“Look at What I Am Saying”: Multimodal Science Teaching

by

Lilian Pozzer-Ardenghi

Full Licentiate in Biological Sciences, Universidade Federal de Santa Maria, Brazil, 2000

Master of Arts, University of Victoria, Canada, 2003

A Dissertation submitted in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

in the Department of Curriculum and Instruction

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ABSTRACT

Language constitutes the dominant representational mode in science teaching, and lectures are still the most prevalent of the teaching methods in school science. In this dissertation, I investigate lectures from a multimodal and communicative perspective to better understand how *teaching* as a cultural-historical and social activity unfolds; that is, I am concerned with *teaching* as a communicative event, where a variety of signs (or semiotic resources), expressed in diverse modalities (or modes of communication) are produced and reproduced while the teacher articulates very specific conceptual meanings for the students. Within a trans-disciplinary approach that merges theoretical and methodical frameworks of social and cultural studies of human activity and interaction, communicative and gestures studies, linguistics, semiotics, pragmatics, and studies on teaching and learning science, I investigate *teaching* as a communicative, dynamic, multimodal, and social activity. My research questions include: What are the resources produced and reproduced in the classroom when the teacher is lecturing? How do these resources interact with each other? What meanings do they carry and how are these associated to achieve the coherence necessary to accomplish the communication of complex and abstract scientific concepts, not only within one lecture, but also within an entire unit of the curricula encompassing various lectures? My results show that, during lecturing, the communication of scientific concepts occur along trajectories driven by the dialectical relation among the various semiotic resources a lecturer makes available that together constitute a unit—the idea. Speech, gestures, and other nonverbal resources are but one-sided expressions of a higher order communicative meaning unit. The iterable nature of the signs produced and reproduced during science lectures permits, supports, and encourages the repetition, variation, and translation of ideas, themes, and languages and therefore permits, supports, and encourages conceptual development at the boundary between the mundane and discipline-specific cultures that students (have to) traverse in learning. It is only within this multimodal and dialectical communicative meaning unit that we can understand and investigate science teaching and learning as these processes naturally occur.

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ACKNOWLEDGMENTS

Thank you, God, for the gifts of life, intelligence, strength, and perseverance.

Thank you, Diego, for your continuous participation in this project, your patience and understanding, your inestimable help always.

Obrigada pai e mãe, por todo o suporte financeiro, moral, emocional, sem o qual eu jamais teria conquistado meu título de Doutora. Obrigada Fernanda e Fabrício, pelo auxílio financeiro nos momentos em que mais precisei durante esta longa vida de estudante. Obrigada aos familiars e amigos pelo suporte que sempre me proporcionaram e que me foi muito válido nestes quarto anos de estudo e distância.

Thank you, all my colleagues at Chat@UVic for all your help and friendliness. Em especial, obrigada Bruno, por toda a ajuda indispensável que me deste durante os derradeiros momentos de preparação desta dissertação.

Thank you, all the staff at the Department of Curriculum & Instruction, Faculty of Education, University of Victoria, for your kindness and willingness to help.

Thank you, Mr. Jantzen, for your willingness and interest in participating in this project. Thank you, all the students and the school staff and administration, who kindly allowed me to collect data for my research.

Thank you especially and most of all, Dr. Michael, for your invitation, your offer of financial support, your patience in mentoring me, and this unique opportunity you gave me to learn so much with you for the past six years.

Thank you also, the Social Sciences and Humanities Research Council of Canada, for the financial support.

To Diego.

Chapter I:

Introduction

This dissertation is about teaching. More specifically, the research I have designed, conducted and submitted to research journals for the past four years, and that is compiled here into the form of chapters, is about the multimodal meaning-making (i.e., semiotic) resources that the teacher makes available when lecturing. My primary aim in investigating lectures from a multimodal and communicative point of view is to better understand how *teaching* as a cultural-historical and social activity unfolds; that is, I am concerned with *teaching* as a communicative event, where a variety of signs (or semiotic resources), expressed in diverse modalities (or modes of communication) are produced and reproduced while the teacher communicates very specific conceptual meanings to students.

My immediate interest falls within the context of science education, mainly due to my background in biology education. However, this research is trans-disciplinary, as it merges theoretical and methodological frameworks of social and cultural studies of human activity and interaction, communicative and gestures studies, linguistics, semiotics, pragmatics, and studies on teaching and learning science into one coherent effort to understand *teaching* as a communicative, dynamic, multimodal, and social activity.

Central to my investigations are issues related to the nature and integration of semiotic resources made available by teachers during lectures. What are the resources produced and reproduced in the classroom when the teacher is lecturing? How do these resources interact with each other? What meanings do they carry and how are these associated to achieve the coherence necessary to accomplish the communication of complex and abstract scientific concepts, not only within one lecture, but also within an

entire unit of the curricula encompassing various lectures? These are some of the central questions I had and to which I provide answers here through the analysis and discussions of the science lectures that compose my database for this doctoral research.

The results of my research are presented in the form of independent and yet interconnected studies, each focusing on a particular aspect of teaching as communicative activity. Thus, my first study, presented in chapter IV and entitled *On Performing Concepts During Science Lectures*, deals with the conceptualization of the dialectical communicative meaning unit, which, following Vygotsky (1986) and McNeill (2002), I consider to be the smallest unit of analysis when investigating the teacher's discourse from a multimodal perspective. Here, discourse takes on a new meaning, as I include in it not only the spoken or written words (e.g., on the chalkboard), but also the prosodic aspects of the speech, the gestures and body orientations, and the material resources in the surrounding setting. Through microanalysis of this multimodal discourse, which I refer to as *performance of concepts*, I show which resources the teacher uses to communicate different scientific concepts during lectures, and how these resources are integrated into the dialectical communicative meaning unit. This study, therefore, lays the ground for the following studies by establishing the fundamental premise upon which my dissertation rests.

In chapter V, I present my second study, entitled *Communicative Development of Scientific Concepts in Lectures*. In this study I adapt the notions of catchment (i.e., repetition of essential features of the gesture|speech dialectic) and growth point (i.e., moment in which an idea in the form of a gesture|speech dialectic is born) (McNeill, 2002) to analyze, from a communicative perspective, the articulation and development of

scientific concepts in the course of several consecutive lessons dealing with the circulatory system. My aim is to understand how ideas are connected to each other to teach particular concepts, and how the repetition of certain resources throughout various lessons provide the *thread* that makes possible to sequentially develop a complex concept during lectures.

Following up on the second part of the study reported in chapter V, chapter VI presents a semiotic microanalysis of the repetition of a particular gesture within and across lessons dealing with the same conceptual topic. As the teacher presents new information during his lectures, catchments and growth points (McNeill, 2002) provide cohesion to the discourse until the concept being taught achieves stabilization. I consider the gesture and word unit as a double signifier (verbal and visual at the same time), and the several repetitions of the gesture throughout various lessons as a special case of sign iteration (Derrida, 1988), thus articulating a novel way of theorizing communication of concepts during lectures.

The fourth study deals with the important topic of reference in communication. In *How Do We Know He Is Not Talking About Himself? Demonstrations in Science Classrooms* (chapter VII), I present a microanalysis of an exemplary case of the teacher demonstrating the actions of someone else in a setting diverse from that of the classroom where both teacher and students are present. I identify the *markers* that help us disambiguate between reference and self-reference, thus providing an answer to the question introduced in the title.

Finally, my fifth study (*Action and Interaction in the Classroom: Teacher's Movements and Associated Pedagogical and Discursive Practices*) presents classrooms

as interactive and social environments where culturally negotiated practices become established and stabilized over time, and where the teacher's actions, including his speech, gestures, and (specially) his physical (bodily) positioning in the room, constitute meaning-making resources used to communicate and to understand what is communicated. Thus, the teacher's actions become the means through which the lesson is organized and interaction is structured, insofar as his physical movement in the room is associated with particular pedagogical, interactive, and discursive practices.

In these five studies, I present the results of original research that is also innovative for science education in the sense that it combines diverse approaches to theorizing and analyzing lectures that have not yet been fully explored in this field of research. Furthermore, the implications of this research are also particularly directed to the science education community, as a new understanding of teaching science through lectures is possible by means of studying them as I have done here.

This doctoral research, in many ways, has been a struggle against an abstraction—the worst kind of struggle, if I may paraphrase one of my favorite authors, José Saramago. But I believe that this is the case any time we engage ourselves in trying to understand the unknown. If there were no questions to struggle with, we would never seek and find answers. The pursuit of knowledge is a constant struggle to make sense and make meaning of the world in which we live, be it concrete or abstract. I present this dissertation as an answer to some of the questions I set out to investigate four years ago. But I am certain (and I hope this will always be the case) that this is not the end of my struggles.

Chapter II:

Theoretical Framework and Literature Review

Lectures as Multimodal, Communicative, and Social Activities

Language constitutes the dominant representational mode in science teaching. Among the teaching methods, lectures are still the most prevalent at all grade levels and worldwide (Roth & Tobin, 1996). Lectures represent an instance of face-to-face communication, with a relatively large number of interacting participants, even if only one participant (the teacher) speaks most of the time. Lectures also constitute a particular societal activity, with culturally and historically specified rules that afford and constrain specific communicative forms (Lemke, 1990). Thus lectures generally emphasize the spoken and written word, and this approach dominates not only teaching but also learning evaluation methodologies. In lectures it is common, for example, to find students taking extensive notes from the teacher's verbal presentations and from what the teacher inscribes on the chalkboard. Although these notes may contain some drawings and diagrams, they are mostly structured in words and, most importantly, they only record words.

For decades communication studies, including studies that focused on classroom communication, were restricted to structural and psychological aspects of language (Duranti, 1985), which was therefore reduced to words available either in speech or in writing and considered in isolation from all the other simultaneously employed resources. Only recently researchers have focused on a multimodal approach to communication (e.g., Bavelas & Chovil, 2000; Duranti & Goodwin, 1992; Goodwin, 1981; Hanks, 1990; Roth, 2004a; Watson & Seiler, 1992), with pragmatic studies departing from a language-centered approach to communication (e.g., Goodwin & Duranti, 1992; Kelly, 2001; Kelly, Barr, Church, & Lynch, 1999), and gestures studies, especially in psychology and

anthropology, arguing for the inseparability of speech and gestures (McNeill, 2002) and the need to include the context into the analysis of language and communication (e.g., Goodwin, 2003; Hanks, 1992).

Moreover, a socio-cultural approach to language takes into account the fact that language is produced for an audience, and therefore, there are an inherent presupposition that what is being communicated is understandable. Thus language seen as action becomes generalizable within the activity (for example, teaching), following culturally and historically developed conventions. This has methodological implications for the study of language in communicative encounters, which I address in the next chapter.

Particularly within science education, a few studies have focused only recently on lectures as multimodal and dynamic events, where meaning is distributed among the different resources used simultaneously (e.g., Knain, 2006; Kress, Jewitt, Ogborn, & Tsatsarelis, 2001; Kress, Ogborn, & Martins, 1998; Márquez, Izquierdo, & Espinet, 2006; Roth & Bowen, 2000; Roth & Lawless, 2002a; Roth & Welzel, 2001; Wells, 2000). In these studies, as well as in this dissertation, modalities or modes are considered to be culturally regularized and organized sets of resources for making meaning in specific situations (Jewitt & Kress, 2003). In science lectures, despite the predominance of language (written and spoken words, including lexica, syntax, pitch, and intonation), other modalities also are present and available for students as meaning-making resources. Some of these modalities are, for example, gestures, which include *gesticulations* (e.g., iconic, deictic, metaphoric, and symbolic gestures) and more structured forms of gestures (e.g., emblems), body and gaze orientation, different locations in the room where the teacher stands for different amounts of time, perceptual gestalts, and various material

resources in the room, such as, for example, the chalkboard (where the teacher writes words, sentences and equations, and draws diagrams and graphs), three-dimensional models, charts and posters, projections on the screen (containing images, text, or both), and videos. In the present dissertation, these different modalities are understood as being integrated within one and the same irreducible meaning unit, within which "different aspects of meaning are carried in different ways by each mode" (Kress & Jewitt, 2003, p. 3). The questions that arise, then, are how do these different modalities *carry* meaning, and how are they integrated to each other to achieve coherence during teaching, not only within the same lesson, but also throughout consecutive lessons dealing with the same scientific topic? How does the teacher *communicate* scientific concepts to the students during the same and across lectures? How different resources are integrated to help us understand what the teacher is communicating (i.e., teaching)?

