co-articulates his appreciation of the fact that Mabel has been honest to him (and the others present). Mabel has acted in a manner that conforms to social rules rather than hiding or being secretive about her Friday-night experience. Deception may be a topic of sociological inquiry, as it pertains to the relation between social actors.

Of course, there is more to the fragment, because the order that can be found as psychological facts (honesty as trait) and sociological facts (non-deception) are in fact outcomes of the interaction ritual that we observe. The social actors use for each other forms of discourse that makes attributions to the individual and the relation so that comes as no surprise that social scientists can discover sociological and psychological facts, an instance of honesty and disclosure, and an instance of trait honesty. It is Mr. M. who suggests that Mabel acted honestly; and it is also Mr. M. who proposes the possibility of an alternative to rational decision making to Mabel, that is, the possibility that she submitted to a craving rather than controlling it and making a rational decision based on the knowledge about foods that he has been attempting to instill in her.

In this brief example, we see how the question of sociological and psychological perspectives goes beyond choosing one or the other to identify order in social interactions (even misconceptions require social interaction, either classrooms or interview situations). We can actually attempt to find out how people interact to produce order as public and visible phenomenon, that is, how they produce orderly and ordered society as a lasting, seemingly immortal phenomenon. In conducting social life, members of society are lay psychologists and lay sociologists, which allows them to predict more or less accurately the behavior of others and the trajectories of social situations. The question for me, therefore, is not whether we should use a sociological or a psychological approach or an approach that somehow combines the two—in additive or mutually constitutive form. To me the ultimate question is about the ordering of social interactions such that social structure emerges as sociological and psychological facts. How do students, teachers, and administrators pull of the production of order? The answer to this question will leave behind the entire dichotomy and dialectic of the sociological and psychological, returning to it only to the extent that social actors themselves mobilize sociological and psychological resources in the production of ordered orderly society and its sociological and psychological facts. This has to be the way we go about our research, because it is the only way in which the disciplines could have come into existence. Any science is both grounded in and presupposes common everyday understandings of the world (Husserl 1939). First there was talk about specific phenomena that emergent fields took as their objects—the ancient Greek already distinguished between the body (*sôma*) and spirit/mind (*psykhè*) so that after the fact it is not surprising to come to a science of the psyche, psychology—and only then were there disciplines. Human societies existed long before the advent of sociologists and sociological societies, psychologists and psychological societies; the origin of these specialized societies lies precisely in lay sociology and lay psychology. Any good science, sociological or psychological, has to be able to account for its own emergence. This is a project that Hegel accomplished for the development of mind and consciousness and that Marx accomplished for the emergence of Capitalist markets and thought of his day. And this is precisely also the point where most present-day sciences fall short. The quest of a reunification may actually lead us to transcend both fields entirely, allowing us to develop a transdisciplinary approach that recognizes its own disciplined beginnings in undisciplinary social interaction rituals.

Coda

This book is the result of a first attempt in dealing with a trend that has led to the splitting not only of social sciences into different disciplines but also to the splitting of research endeavors within applied disciplines such as science education. The book as a whole prepares a ground upon which we might expect new forms of endeavor to emerge in the quest to find out answers to interesting questions such as the one about how human beings learn and become competent users of science discourse in formal institutions as well as in non-formal and informal settings. Once we set our goals—for example, to understand learning—we may actually no longer be concerned about whether what we do is sociologically or psychologically informed and rather focus on the best understandings that we can achieve. This requires us to enact radical doubt with respect to our own preconceptions and presuppositions and define the object of interest through critical analysis rather than through the lens of a favored method or favored theory (Bourdieu 1992). Sociology | psychology may then be just the first element in a sociology | psychology | literary criticism | … chain that involves many other currently separate disciplinary pursuits. What we need is a science of science education that studies phenomena in non-reductionist ways, a science of science education more concerned with phenomena and less with discipline-oriented theories and even less with methods that leave unspecified the very ways in which orderly society is produced.

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