These constitute some of the questions I pursue in the studies that comprise this dissertation. In science education, there currently is a lack of research on the role and integration of multiple resources during lectures. Further research is needed focusing on the nature of the relationship between speech, gesture, and other semiotic resources that speakers produce and the context in which co-participants find themselves and which they co-produce. To understand what students can *learn* from a lecture we need to better understand the resources that the teacher produces to assist listeners in making sense and learning. This doctoral research is entirely devoted to the nature of the meaning-making resources a lecturer produces and their integration, and, therefore, it situates itself in a line of research concerned with the nature of science lectures (Pozzer-Ardenghi & Roth, 2005; Roth & Tobin, 1996; Roth, Tobin, & Shaw, 1997) and gestures studies in teaching

and learning contexts (e.g., Crowder, 1996; Flevares & Perry, 2001; Goldin-Meadow, 2000, 2004; Koschmann & LeBaron, 2002; Roth, 2000, 2001; Valenzeno, Alibali, & Klatizky, 2003; Wall, 2006; Wells, 2000).

At a macro level, I consider lectures as cultural, historical, and social activities (e.g., Engeström, 1987; Roth, 2004b), where tools (e.g., chalkboard, textbooks, speech, and gestures), rules (e.g., socially conventionalized behavior and school's dressing code), division of labor (the teacher is responsible for *lecturing* and providing information to students, who are expected to *learn*), and the community (teacher, students, school staff, and parents) mediate interactions. Within this framework, actions determine and are determined by the activity (Roth, 2004b); that is, the activity is constituted by actions, which are performed to realize goals and make sense only within the overarching activity. For instance, in the classroom the teacher's actions (e.g., movement from one location to another, orientation of his body in particular ways, gestures and words) are understood only within the context of the lesson, but at the same time, these actions realize and structure the lesson and are resources for other actions (e.g., in a question–response pair, the former is a resource for the latter) and the interaction between students and teacher.

At a microlevel, the various modalities the teacher uses when lecturing constitute meaning-making resources, that is, *signs*, which are produced, reproduced and modified in the course of teaching particular scientific concepts. Thus, in my attempt to better understand science lectures as multimodal, communicative, and social events, I engage in semiotic and micro analyses of the integration of words, prosody, gestures, and other nonverbal resources within a meaning unit, without, however, losing sight of the broader context of a lecture as culturally, historically, and socially constructed activity.

Semiotics: Signs and Meanings in Science Teaching

In classroom communication, a variety of signs—including those of written, oral, gestural, and orientational nature—are produced (Roth & Pozzer-Ardenghi, 2006). This is the case particularly in lectures, where a teacher introduces concepts and terms, perhaps for the first time, to a mostly listening audience. In such situations, both verbal and nonverbal aspects of communication constitute semiotic resources that the teacher relies on in the attempt to communicate very specific scientific meanings to students. In this dissertation, I follow the Saussurean definition of sign as "the combination of a concept and a sound-image" (Bally & Sechehaye, 1966, p. 67). Saussure designated the concept as the *signified* (signifié) and the sound-image as the *signifier* (signifiant). Thus, signs present a "double form, consisting of signifiers (the carriers of meaning) and signifieds, the concept or meaning" (Hodge & Kress, 1988, p. 17). Throughout this dissertation, I also make extensive use of the term *semiotic resource*, which I consider to be all those resources—whether traditionally thought of as signs or not—that the teacher uses when communicating, both verbal and nonverbal, and also other material entities that can be interpreted to *make meaning*. That is, besides the teacher's spoken and written words, drawings, and diagrams (which are more readily identified as *signs*), prosodic aspects of his speech (such as, for example, intonation, pitch, and speed of pronunciation), his gestures, body postures, facial expressions, and even different locations in which he stands are also considered to be semiotic resources that are available for interpretation and have *meaning*. Moreover, concrete objects in the room, such as the furniture in the classroom and three-dimensional models the teacher uses, may also become semiotic resources integrated with speech, gestures, etc. within the

same meaning unit when the teacher teaches.

Therefore, in the studies of classroom communication that I present here, there exists a complex organization of a large range of signs that appear to contribute to the meaning-making efforts of the teacher lecturing to students. The organization of the teacher's discourse, not only within the same lesson, but also (and especially) throughout several lessons, permits the same topic to be dealt with during different lessons and later lessons to build on concepts already communicated in previous lessons. The question that arises then is how can topical cohesion be achieved by means other than words (verbal and written signs) alone? Part of the answer resides on the repetition of the signs the teacher uses within and across lessons, a phenomenon I investigate in detail from a semiotic perspective in chapter V.

The repetition of signs also is central to the language philosophy Jacques Derrida has developed in the course of several decades of research. Thus any sign (written or oral) carries with(in) it the possibility to be repeated in a context different than the original context in which it was produced, and apart from the subject who first produced it, while still being recognizable. This property of the sign, its *iterability*, permits it to be detached from the moment it was produced and even from its referent and signified:

> [T]he unit of the signifying form only constitutes itself by virtue of its iterability, by the possibility of its being repeated in the absence not only of its 'referent,' which is self-evident, but in the absence of a determinate signified or of the intention of actual signification, as well as of all intention of present communication. (Derrida, 1988, p. 10)

The iterability of the sign implies that, on the one hand, "a certain self-identity of

this element (mark, sign, etc.) is required to permit its recognition and repetition," whereas, on the other hand, "the very iterability which constituted their [the signs] identity does not permit them ever to be a unity that is identical to itself" (Derrida, 1988, p. 10). Thus, an identity of non-identical entities exist within the sign, which allows it to be repeated and to be identified as a repetition of the same sign even in the face of variations that render the sign different. When considering speech and gestures together, as they occur during the science lectures I videotaped, the sign is composed of an inherently contradictory double signifier (gesture and word), which presents variation while the idea denoted still remains identifiable as the same. That is, as the sign is repeated (iterated) within and across lessons, and even though it is still recognizable as repetition, it presents variations that correspond to variations in the concepts the teacher is teaching. The micro-semiotic analysis of the signs as these occur and re-occur in the teacher's discourse sheds light on teaching as a sequentially organized communicative endeavor, helping us understand how teaching scientific concepts ensues through consecutive lessons.

Studies on Gestures

Gestures studies have been traditionally developed in psychology (e.g., Goldin-Meadow, 2000; McNeill, 1992) and anthropology (e.g., Goodwin, 1995; Haviland, 1993; Kendon, 1997), but recently some studies in education have started to pay attention to nonverbal aspects of communication in both teaching and learning settings, specially with the increasing interest in multimodality in classroom communication.

Studies on gestures as spontaneous occurrences in daily communication first appeared with Efron (1941/1972), and then reappeared with renewed strength in

Kendon's (e.g., 1972, 1980) work. Contemporary studies on gestures range from psychology, linguistics, and social sciences (including, more recently, education) to neuro-cognitive research and computer science (McNeill, 2005). According to McNeill (2000), four main approaches in gesture studies are currently identified: (a) the social-interactive approach aims at understanding gestures' role within social interactive contexts, (b) the cognitive psychological approach is preoccupied with the origins of gestures and their relations to speech production, (c) the modeling approach aims at developing computational models of gesture-speech performance, and (d) another approach studies sign language and the transition from gesticulations to sign. The research I present here falls within the first approach, which is concerned with gesture as an inherently aspect of language and how it is integrated to other resources in everyday communication, including teaching and learning contexts.

Gestures in Teaching and Learning Contexts

Among the various different resources, gestures are the most frequently nonverbal form of communication in teaching (Goldin-Meadow, 2004). Furthermore, gestures constitute the primary means through which integration of all the other resources that form the meaning unit during teaching occurs. Gestures and body orientations connect all the various resources concomitantly used to teach scientific concepts, which are, therefore, distributed into the various modalities employed.

Recently, studies on gestures and its implications for teaching and learning in various age groups and contexts have been developed. These studies, however, are still relatively scarce and, especially in science education, there are even fewer (see the reviews in Roth, 2001, 2003a). Two research groups are most prominent in gestures

studies within education: Susan Goldin-Meadow's research group at the University of Chicago and Wolff-Michael Roth's interdisciplinary research group at the University of Victoria. Goldin-Meadow's research group has developed research on gestures and its implications for teaching and learning (Goldin-Meadow, 2000, 2002, 2003, 2004; Goldin-Meadow & Wagner, 2005), particularly in mathematics and mainly from experimental settings. These studies show that students and teachers alike pay attention to information conveyed in gestures. For instance, teachers (and also children) make reference to information students have produced through gestures only (Alibali, Flevares, & Goldin-Meadow, 1997; Church, 1999; Kelly & Church, 1998), and learners do take advantage of relevant information carried in instructors' gestures during instruction (Goldin-Meadow, Kim, & Singer, 1999; Singer & Goldin-Meadow, 2005); moreover, the use of gestures during instruction promotes learning (Valenzeno et al., 2003) and encourages learners to produce gestures of their own (Cook & Goldin-Meadow, 2006), which leads to learning, as the more children (and adults) gesture when explaining a task, the better they perform on this task (Ehrlich, Levine, & Goldin-Meadow, 2006; Goldin-Meadow, Nusbaum, Kelly, & Wagner, 2001). Another interesting finding regards the readiness of children to learn, which may be inferred by observing speech and gestures mismatches in the child's discourse. Children who produce mismatches are more likely to benefit from instruction (Alibali & Goldin-Meadow, 1993) and to receive more variable instruction from teachers (Goldin-Meadow & Singer, 2003).

At the forefront of gesture studies on science education is the research conducted by Roth and his collaborators (e.g., Roth, 2000, 2001, 2002, 2003a, 2003b, 2004a), of which this dissertation is a part. This research is developed within authentic settings, such

as classrooms and laboratories, with naturally occurring interaction and communication. This research shows that gestures play a crucial role in the development of students' scientific literacy. For instance, students' actions (including gestures) in laboratory settings are integrated with, constitute, and help develop their scientific discourse (Roth, 1996, 1999). As students become familiar with a topic and learn how to appropriately use scientific terms in their discourse, the gestures, which initially preceded talk and already described scientific phenomena even when the utterances did not, achieve synchronization with speech and students rely less on gestures and more upon verbal modes of communication (Roth, 2000; Roth & Lawless, 2002a, 2002b, 2002c; Roth & Welzel, 2001). Thus gestures that were initially similar to actions enacted during scientific activity become increasingly metonymic in form as students develop scientific discursive practices (Roth & Lawless, 2002d). Gestures also constitute the ground for utterances and graphical representations, aligning these two domains of scientific knowledge. Thus when there is misalignment between gestures and speech, it leads to misunderstandings and difficulty in making sense of scientific concepts presented in lectures (Roth & Bowen, 2000). Besides gestures, body positioning and orientation also play important roles in teaching environments. The spatial orientation of the teacher in relation to the students and other material and abstract entities in the setting constrain the types of resources the teacher makes available for students and, consequently, the meanings they can make and what they learn from the lecture (Roth & Lawless, 2002e; Roth, McGinn, Woszczyna, & Boutonné, 1999). Alignment is also important in coteaching, when the teaching partners increasingly coordinate and synchronize not only their teaching practices, but also their gestures, body positioning, and orientations (Roth,

Tobin, Carambo, & Dalland, 2005). Research on social interaction in instructional settings generally (e.g., Goodwin, 2002) and in classrooms particularly (e.g., Franks & Jewitt, 2001) also provides evidence for the importance of embodiment in interaction participants' mutual understanding. Because interaction participants are agents, their ability to (bodily and discursively) position themselves differently during their encounters helps structure the event in progress (Goodwin, 2007), as this is the case, for example, in school lectures.

Types of Gestures

Throughout this dissertation, I follow McNeill's (1992) classification of gestures. This classification includes a continuum (which McNeill named *Kendon Continuum*, in honor of Adam Kendon's distinction of gesture types). This continuum presents in one extreme the gestures that occur in the absence of verbal language and that possess linguistic properties, such as the gestures performed in sign language. At the other extreme of the continuum are the gestures called *gesticulations*, which occur with speech and are non-conventionalized and do not possess linguistic properties.

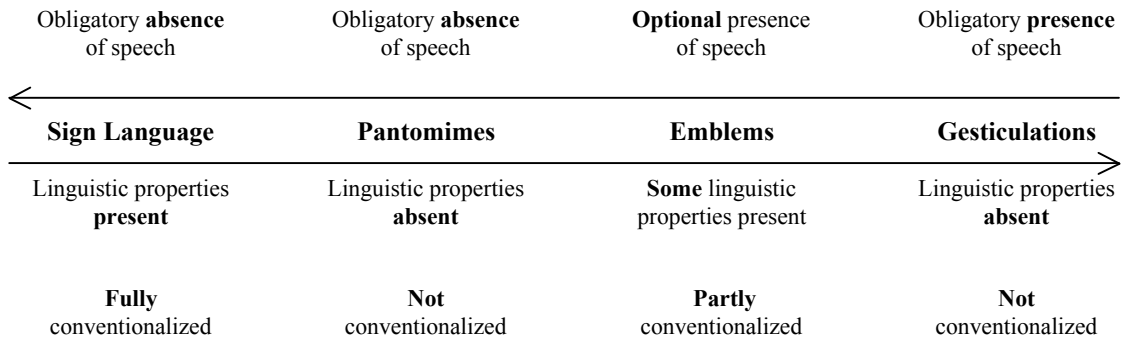

Figure 2.1. The gesture continuum. Adapted from McNeill's (2005) Continua.

Between the two extremes of the continuum, one can find categories of gestures that vary in conventionalization and absence or presence of linguistic properties and

speech (see Figure 2.1). These categories include *emblems* and *pantomimes*. The former are gestures that are partly conventionalized, may or may not be accompanied by speech, and present some linguistic properties. An example of an emblem is the gesture for *okay* (the tips of the thumb and index fingers touching to form a circle and the other three fingers extended). In North America, for instance, this gesture presents a conventionalized meaning and shape; in Brazil, although it also presents the same conventionalized shape, its meaning differs drastically (it is considered an insult of sexual innuendo). The pantomimes are the gestures performed by mimers in dumb shows, for example. They occur obligatorily in the absence of speech, and they are non-conventionalized and do not present linguistic properties. From these four major categories of gestures, I am particularly concerned here with gesticulations.

Gesticulations are "motion[s] that embod[y] a meaning relatable to the accompanying speech" (McNeill, 2005, p. 5). This type of gesture is characterized by the obligatory presence of speech, as they are meaningful only in conjunction with the synchronous word(s) uttered. They are nonconventionalized, nonmorphemic, and cannot be syntactically combined with other gestures (McNeill, 2005). Gesticulations are usually hand and arm movements that accompany speech, but they may also include movements performed with the head, nose, elbows, feet, lips, gaze, or any other body part.

Gesticulations are closely connected to speech production, occurring "as a succession of enactments whose sequencing is governed by the order of presentation of ideas in the discourse" (Kendon, 1980, p. 223). Moreover, in further evidence to their integration with speech, gesticulations seem to occur more often when speakers talk fluently on a topic they are familiar with, as opposed to a topic that they do not master as

well (Baxter, Winter, & Hammer, 1968), and they are suppressed together with speech, as in the case of a person stammering (Mayberry & Jacques, 2000). Gesture and speech are produced together even when congenitally blind people talk to each other (Iverson & Goldin-Meadow, 2001).

Further to McNeill's (1992) classification of gestures, gesticulations are categorized within four groups of gestures: beat, metaphoric, iconic, and deictic. *Beats* are gestures that are void of propositional or topical content, and yet lend a temporal or emphatic structure to communication. They function as interactive gestures, which serve to regulate the coordination of speaking turns, to seek or request a response, or to acknowledge understanding (Bavelas, Chovil, Coates, & Roe, 1995). These spontaneous gestures occur frequently throughout my database (a counting of all the gestures that the teacher performed during a regular seventy-minutes lesson resulted in 82 beats), and they usually functioned to emphasize particular words.

Metaphorical gestures are representational gestures that provide a visual expression of abstract rather than concrete entities. Simply put, metaphorical gestures refer to *metaphors* that render an abstract entity concrete during the communication encounter. For example, using both hands to shape a ball when talking about knowledge is an example of metaphorical gesture; that is, in this case, knowledge is metaphorically depicted as an enclosed entity that can be manipulated (i.e., the *ball* formed by the hand gesture). Metaphorical gestures also occur in my database, although with much lower frequency than the other types of gestures.

Iconic gestures bear a perceptual similarity with concrete entities and events. This perceptual similarity constitutes their communicative strength because of a nearly

transparent relationship to the thing they convey, particularly within a narrative event in which they depict co-present concrete objects and events (McNeill, 1992). The gesture in Figure 2.2, for example, is similar to a capillary bed in its structure: the teacher's fingers are shaping the "branching" of capillaries from veins and arteries in our circulatory system. Iconic gestures often occur during the science lessons in my database, and the referents of these gestures constitute at times important aspects of concepts that are not articulated in words, as I demonstrate in my analysis in three of the studies presented in this dissertation.

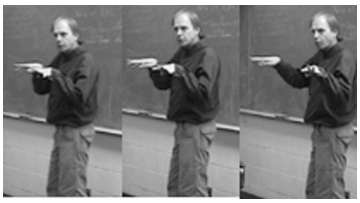

Figure 2.2. An example of an iconic gesture representing the branching of capillaries within the context of teaching about circulatory system.

Deictic gestures include all the pointing gestures made with fingers, hands, arms, head, eye gaze, or any other body part, as long as it is clearly discernible that the gesturer is pointing to something. Pointing (deictic) gestures are used to establish situated linkages between talk, on the one hand, and the physical setting, on the other; their function is similar to that of words such as *this*, *that*, *here*, or *there*, and they frequently accompany them, helping disambiguate their referent. Deictic gestures are used to establish a distinction between figure (topic)—that which is pointed to—and ground (Hanks, 1992)—that against which figure becomes what it is—in a dynamic process through which participants in conversation take some position in the world (Merleau-Ponty, 1962) and which provides a template for interactions.

Indexicality can also be achieved through semiotic resources other than pointing

gestures, such as iconic gestures (or pointing gestures that create an iconic representation [Haviland, 2003]). For example, when the biology teacher in my database places his hand on his neck, as if grabbing it, and then moves his head from left to right repeatedly while talking about the muscles that control the movement of the head, this movement (placing the hand on his neck) can be interpreted as a deictic gesture. Its referent here is not the neck (where the hand rests) but the moving head, or, more precisely yet, the muscles that control this movement. In this situation, the teacher's gesture is framing the head, that is, by grabbing his neck he is "separating" the head from the rest of the body, and, at the same time, he is bringing the head to the foreground, as if he were in fact able to detach it and use it as an object of a demonstration. Here, the teacher frames his head as an object through his gesture, which then becomes the referent of both his deictic gesture and his speech. Thus, depending on the interaction context, other gestures and even actions may function as indexes (e.g., demonstrations can also be considered as indexes for someone or something else, as presented in my analysis in chapter VII).

Deictic gestures are the most common in my database (222 deictic gestures performed during one 70-minute lesson, from a total of 485 gestures of the gesticulation type). Usually they are used to point to something materially existing in the classroom, particularly an inscription, but there are instances when the teacher points to things that are not present in the room at the time. This is in fact another function of deictic gestures, which may be used to establish and maintain abstract spaces during communication (Haviland, 1993; Ochs, Gonzales, & Jacoby, 1996). The importance of deictic gestures to disambiguate referents and achieve reference in communication has led to various studies in cross-cultural communication (Kita, 2003). The intrinsic relation of deictic gestures to

referencing in communication makes it a topic of interest for many scholars interested in communication and social interaction. Moreover, deictic gestures, such as pointing, and verbal deictic expressions (e.g., *here* and *those*) make salient the issue of including the context in the unit of analysis of language and interaction (Duranti & Goodwin, 1992). Indeed, deixis is an essential aspect of the production of context in face-to-face communication and of the organization of perception and orientation during social interaction (Hanks, 1992).

Phases of Gestures

Although gesticulations do not present language-like features, it is still possible to distinguish movements that constitute different parts or *phases* of the gesture (McNeill, 2005). Before a gesture is performed, there usually is a *preparation phase*, which corresponds to the moment the speaker abandons the previous position (i.e., *rest position*) and moves the hands, arms, or both in preparation for the gesture he or she is going to perform. These movements that antecede the gesture constitute the *preparation phase* of the gesture, whereas the actual movement identified as the gesture is called the *stroke*. The stroke usually coincides with the utterance of the word or words that are most closely associated with the imagery of the gesture (though there are instances, especially during conceptual development, when the stroke and the corresponding word do not appear simultaneously [Alibali & Goldin-Meadow, 1993; Roth & Lawless, 2002b]). Analyzing the movements that constitute the stroke of the gesture and the word(s) associated with this gesture phase allow us to more precisely articulate the meaning of the communicative gesture-word unit. After the stroke of the gesture has been performed, the hand is brought back to rest position, with movements that signal the end of the gesture.

This final phase is denoted by the term *retraction phase*. It is important to note, however, that not all gestures present all three phases; one gesture, for example, can immediately follow another, thus skipping the preparation phase, also resulting in the first gesture missing the retraction phase. Thus, only the stroke phase of a gesture is obligatory.

For example, consider the gesture represented in Figure 2.2 (showed earlier). The gesture starts with the palms of the hands facing down and with both hands open and placed side-by-side at the level of the teacher's chest. To get to this initial position, the teacher has to lift his hands and place them in this particular manner. These movements that antecede the gesture constitute the *preparation phase* of the gesture and are represented in the still frames in Figure 2.3. The teacher shifts body orientation, turning to face the students, while lifting his hands and arms from rest position (first still frame in Figure 2.3) to the level of his chest (last still-frame in Figure 2.3), when he is then ready to perform the gesture.

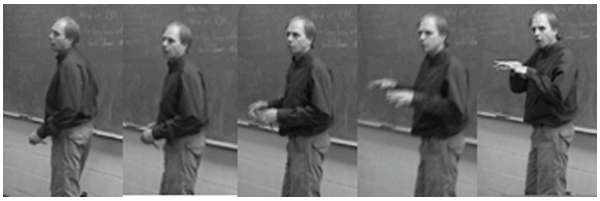

Figure 2.3. Preparation phase of the gesture represented in Figure 2.2.

After the stroke of the gesture has been performed, the hands are brought back to rest position, with movements that signaled the end of the gesture, that is, the *retraction phase*. Figure 2.4 presents the retraction phase of the gesture represented in Figure 2.2.

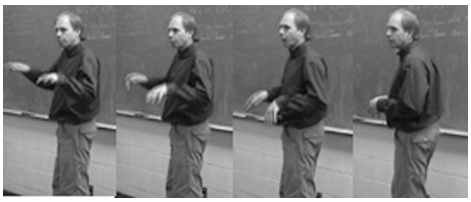

Figure 2.4. Retraction phase of the gesture represented in Figure 2.2.

Gesticulations are non-conventional and idiosyncratic gestures, and their meaning is global (McNeill, 2002); that is, any part of the gesture has meaning only when the entire gesture is taken into consideration. These characteristics of gestures place them on opposing grounds in relation to speech (which is linear and sequential, derives the meaning of the whole from its parts, and it is based on pre-established conventions of meaning on the form of signifier-signified pair).

Gesture and Speech Dialectics

In the research I present here, I follow a line of work begun by the Russian social psychologist Lev S. Vygotsky (e.g., 1986) and taken up by David McNeill (e.g., 1992) to regard ideas and meaning units as constituted by at least two aspects that stand in a dialectical relation—gesture and speech. In the dialectical approach proposed, speech and gesture are different ways in which an idea expresses itself, but the two expressions cannot be reduced to each other. Thus gestures and speech are dialectically related, each constituting a realization of a whole *communicative* unit. Both dialectical materialist psychology (Vygotsky, 1986) and phenomenology (Merleau-Ponty, 1962) suggest *meaning* as constituting this unit. The idea or meaning unit, in Hegelian language,

sublates (i.e., integrates and overcomes [Hegel, 1977]) the different expressions (speech and gesture); however, in doing so, it also harbors an inner contradiction: Gesture and speech are radically different yet are (one-sided, partial) expressions of the same higher order idea. That is, because speech and gesture are both identical (i.e., concrete realization of *meaning*) and non-identical (i.e., they constitute two different modalities, with diverse characteristics), there is a contradiction, which leads to an instability of imagery (gesture) and language (speech) that propels communication forward, until the speaker has a sense of having achieved some stopping order that derives from a sense of semantic and grammatical completion (McNeill, 2002).

This dialectical unit, however, may include more than speech and gestures; it also includes other semiotic resources that are made available in the setting and to which conversation participants are attuned (Roth & Pozzer-Ardenghi, 2006). The dialectical communicative meaning unit is thus constituted by all the verbal, nonverbal, and material resources available in the setting; but meaning cannot be reduced and represented by any one of these *moments* on its own. When attempting to understand teaching from a communicative stance, therefore, I take into consideration this meaning unit, which is the smallest unit of communication and also the smallest unit of analysis, in the sense that no isolated moment can be investigated independent of the others. (In dialectical approaches, the notion *moment* refers to aspects that can be identified and isolated within the unit but that cannot be understood independent from the unit.) Neither speech nor gesture accurately and entirely represents this unit, but only partially, obliquely, and one-sidedly refers to it. Each single resource is but a one-sided expression of the whole idea communicated; they are identical in the sense that through them the communicative

meaning unit expresses itself; they inherently are non-identical because they constitute radically different forms and contents of matter (gestures are global and synthetic, with the meaning of the parts determined by the meaning of the whole, whereas speech is segmented and analytic, with the sequence of words determining the meaning of the sentence [McNeill, 2005]). In this sense, all the semiotic resources that express the communicative meaning unit constitute an identity of non-identical things and they presuppose each other in a relation that is inherently dynamic.

Accordingly, *meaning* is not simply distributed across each one of the modalities; neither is meaning the sum total of these resources. Rather, meaning arises from the dialectical (mutually presupposing and mutually constituting) relation among all these perceptually different (hence, non-identical) resources (Vygotsky, 1986). To reiterate, although each modality may function best to present one type of information (or, more precisely, to present information in one specific manner), no one of these modalities carries meaning in isolation from the others, and, as such, no one should be investigated as a modality in isolation from the other modalities. Following Vygotsky, the contribution of each modality can be established only in its relation and dependence to all other modalities, and communication as a whole is subordinated to the ongoing activity. Thus, investigating only the words the teacher utters during a science lesson does not allow one to fully grasp how a particular scientific concept is *taught*. Conversely, the study of gestures in isolation from the speech and the material resources available in the setting is a poor approach to understand communication of new concepts during science teaching. Throughout this dissertation, I aim at articulating and analyzing the entire unit, which the teacher uses for publicly articulating scientific concepts to make resources

available for understanding and learning. Teaching, from this perspective, is a complex performance requiring and producing multiple resources of very different nature.

Catchments and Growth Points

Within gesture studies and of particular interest here are the theoretical concepts developed by David McNeill (1985), who has built his theory of communicative action on Lev S. Vygotsky's (1986) ideas of activity as an irreducible unit that integrates consciousness and the material world. In Vygotsky's sociocultural and cultural-historical theory, activity—including communication—constitutes an irreducible unit. The meaning of a gesture|speech ensemble during discourse therefore remains irreducible and this meaning is tied to the activity as a whole. Similarly to the activity in its entirety, communicative meaning units develop from initial seeds (the genetic origins of ideas communicated) and then develop. These meaning units therefore can be understood only if they are studied in an historical approach. The two concepts of *growth points* and *catchments* are designed to allow us the study of communicative meaning units because these concepts identify the moments new ideas are brought into a conversation, as well as the unfolding thematic structure of discourse that develops when the core ideas are repeated.

The growth point is proposed as "the minimal unit of an imagery-language dialectic…. a package that has both linguistic categorical and imagistic components" (McNeill, 2005, p. 105). Growth points are always associated with the context of the communicative action, and they represent the moment in which a speaker's idea unit initially takes form in discourse, that is, they mark the "specific starting point for a unitary thought" (McNeill, 2005, p. 106). They constitute a minimal unit or idea that

integrates imagery (gesture) and words (speech), but which may also include other semiotic resources such as visual representations, salient aspects of the setting, prosody, and orientation (e.g., Roth, 2004a), all as part of the same communicative meaning unit. Whatever is communicated emerges at a certain point in the conversation, and although it relates to the previous context, it does not exist previously to the very moment when it is articulated. For Vygotsky, this growth point constitutes the general, which concretely realizes itself in different ways (i.e., particularizes itself) with each repetition.

Alternatively, during a conversation there are many other moments when participants try to articulate and stabilize an idea; usually, in the search for stabilization, an idea is recurrently addressed. These moments of recurrence are identified through the repetition of certain gesture features, which constitute catchments (McNeill, 2002). The existence of catchments points to a common idea. Thus catchments are defined as recurrences in one or more features of a gesture into other gestures, consecutive or not. "A catchment is a kind of thread of visuospatial imagery that runs through a discourse to reveal the large discourse units that encompass the otherwise separate parts" (McNeill, 2005, p. 117). Therefore, the analysis of catchments permits the identification of meanings that the speaker considers to be related to each other, thus revealing larger discourse units (McNeill, 2005). The catchment is motivated by thematic content embodied in the feature of the gestures that recurs but that develops and therefore also changes during recurrence. In this sense, the various repetitions of a gesture can be thought of as attempts to stabilize and develop the topic or content of the lecture. In my database, these repetitions constitute the context within which new information is presented, thus connecting a variety of different scientific terms with a particular

scientific concept. The analysis of catchments and growth points, therefore, is particularly useful to understand, from a communicative perspective, how scientific concepts are articulated in a developing and unfolding fashion within and across lecture situations, when new aspects of a certain concept are introduced while others are repeated and reinforced.

Chapter III:

Methods

The database for all the five studies that are presented in this dissertation is composed of 26 consecutive lessons I videotaped, with the help of a research assistant[1], at a private school in Greater Victoria, British Columbia. My choice of school was based on two criteria: (a) the proximity of the school to either the University of Victoria, where I developed my research, or my home, and (b) the willingness of both teacher and students to participate in this type of research endeavor. The first criterion was important to avoid long commuting between my home, the research lab at the University of Victoria, and the school, not only because of transportation related issues, such as, for example, carrying heavy videotaping equipment on a daily basis between the school and the research lab, but also because of time consumption. The second criterion constituted an inevitable requisite for the research to exist in the first place, and I was fortunate to encounter a very welcoming and participative school administration and staff, as well as students, at my very first attempt to contact a school.

Insofar as my interest was to collect data on classroom interaction, focusing particularly on the use of gestures and other nonverbal resources during teaching, the subject matter of the lessons did not constitute a primary criterion for selecting the school where the data collection would take place. However, because of my background in biology, I decided to collect data in a biology course, if possible. Thus, when contacting the school principal, I already made explicit my preference for a biology course at secondary level as the setting of the data collection. Once again, I was fortunate in this selection, as the biology teacher in this school was not only willing to open his classroom for me, but he also was personally interested in research in science education, and he was responsible at the time for providing relevant and new educational research information during staff meetings.

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[1] I thank Diego Machado Ardenghi for operating one of the two camcorders during the 26 lessons that compose my database, and also for transcribing some of the videotapes.

Finally, selecting a private school as the setting for data collection simplified and expedited the process of obtaining permission to participate on and videotape the lessons, as I could negotiate my presence in the school directly with the school administration and the teacher and students implicated in the process.

Written consent was obtained from all the students (and their parents or legal guardians) in the biology course, and from the teacher as well. For each one of the five research studies reported here, I have also obtained case-by-case written consent from the teacher to display his image in publications, presentations and in this dissertation.

Biology Course, Teacher, Students, and the Layout of the Classroom

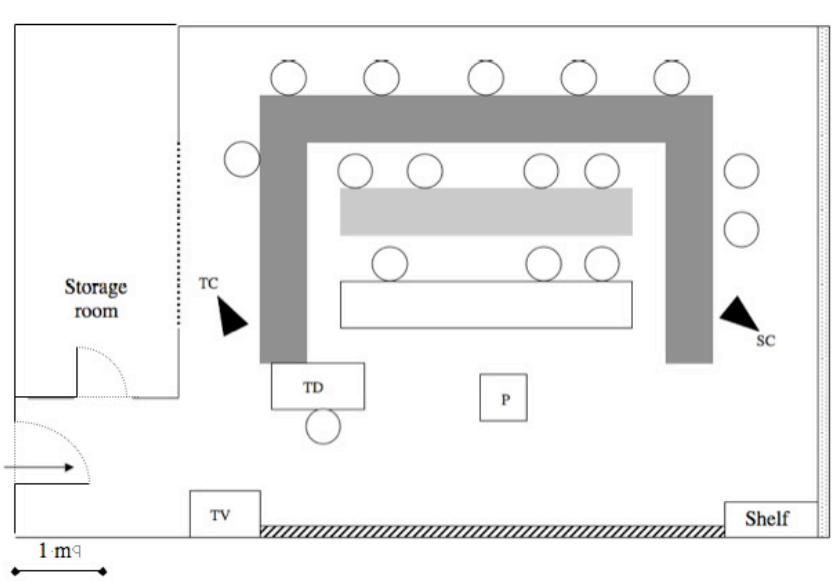
Once I had selected the school where I would collect my data for my Ph.D. research, and after obtaining all the required written consents and authorizations from the school, the teacher, and the students involved, I negotiated with the teacher a date to start the data collection. The grade twelve biology course that I videotaped started on early September and finished on end of January. During these five months, students attended this course every weekday. Each lesson lasted 70 minutes, and most of them were lecture-style, with the exception of occasional video screenings and the days of exams.

The biological content of the selected biology course included topics on human anatomy and physiology. The particular 26 lessons I videotaped dealt with nervous system, hormonal control, circulatory system, immunology, respiratory system, excretory system, homeostasis, and male and female reproductive systems, in this sequence.

The teacher of this biology course has many years of experience as a biology teacher and within this particular school. As mentioned earlier, at the time of the data collection, he was also responsible for updating his colleagues on matters related to science education research during

staff meetings. Fifteen students participated in this course, seven males and eight females, all of the same age group. All students were English native speakers, and none of them were new to the school in the academic year when the data was collected.

The floor plan of the classroom where most of the lessons I videotaped took place is represented in the diagram in Figure 3.1. However, not all of the lessons videotaped occurred in this room. Two lessons happened in another classroom, and other two lessons in a third classroom. Both alternative classrooms were more traditionally configured, with student chairs equipped with writing worktops placed in rows in front of the chalkboard.



Legend:

Arrow: entrance through the room door
Storage room: attached room with teaching and laboratory materials **Dotted line**: opening of Storage Room into the classroom
TV: TV and video equipment cart
Diagonally striped area: chalkboard
Shelf: bookshelf
TD: teacher's desk
P: table with projector
TC: camera focusing on teacher
SC: camera focusing on students
White rectangle: students' lab bench in the first level of the room
Light gray area: students' lab bench in the second level of the room
Dark gray area: students' lab bench in the highest level of the room
White circles: seats
Dotted area: windows

Figure 3.1. Diagram of the floor plan of the classroom where most of the lessons videotaped took place.

Despite the fact that this classroom was set up as a laboratory, none of the lessons I recorded involved laboratory activities; the teacher taught the subject primarily by means of lectures, involving a variety of visual resources beyond the use of the chalkboard, including videos, three-dimensional models, overhead projections, demonstrations, and students' presentations.

Data Collection

I started videotaping this 12th-grade biology class on November 24th and videotaped 26 consecutive lessons until January 22nd. I videotaped every lesson, with the exception of exam days (that is, the days in which the only activity would be students completing written examinations). In total, the data collected amounts for over 30 hours of videotaped material for each one of the two camcorders used.

With the help of a research assistant, I videotaped the lessons using two camcorders. One of the camcorders focused on the teacher whereas the other focused on the students. After the first few lessons, when I experimented with different positions for the cameras, I decided on a position for the two cameras, one on each side of the classroom and towards the front of the room, as shown in Figure 3.1. The camcorder that focused on the students was fixed on a tripod from where it could be moved sideways and up and down as necessary. I used a wide lens to capture all the students in a single frame. The camcorder focusing on the teacher was movable and handheld, thus capable of following the teacher around the room and capturing his body movements, gestures, facial expressions, positions in the room, and also all the visual and material resources he used, such as, for example, the chalkboard and what was written and drawn on it, the projected images on the screen, various three-dimensional models and props, the TV, and maps and diagrams hanging over the chalkboard.

Data Analysis

I videotaped the lessons using two digital camcorders, which allowed me to play the recorded material on the computer. I used iMovie® 3.0.3, a free software package for Apple Computer Inc.©™, to watch the video frame-by-frame in the computer. This allowed me to

perform microanalysis of the gestures and other movements enacted by the teacher. This same software also facilitated playing the movie during transcribing. To avoid fully transcribing all the 26 videotapes, I designed a coding system (that is, a text file containing the main events in classroom activity, speech, and gestures that happened in each lesson, and the correspondent time in the videotape) from which I could easily find a specific phenomenon in any one of the 26 videotapes.

To facilitate the data analysis, I produced smaller (one to two minutes) episodes of selected parts from the 70-minute lessons, exporting these episodes into QuickTime™. Then, each QuickTime™ short episode was transcribed verbatim, including pauses and verbal descriptions of nonverbal actions when necessary. To measure pauses (in milliseconds) in the discourse, I used Peak™ DV 3.0. This software was also helpful to synchronize speech and gestures, as it allows me to watch the video in a separate window simultaneously with the graphic representation of the sound (see Figure 3.2). Thus I was able to select a particular word or utterance in the graphical representation of the sound and listen to it repeatedly while watching the synchronous video image. Alternatively, when searching for the stroke of a particular gesture, I could select the particular section where the stroke occurred and listen to it repeatedly, thus identifying the exact utterance that corresponded to the stroke of the gesture. The same procedure was used to identify, synchronize, and measure the time of preparation and retraction phases of gestures, and pre and post-stroke holds.

To measure variations in pitch and intensity of speech, I used PRAAT© 4.5.02, a freely downloadable multi-platform software program[2]. I converted the QuickTime™ short episodes into sound format and then played them in PRAAT© 4.5.02, producing graphics for both

[2] PRAAT, copyright by Paul Boersma and David Weenink, can be downloaded from http://www.fon.hum.uva.nl/praat/

intensity (volume) of speech and pitch. Using this software, I was also able to synchronize words uttered with the exact curve in the graphical representation of intensity and pitch. I subsequently added these words to the graphical images using Adobe PhotoShop® 7.0. This same software was used to produce all the video still-frames that illustrate the teacher's gestures and positions in the room. I used a function of Apple Computer Inc.©™ that allowed me to capture a particular frame of the video as I was playing it on iMovie®, and then paste this image to Adobe PhotoShop® 7.0 and prepare it for insertion in the text file.

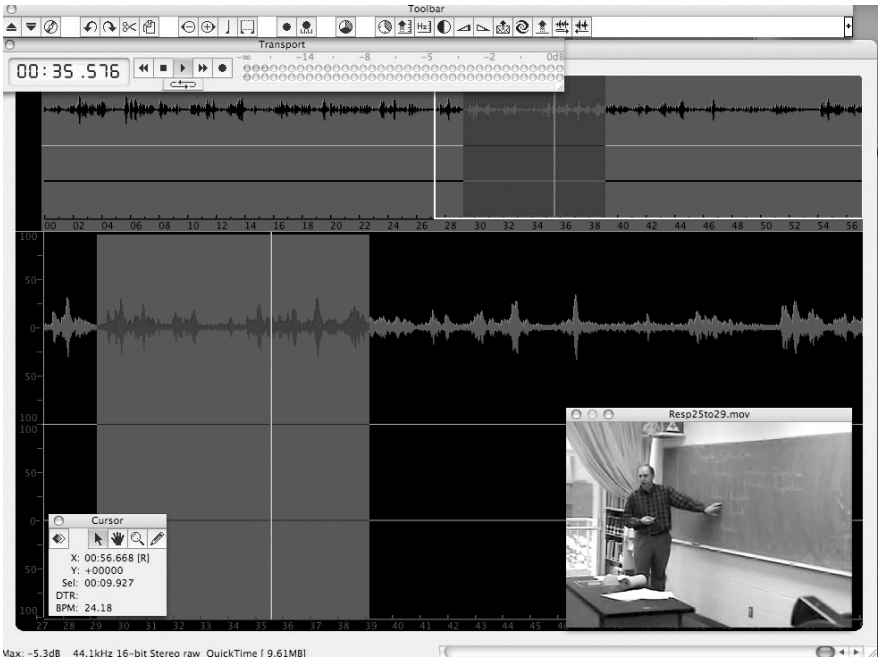


Figure 3.2. Illustration of Peak™ DV 3.0 software main screen, which makes possible the synchronization of speech and gestures by playing simultaneously the video and the graphic representation of the sound.

Data Selection and Analysis in the Five Individual Studies

In this section I briefly articulate the particular aspects of the selection and analysis of the data used in each one of the five studies that comprise this dissertation. Although all five studies used the same database, each one of them is unique either because of the particular sections of the data used or because of the specific focus of the analysis. Thus, for example, the data used

for the studies reported in chapters IV, V, and VI present lessons that dealt with circulatory system. Each one of these studies, nevertheless, present a different focus of analysis; for instance, the study on chapter VI is a semiotic microanalysis of the gestures and words the teacher used and repeated throughout several lessons, whereas the study on chapter IV presents only a fragment of one of the lessons on circulatory system as an illustrative example for the theoretical position I take in that study. Chapters VII and VIII deal with different aspects of teaching and communication in the classroom, each chapter involving different levels of analysis (micro and meso, respectively), and also making use of two different lessons as dataset.

For all the five studies reported here, I analyzed the recordings of the teacher. This decision was based primarily on the quality of the data collected; that is, the tapes resulting from the camera that focused on the students did not provided me with good enough sound and visual quality of data to pursue a microanalysis of speech, gesture, and other resources being used by the students. Despite not using the *students* tapes to perform microanalysis, I did watch these tapes to search for particular details that were not clear in the other tapes (the *teacher* tapes), such as, for example, physical configuration of the room and words uttered by the teacher (at times, the sound quality of the *students* tapes were best for understanding what the teacher was saying). Watching the *students* tapes also provided me with a better understanding of the students' participation during the lessons, particularly the silent forms of participation and interaction, which included back channeling (Bavelas et al., 1995), such as, for example, nodding and various facial expressions.

However, I would like to point out that I do acknowledge that students' and teacher's interaction is constituent and constitutive of the communication; moreover, this interaction between students and teacher exists at a primordial level, once we take into consideration the fact

that communication and language, from a socio-cultural perspective, is produced *for* an audience. Therefore, the semiotic resources the teacher makes available when teaching are produced for the audience (fifteen male and female students, in the case of my data), and already, in their production, presuppose the intelligibility of the communication. In this sense, these resources, even though produced by one particular teacher within a particular setting and talking about a particular topic, become generalizable to other people (for example, teachers) engaging in similar activities (for example, lectures).

Although each study makes use of a limited section of the entire database, my constant involvement with all the lessons that comprise this database provided me with a deep and broad knowledge of all the 26 lessons recorded, even though only parts of it were further analyzed and presented in each study, as the nature of both the topic of my research and the particular (micro)analysis I conducted require focusing on relatively short timed data samples.

Chapter IV: On Performing Concepts During Science Lectures

In this study, I argue for a conception of conceptions and knowledge that includes the complexity of multimodal teaching and learning environments, as well as a dialectical approach to the relation between diverse modalities used by the teacher when lecturing scientific concepts. My dataset for this particular study, therefore, constitutes a resource for illustrations rather than the source for an inductive research process. Thus, I selected episodes within the larger database that provided illustration for the particular arguments I developed in this study. Although purposefully selected, these episodes are representative of the larger database, and many other instances in various other lessons could have been used to exemplify the same point in the very same way. The episodes I ultimately selected present the teacher simultaneously using a variety of resources to teach a scientific concept. My analysis focused on the integration of these

resources within the meaning unit, particularly on the communicative and integrative functions of gestures. I presented the data in still-frames extracted from the video, coupled with the corresponding verbal articulations, which I transcribed verbatim, although I did not include pauses or prosodic aspects of speech in the transcription, as these were not necessary for this particular study. I then added verbal descriptions of the synchronized gestures and body movements to the transcriptions. Salient aspects of the setting were digitally enhanced (using Adobe PhotoShop® 7.0) to provide better visualization in the still-frames (for example, I increased the contrast and altered the hue of the drawings on the chalkboard to render them more visually accessible).

Chapter V: Communicative Development of Scientific Concepts in Lectures

In this study, I am concerned with the communicative development of ideas and concepts in lectures. Specifically, I focused on how a teacher communicates (i.e., teaches) a concept throughout several consecutive lessons, and how different ideas are communicatively associated to other ideas, previously presented. To follow the development of the concepts during the same and across different lessons, I selected an entire unit, circulatory system, and proceeded to analyze all the lessons in which this topic was taught. During seven consecutive lessons (over nine hours of recorded material), the teacher introduces to students concepts related to the circulatory system. I carefully and repeatedly watched each one of these lessons, searching particularly for the occurrence of catchments and growth points (refer to chapter II for a review of these concepts). The unit of analysis included not only the teacher's speech, but also all the other resources employed to communicate a particular concept, such as material resources and prosody, for example. Ultimately, I selected one particular gesture and followed its recurrence (catchments) throughout consecutive lessons in an attempt to understand and articulate how a

particular concept evolves within and across lessons.

Insofar as I used the theoretical concepts of growth points and catchments (McNeill, 2000), I engaged in a microanalysis of the gestures, searching the different phases of the gesture (that is, preparation phase, stroke, retraction phase) and synchronizing each phase with the accompanying utterance and also producing pitch and intensity variation graphs. In the presentation of the data, each still-frame captures either the beginning of the stroke of the gesture or it's ending. Some still-frames capture other developments of the gesture, as these were considered important for my analysis. The still-frames were also used when a particular gesture presented a pre-stroke hold, a post-stroke hold, or both, in which case the still-frames represent these pre- or post-stroke holds. When a pre- or post-stroke hold occurred without synchronized speech, I presented only the duration of these events (in milliseconds) and the representative still-frame, inasmuch as in the absence of speech, there is no purpose (and indeed no feasibility) in producing pitch and intensity variations graphs.

Chapter VI: Catchments, Growth Points, and the Iterability of Signs in Classroom Communication

This study is a semiotic analysis of gestures and words integration and repetition within and across lessons. I interweave David McNeill's (2002) concepts of *catchment* and *growth point* with Jacques Derrida's (1988) concept of *iterability of signs*, within the context of teaching science with words and gestures. The particular dataset I selected to perform this analysis is composed of 14 repetitions of a gesture during consecutive lessons on circulatory system. In chapter V, I have already analyzed these gesture occurrences from the point of view of the communicative development of the concepts, thus emphasizing the scientific concepts and the sequential order in which these gestures occurred. Here, however, I focused only on the stroke of

each gesture, and all the illustrations are thus limited to this particular phase of the gesture. The various repetitions were grouped according to the similarities of the main features of the gestures using Adobe PhotoShop® 7.0.

Chapter VII: How Do We Know He Is Not Talking About Himself? Demonstrations in Science Classrooms

Through careful and repeated viewings of the entire database, I identified the phenomenon I investigate in this study, namely, the occurrence of demonstrations in which the teacher speaks and moves as someone else in a different context than the classroom environment. My interest was in understanding what are the semiotic resources made available during these events that allow one to distinguish between self-reference (that is, when the teacher makes reference to himself, as teacher in the classroom) and reference to someone else, different than the teacher in the classroom context (that is, when he demonstrates someone else in a different situation). Once my topic of interest for this study was identified, I searched the entire database for all the occurrences of this particular phenomenon. I then proceeded to analyze the selected episodes, searching for a specific episode representative of all the other instances in which the phenomenon occurred and that I could analyze in more depth. Ultimately, I selected one episode for microanalysis and insertion in the text as exemplary of the phenomenon investigated. I produced graphic representations of pitch and intensity variations and still-frames for different moments of the episode, as necessary for exemplification of the analysis.

Chapter VIII: Action and Interaction in the Classroom: Teacher's Movement and Associated Pedagogical and Discursive Practices

In this study, I analyze lessons as multimodal, social, and interactive phenomena. Insofar as any lecture-style lesson in the database could be used to exemplify my findings, I randomly

selected one lesson to analyze and use as illustrative in this study. After separating all the lecture-style lessons in the database, I choose one by its number. The selected videotape presented a lesson on respiratory system, which is representative of other lessons in my database, in both duration and teaching strategies and resources used[3].

In this study, I am concerned with the teacher's movement in the classroom as a meaning-making resource; thus, I identified and analyzed the teacher's locations in the room and his movements between these locations in relation to the different pedagogical, interactive and discursive practices that are associated within the teacher's *actions*. By carefully and repeatedly watching the videotape, I recorded the time the teacher spent in different locations in the room, ultimately identifying for heuristic purposes five different general locations, which I represented in a diagram I created using Microsoft® Word X for Mac® and exporting it to Adobe PhotoShop® 7.0.

The time the teacher spent in each location was recorded using hours, minutes, seconds, and hundredths of seconds (for example, 0:04:24:13). Every time the teacher started to move from one location to the next, I stopped the videotape and recorded the absolute time displayed on the screen on a table created for that purpose. Insofar as I used hundredths of seconds as the unit of time, any time spent between locations was significant, and it was arbitrarily included as time spent in the new location.

For each of the locations, I identified the associated pedagogical, interactive, and discursive practices. I counted and classified each gesture the teacher performed during the entire lesson, recording this information in a separate table, where subsequently I also added the

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3 In some lessons, the teacher used three-dimensional models of various human organs, which he did not use in this particular lesson. However, in the majority of the lessons the teacher used the same resources as in the lesson I analyzed for this study, that is, speech, gestures, and the chalkboard (written words and drawings). His teaching strategies involved lecturing and students' paper exercises in most cases, which is also the case in the selected lesson.

different locations in which the teacher stood and the pedagogical, interactive, and discursive practices I had identified. Therefore, for each location where the teacher stands during the lesson, I recorded the total time spent, the corresponding practices enacted and the number of gestures performed. These results are presented in a table in chapter VIII. I also generated still-frames to exemplify the teacher's locations and other relevant gesture or body positioning.

Synchronizing the teacher's movements with the occurrence of speech and gesture allowed me to understand the teacher's actions as part of the larger activity of lecturing, analyzing what events lead to the movement between locations, and what events follow as a result of this movement. The results of this analysis are presented in chapter VIII and they provide insights on the nature of classroom teaching as a multimodal, social, and interactive phenomenon, and particularly, on the role of teacher's actions in organizing and structuring classroom activity.

Chapter IV:

On Performing Concepts During Science Lectures

Preface

In this study, I articulate and theorize, from a multimodal perspective, how various resources interact during lectures. I focus exclusively on the teacher's multimodal discourse. As illustrations for my argument in this study, I selected episodes in which the teacher makes simultaneous use of a variety of resources to teach a scientific concept. I analyzed these episodes, focusing particularly on the integration of these resources within the communicative meaning unit, and generating hypotheses about the communicative and integrative functions of gestures within this unit. I pay particular attention to the conceptualization of the dialectical, communicative, meaning unit, which I articulate following Vygotsky's (1986) notions of meaning unit and McNeill's (2002) dialectics of speech and gesture. In this sense, this study constitutes the background for the following studies in this dissertation, as it provides the basic framework for the analysis I conduct in the other studies (that is, that lectures are indeed multimodal and that the multiple resources are integrated into this dialectical, communicative, meaning unit). A different version of this study has been published in Science Education earlier this year.

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The Role of Gestures and Other Nonverbal Resources in Creating a Meaning Unit: Integration of Multiple Resources and Communication of Scientific, Conceptual Information

When teachers lecture during science lessons, they make use of different resources to convey the meaning of what they are trying to teach. Speech is but one resource; many other nonverbal and material resources are used. How are these resources

related to one another? What are their functions? How do these resources work together to teach scientific concepts? In this study, I argue that these available resources—though inherently different—constitute, in their simultaneity and totality, irreducible units of meaning. That is, we cannot think of these resources as elements that taken alone, in combination, as sum, or in interaction express meaning; rather, the meaning unit is expressed differently in, but cannot be reduced to, these resources. I provide examples to show how the teacher employs and provides meaning-making resources across several modalities, and how these modalities are integrated to teach a scientific concept. On the basis of these examples, I subsequently theorize content knowledge in general and conceptual knowledge in particular in terms of the simultaneous, mutually presupposing modalities. Thus, I propose a notion of knowledge that transcends the word-centered conceptions salient in current science education practice, arguing that conceptions as articulated by lecturers are not words that teachers say, but rather that conceptions are units that are revealed differently in the various different modalities materially enacted by speakers. It is in the totality of the public teacher presentation of an idea that the concept is presented, whereby the different modalities are understood—following Vygotsky (1986) and McNeill (2002)—as different expressions of the same underlying meaning unit. The upshot of such a reconceptualization of science content and conceptual knowledge is a rethinking of a variety of science education practices, including, for example, student assessment.

Both sample episodes used here show how the teacher makes use of a variety of nonverbal resources simultaneously as part of teaching scientific concepts. In these situations, gestures, body position, gaze orientation, and material artifacts are integrated

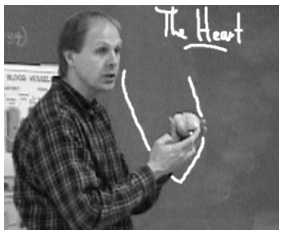
to present a concept. This means that we cannot simply add up the sense of a word and a diagram, or a word and a gesture to get at the meaning unit that the teacher tries to communicate. Instead, each aspect that expresses the meaning unit (word, gesture, inscription, body position, and so on), though radically different in its physical manifestation, *presupposes* all other elements. The elements do not exist independently but only in and through their relation to all other elements.

Communicative Articulation of Biological Facts

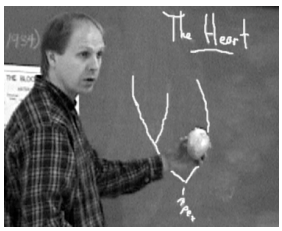
My first episode comes from the second of five consecutive lessons on the circulatory system. In this lesson, the teacher was presenting to students the anatomy of the heart, identifying its parts and respective function in the circulatory system. The teacher made use of a schematic drawing on the chalkboard and of a three-dimensional model of a heart. After it has been completed, the point of the first part (Episode 4.1a) of this episode will have been the identification of the left ventricle.

Episode 4.1a: Identifying the left ventricle[1]

01 The heart has a [point to it],
[*points to the 3D model of the heart*]

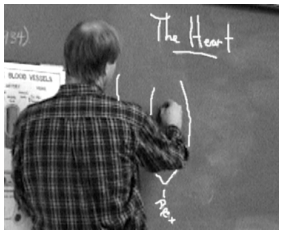


02 which [is called the apex]. And on the
[*turns and writes* apex]
03 outside [there is a bit of a crevice],
[*turns and draws a line on the diagram*]
04 a little groove [right through there],
[*holds the 3D model of the heart away from himself, which allows students to see it*]



[1] Words between brackets are synchronized with actions described below the sentences, also within brackets.

05 and so [all of these is left ventricle].
[*turns to the chalkboard and inscribes* LV *on the diagram*]



In the course of this episode, the audience is presented with multiple resources for identifying and locating the left ventricle. The way in which the teacher makes the apex present is through the simultaneous use of speech, deictic gesture, and material artifact (three-dimensional model of the heart). The teacher starts by articulating the existence of a *point* in the heart (line 01), and providing a name for it (*apex* [line 02]). At the same time that the teacher affirms verbally that *the heart has a point to it*, he also holds the three-dimensional model of the heart so that students can see it, and then points to the apex, therefore providing students with a specific location for it. While talking about the crevice on the outside of the heart (lines 03–04), the teacher draws a line on the diagram; he then turns towards the audience and holds the three-dimensional model of the heart away from himself and fully visible to students in order to show them the object to which he is making verbal reference. He subsequently turns towards the chalkboard, and writes down on it *LV* connecting it to the diagram of the heart he is developing.

Here it is noticeable already how at least four different resources (i.e., speech, gesture, three-dimensional model, and diagram on chalkboard) are used concomitantly to teach students a concept. In other words, the concept of *left ventricle*, its location and some of its features come to exist in the totality of the presentation. Any single articulation (word, gesture, diagram) taken by itself is insufficient. Thus, the sentence *And on the outside there is a bit of a crevice, a little groove right through there* makes little sense, even when considered just among the other words. For example, *And on the*

outside concurrently requires the heart as a whole, not only the left ventricle to make a more determinate meaning element. Taken by itself, the model of the heart does not communicate much, for there is evidence that students do not see what is relevant to a scientific concept prior to instruction, even seeing contradictory features in the same presentation; prior to knowing what a lecture is intended to teach them, students do not know which possible figure|ground configuration is the one that is relevant (Roth, 2006a).

The line inscribed on the chalkboard does not make sense in itself. It is related to something else on the three-dimensional model of the heart. More so, any feature of the three-dimensional model becomes salient if it can be related to something on the diagram. Thus lines on the diagram and features of the heart mutually presuppose and constitute each other's salience—which, here, comes from the perceptual similarity of a chalk-drawn line with respect to the other two-dimensional features, the relation of these features (e.g., shape) to the three-dimensional model, and the relation of one feature (crevice) to the line drawn. It is because of perceptual similarity that something becomes figure against everything as a ground, and this something has *crevice* and *little groove* as its verbal equivalent.

The idea of the left ventricle as an important and differentiable part of the heart is embodied in the mutually constitutive relationship of talk, three-dimensional model, and two-dimensional diagram. The sense of the word *crevice* in the present context arises from its relationship to the cotemporaneous groove in the three-dimensional model and the line in the chalkboard diagram. They form the unit crevice|three-dimensional groove|two-dimensional line. Each of the three elements of the unit presupposes the

others to become salient against everything else available as resources in this classroom. The word *crevice* is salient and defined by the three-dimensional groove and the two-dimensional line, as much as the two-dimensional line is salient because of the words *crevice* and *groove* and the visible groove in the three-dimensional model.

The teacher shifts his body orientation once more from facing the class (line 04) to facing the chalkboard (line 05). In the latter position he adds to a diagram that already exists and is elaborated by the inscription *LV*. Taken by itself, the *LV* inscribed on the chalkboard means little; its sense simultaneously requires the remainder of the diagram, the model heart, and the utterance *left ventricle* that it denotes in a culturally acceptable way (abbreviation that uses initials of words). The teacher did more than turn toward the chalkboard to write, *LV*. In this turning, he also suggests (implicitly) that his audience is to shift its attention from his talk and the three-dimensional model to the (two-dimensional) diagram inscribed on the chalkboard. In fact, if we only had the words, we would not be aware that the focus has shifted from the three-dimensional model to the two-dimensional diagram. The shifting body position therefore is part of the gestalt switch that leads to a new figure|ground configuration—i.e., drawing versus a diffuse everything else.

Episode 4.1a concludes with the teacher's statement *All of this is left ventricle*. His statement actually means much more than the teacher probably would have ever considered. It may be that his orientation had been to the location, apex, and crevice represented in the diagram. In fact, however, his presentation included three different representations of the heart and a body orientation that cued a switch between these very different representations (a diagram, a model, and words), a switch that was not cued

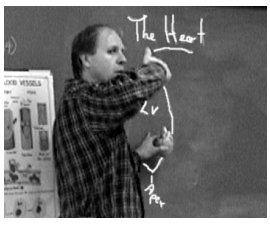
verbally. But the switch is important to understand that the diagram, in all its perceptible difference, pertains to some idea that is constituted by and available in the presentation as a whole. The integrative function of gestures is already evident, insofar as the teacher's gestures functions not only to point to specific parts of the model or the drawing, but also to connect speech and material artifacts into the meaning unit.

Communicative Articulation of Biological Processes

In the previous episode, I exemplified how the sense of a static phenomenon—here, *the left ventricle*—physically is made available in the classroom to be perceived (heard, seen). Static phenomena might lend themselves to presentations primarily using words—the categorical nature of facts and the categorical (i.e., typological [Lemke, 1998]) nature of words share structural features. But dynamic processes are difficult to communicate by means of words, for processes involve changes, which are more easily articulated by means that are topological in nature. The following example (Episode 4.1b)— constituting the continuation of Episode 4.1a—shows how dynamic processes are made available to audiences. In this new episode, the teacher articulates the work done by the left ventricle in general and the blood flow through the body in particular.

Episode 4.1b: Describing the functions of the left ventricle.

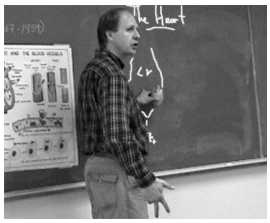
06 The left ventricle is absolutely massive in terms of its proportion, that's
07 because it's got the biggest job to do, this is a [massive] pumping chamber,
[*points left hand, holding the 3D heart, to the diagram on the chalkboard]*
08 it's got to send the blood [all the way up to the head],
[*points his thumb up*]



09 all the way down to the capillaries right to the tips of [your toes],
[*holds his arm stretched down with extended fingers pointing down, lowers his head*]

10 and with enough [pressure]
[*starts circular movement downwards*]

11 to- [to bring] it
[*continues circular movement, now coming upwards*]



12 [all back] to the, the heart again.
[*ends the first complete circle at the level of his face*]

During this episode, the teacher continues describing the left ventricle (lines 06–07), and he elaborates on its function by saying *it's got to send the blood all the way up to the head, all the way down to the capillaries right to the tips of your toes* (lines 08–09). While uttering this sentence, the teacher performs two consecutive deictic gestures, first lifting his right hand to his head and pointing upwards with his thumb, and then bringing his hand down, and keeping his arm and fingers stretched down until he completes the sentence. Here, the gestures of pointing upwards and downwards communicate the dynamic process of the blood flowing to the head and to the toes, respectively. However, these gestures are not only pointing (deictic) gestures; rather, they present iconicity (visual semblance) in the continuity of the movement. That is, when

bringing his arm up, the teacher slows down this movement and thereby achieves—though likely not in a conscious manner—perfect synchronization with the words being uttered; thus, the gesture is not only one of pointing, but it is constituted of a continuous, dynamic movement, that represents a continuous, dynamic process—blood flowing. The dynamic aspect of the teacher's gestures is juxtaposed to the categorical nature of his words when describing the blood flowing from the heart to other parts of the body.

In the sequence, the teacher introduces another aspect of blood circulation, which is directly related to the idea of the left ventricle being a *massive, pumping chamber*. In lines 10–12, the teacher adds *and with enough pressure to bring it all back to the heart again,* while simultaneously gesturing with his right arm and hand. He performs a circular movement with his right arm, starting from the middle section of his body (figure in line 10), and he continues moving his hand forward and downward in a clockwise movement (figure in line 11). He brings his hand all the way up to his face (figure in line 12), and then he moves his arm down again, repeating the circular movement once more, ending it again with his hand at the level of his face. This circular gesture signifies only in relation to the previous two consecutive gestures the teacher had enacted. That is, to understand the circular movement we need to take into consideration the entire meaning unit, which includes the continuity of gestures pointing up and down, as well as the words that accompanied the gestures. It is necessary, for instance, to associate the verbal description of the left ventricle as a *massive pumping chamber* (line 07) and the idea conveyed in the immediately following speech and gestures ensemble (lines 08-09). Thus, *all the way up to the head* and *all the way down… right to the tips of your toes*

emphasizes the long trajectory the blood needs to cover. The fact that blood is sent to these extreme parts of the body and that it needs to return to the heart functions as a justification for the left ventricle being *absolutely massive*. This verbal articulation of the phenomenon, however, does not include the continuous and dynamic nature of blood circulation. This latter aspect is made available through gestures, which inherently lend themselves to articulate and demonstrate dynamic phenomena.

Even though the teacher does not talk about blood circulation, this concept is present in his teaching through the enactment of circular (iconic) gestures, which represented the dynamic and continuous aspect of blood circulation. The circular aspect of the movement and the fact that it is repeated contribute to the idea that circulation of blood is a continuous process, instead of constituting, for example, an intermittent process. Moreover, this gesture also helps to establish the circularity of the process, in which *blood going back to the heart* is part of this continuous process and is happening all the time, concomitantly with *blood going up to the head* and *down to the tip of your toes*.

All the while the teacher is gesturing with his right arm and hand (lines 10–12), his left hand holds the three-dimensional model of the heart and is positioned on top of the area in the diagram of the heart on the chalkboard that represents the left ventricle. This provides a direct and material connection between the diagram and what the teacher is talking and gesturing about, that is, the left ventricle. The teacher is positioned sideways to the audience, so both his hands and the chalkboard are visible to students; these resources are then available for making sense of and understanding the concept the teacher is articulating, which is distributed into all these multiple modalities.

Communicative Articulation of Unfamiliar Concepts Through Familiar, Embodied Demonstrations

Scientific concepts are communicatively articulated in the classroom through a multitude of different modalities that are integrated into the meaning unit. These different modalities bring forth both static and dynamic aspects of the concepts, as I have shown in the two episodes here analyzed, but they may also contribute to bridge between unfamiliar, abstract concepts and the familiar, embodied, and everyday-life experiences of students.

The following illustrative episode was extracted from a lesson on the regulation of blood pressure. In the particular moment in the lesson represented in the episode, the teacher talks about the kidneys, its parts and location in the body, using at the same time, speech, gestures, body orientation, and material artifacts (i.e., a three-dimensional model of a human torso, the chalkboard, and his own body).

Episode 4.2: Locating the kidneys.

01 The kidneys are located more towards the back of the abdominal [cavity],
[*Left hand points to left kidney on the 3D model*]

02 on either side of [your spinal cord, down and there],
[*Points to his back, with thumb and index fingers wide apart*]

03 so if you have a, if you're playing football and somebody hits you really
04 hard on the back, that's why you can do ki- ki- kidney damage, kidney injury.

In this episode, the teacher talks about the location of the kidneys. He starts by using a three-dimensional model of a human torso. He points to the kidneys on the

model, locating them *towards the back of the abdominal cavity* (line 01). The three-dimensional model used is much smaller in relation to an adult person's body, which could make it more difficult for students to be able to see the kidneys in this particular model. Moreover, the model renders an internal perspective of the location of the kidneys, which is not a familiar way of perceiving human bodies in everyday life.

The teacher then makes the location of the kidneys more specific by adding that the kidneys are *on either side of your spinal cord* (line 02). This is a categorical statement highlighting a symmetrical feature, which the audience has to find in the situation at hand. That is, the words mark symmetry, but the students have to perceptually isolate symmetry in the physical situation. Any found symmetry then is an instance of constituting the suitability or veracity of the symmetry embodied in the utterance *on either side*. That is, the meaning of symmetry arises from the synergistic effect of any perceptual symmetry found and the utterance. But the teacher does more, thereby providing other resources that will constitute the communicative meaning unit.

While uttering *your spinal cord, down and there* he turns his back to students and points to his own back, with index and thumb fingers wide apart, pointing at each side of his lower back, which constitutes the approximate location of the kidneys on a human body. In this instance, the teacher's body becomes a material artifact, another resource that is used as part of the meaning unit *kidney*. By pointing to himself, the teacher transforms his own body into an artifact, a model, that can be more easily seen by students, and that is more naturally related to students' own bodies. As a concrete model it has advantages, for it not only has the normal size of a human body, but it also provides an external perspective, which is the way in which we normally perceive and refer to

human bodies. By elaborating on a hypothetical kidney injury situation, the teacher further articulates the scientific concept in the realm of everyday life, providing the audience with a meaning-making resource for identification with what is being taught.

Whereas the teacher's words articulate the location of the kidneys on each side of the spinal cord, towards the back of the abdominal cavity, the teacher's deictic gestures provide a much more precise location of these organs from two different perspectives (first, from inside the human body when using the three-dimensional model, and then from outside a human body, when the teacher uses his own body as an example). Here, the copresence of multiple modalities for teaching a concept is made salient, as a variety of resources (i.e., speech, gestures, and material artifacts) are used concomitantly to achieve the intended teaching outcome (i.e., locating the kidneys on the human body).

Therefore, in Episode 4.2 and similarly to what happened in Episodes 4.1a and 4.1b, the teacher makes use of a variety of resources in addition to words that *together* articulate and therefore *teach* a scientific concept. In Episodes 4.1a and 4.1b, the teacher simultaneously expressed the anatomy of the heart and the circulation of the blood in speech, gestures, body orientations, and material artifacts. Similarly, in Episode 4.2, the location of the kidneys is simultaneously but differently expressed in verbal and nonverbal resources that *in their totality* rendered the teaching of these concepts possible. Each one of the modalities used expressed the same concept in a different way, yet the concept cannot be reduced to any one of these modalities. For example, whereas the teacher's speech articulated a general location of the kidneys on the abdominal cavity, his deictic gestures on the three-dimensional model of a human torso (material artifact) provided more specificity to this general assertion. Moreover, when the gestures are

performed on the teacher's own body, the integration of body orientation, speech, and gestures provide an even more specific location for the kidneys on the human bodies, transforming the teacher's body into a material artifact over which the concept is distributed in more than one way, and made more familiar to students.

Toward a Holistic Conception of Scientific Concepts in Lectures

In the examples provided above, the scientific concepts being taught exist simultaneously in a variety of different modes, including the imagistic, bodily, gestural, and verbal modes. All of these modes are realized materially in the situation—even *words*, which at the heart merely are (material) sounds that we have learned to hear in particular and codified ways. From sociocultural and cultural-historical perspectives, all of these material resources are different expressions of the same meaning unit on the surface denoted by a concept word. From the teacher's perspective, the concepts are therefore *performed*, because he actively produced the different material resources (sounds, gestures, body orientations, and so on). The teacher's concept therefore exists not merely in a word or in his head *but in his entire performance in specific contexts*. Turning around and pointing to the body is as much part of the concept *kidney* as making sounds that we hear as *kidney* or *kidneys are located more towards the back of the abdominal cavity*. The word *kidney* is a metonym denoting the teacher performance as a whole rather than constituting a concept.

Similarly, the concept of circulation of blood presented in Episode 4.1b is distributed in all the various modalities the teacher used to teach it, including speech, gestures, and material artifacts. Whereas the teacher talks about the blood leaving the heart and going to the head and to the toes, his gestures provide the image of circulation

when he performed consecutive circular movements with his arm and hand. These gestures provided a visual, topological aspect of the concept of circulation; that is, the repetitive circular movements introduce the dynamic and continuous aspects of the circulation of the blood, at the same time that the verbal mode articulates the direction of the blood flow (from the heart to the head or toes). Gesture and speech stand in a dialectical relationship in which they presuppose each other; that is, the gesture becomes *circulation of blood* when juxtaposed to the words being uttered *send blood all the way up to the head… to the tip of your toes, and with enough pressure to bring it all back to the heart again*. These words, on the other hand, are made salient as part of the articulation of blood circulation because of its integration with the circular gesture. Moreover, while the lecturer is gesturing with his right arm and hand, he also is pointing with his left hand to the diagrammatic representation of the heart on the chalkboard, situating his talk and gesture in relation to that specific area of the diagram, which is therefore an integral part of the meaning unit.

Similarly, in Episode 4.2, the location of the kidneys is accomplished through the use of various modalities, each presenting different aspects of the same concept; for instance, pointing to the kidneys on a three-dimensional model of human torso provides a different perspective of the location of these organs than pointing to one's back. In the former, the kidneys are seen from an internal perspective, and its location is presented in relation to other internal organs inside the abdominal cavity. An external perspective is presented when the teacher points to his back, situating the kidneys to each side of the spinal cord, and articulating the possibilities of an external injury that could cause damage to the kidneys, for example. In both cases, the deictic gestures function not only

to point to the referents of the speech, but also to provide new perspectives to the location of the kidneys not accomplished by the use of words exclusively. That is, the deictic gestures provide a dimension of specificity that the words alone lack.

In lectures, different modalities are used to express the *same* meaning unit when a teacher is *performing* a scientific concept. Concepts articulated in lectures, therefore, are distributed among these various modalities. But these different modalities cannot be added up; they are *not* basic elements to which meaning can be reduced in the way that molecules (compounds) can be reduced to atoms (elements) and their interaction. Rather, meaning constitutes a *unit* that is more encompassing than any individual modality, their sum total, or their interaction; as *unit*, meaning therefore cannot be reduced to any of the modalities in which it expresses itself (Vygotsky, 1986). Thus, for example, a pointing (deictic) gesture and a feature in a diagram towards which the pointing is performed are mutually constitutive, and need to be understood in a dialectical way. The pointing becomes salient because there is something (a feature in the diagram) to be pointed to. But this feature of the diagram becomes salient because of the deictic gesture. That is, gesture and feature together (not independently) establish their mutual relevance and salience.

The different modalities therefore function as meaning-making resources that may help the audience members to learn these concepts, because they articulate concepts in very different ways. Future research, however, needs to find out which of these different resources audience members actually rather than possibly draw on for making sense and consequently for learning the concepts publicly performed in the lecture. There is a synergy that changes what and how we understand. If we change the setting a little bit,

what students say about some phenomenon—and therefore the *conception* they exhibit for the researcher to take from their talk—may be radically different. Thus, Schoultz, Säljö, and Wyndhamn (2001) provide evidence that children's talk about the earth changes when a globe is present in the interview: the inferences researchers make lead to very different results concerning children's *conceptions* of the earth. The importance of the context as an inseparable aspect within the unit of analysis for studies of students' conceptions has also been empirically demonstrated in other recent studies (e.g., Givry & Roth, 2006). However, if we were to acknowledge the multimodal and situated nature of concepts and conceptions, we ought to re-think the way in which students are currently assessed at schools. If it is irrefutable that teaching is in fact a multimodal, dynamic, and complex event, and that students' understandings and conceptions change once nonverbal resources are provided to them, why is it that we still insist in evaluating students' learning from exclusively word-centered approaches?

Conclusion

Lectures, as other forms of communication, involve more than spoken and written words. They are complex and dynamic events where multiple resources are co-deployed to teach various concepts. Each one of the resources employed provides different types and amounts of information that need to be taken into consideration all together, as a unit, in order to convey meaning.

In this study, I argue for the mutually constitutive nature of science concepts differently expressed in a variety of modalities. I make salient the various different resources the teacher uses when teaching scientific concepts, and how each one of these resources contributes different aspects of the same concept. Concepts, therefore, are

distributed among the various different resources used, which at times may include speech, gestures, body orientation, gaze orientation, and material artifacts, such as, for example, drawings on the chalkboard, three-dimensional models of human internal organs, and diagrams or photographs projected on a screen. Most importantly, concepts are *performed* and therefore only exist within the person-acting-in-setting unit, the only way in which the psychological construct of aptitude makes sense and is useful (Snow, 1992). This includes the multidimensional nature of performing concepts, on the parts of students and teachers alike (Snow, 1997).

In these multimodal classes, gestures are a ubiquitous mode of communication, that not only integrate speech and its referents, but that can also be used to integrate two different material resources, such as, for example, drawings on the chalkboard and three-dimensional models. My examples show that this integration provides the coherence of the meaning unit and also allows for comparisons between the various resources being used. The function of gestures in teaching science, however, is not limited to the integration of multiple resources. Gestures also function communicatively to provide unique scientific information, both related to static phenomena (e.g., deictic gestures on Episode 4.1a) and dynamic processes (e.g., iconic gesture representing circulation of blood in Episode 4.1b), which needs to be acknowledged and understood as part of the meaning unit to achieve comprehension of a particular scientific concept.

Chapter V:

Communicative Development of Scientific Concepts in Lectures

Preface

This study focuses on how scientific concepts are communicatively articulated during one lesson and through consecutive lessons on the same topic. It is a more sophisticated and more detailed analysis of the dialectical, communicative, meaning unit than the analysis I did in the previous study (chapter IV). My interest on this topic started with the identification of various gestures that the teacher repeated during consecutive lessons. Once I started analyzing these instances, I realized it was necessary to locate the very first time the gesture was used to be able to follow its recurrence through lessons and to make sense of these gestures as part of the communicative meaning unit. Insofar as these repetitions fitted the definition of a catchment (McNeill, 2002), I decided to employ this theoretical and analytical stance to analyze all the occurrences of one of the gestures, also locating the initial growth point (McNeill, 2002) that could be identified as the beginning of the lesson on the particular conceptual topic within which the gesture was being used. A different version of this study has been submitted to Journal of Research in Science Teaching, where it is still under review.

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Growth Points and Catchments in the Lectures on Blood Circulation

In lectures, a concept is not transmitted to students in an instant. Rather, lecturers develop a concept in and through the material production of semiotic resources until some point when the speakers feel that they have completed teaching the concept. That is, the communication of scientific concepts occurs through the temporal deployment of a variety of different semiotic resources that constitute a communicative meaning unit. Thus, at any given time, the lecturer's speech (i.e., the words he utters), his body orientations, the gestures he performs, and drawings

on the chalkboard might all be part of the communicative meaning unit, contributing different aspects of a scientific concept that is being taught. Each new aspect of a concept or each new related idea that is brought to the communicative meaning unit at some point in time, thereby becoming salient information in contrast with everything else already present and presented that served as the background to the novelty, constitute growth points (McNeill, 2002).

In this study, I describe the process of communicative development of concepts first through a microanalysis of the communicative meaning unit in the opening lesson dealing with circulatory system, when the teacher first introduces concepts related to blood circulation. I articulate in my analysis an initial occurrence of growth points, when new ideas are introduced into the communicative meaning unit. These ideas will later reoccur as the teaching of the concepts progresses in time and complexity, until they are stabilized. That is, the recurrences mark the search for stabilization of the concepts being taught and coincide with the catchments (McNeill, 2002) the teacher enacts. Therefore, in the first section I focus on the occurrence of catchments and growth points *within* the same lesson, following the sequential introduction of new aspects of the concept of blood circulation. In the second section, I focus on the occurrence of catchments and growth points *across* the five lessons that compose the unit concerning circulatory system, further explicating the process through which concepts are taught in science lessons. The identification of catchments and growth points allow me to determine, from a communicative point of view, the development of the concepts, from when they are still seeking stabilization to when they are already stabilized, and new ideas can then be introduced.

The Receiving Chambers of the Heart: Introducing the Concept of Circulation of Blood

During the opening lesson dealing with circulatory system, the teacher presents for the first time concepts related to blood circulation and anatomy and physiology of the heart, such as

the four chambers[1] that constitute the heart, and the flux of blood between these chambers and other parts of the body. The teacher starts by drawing a square diagram (Figure 5.1) on the chalkboard, which is then identified as a diagram of the heart. He then writes *R* and *L* on each side of this diagram, identifying the right and left sides of it, respectively.

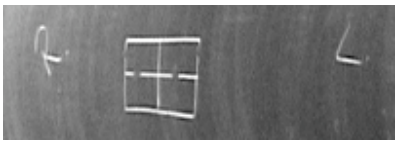

Figure 5.1. The teacher's square diagram of the heart.

When Episode 5.1 begins, the teacher identifies for the first time (in this class) the chambers of the heart. Synchronously with the utterance of *ones are the receiving chambers* (line 01) the teacher performs a gesture (Figure 5.2). This particular gesture, as other gestures more generally, has a preparation phase, a stroke, and a retraction phase. The preparation phase for this gesture begins when the teacher brings his right hand away from the chalkboard and starts to take his left hand out of his pocket. Throughout the preparation phase of this gesture, the teacher shifts his body orientation from the chalkboard to the students. By turning towards the students, the teacher communicates what should be the focus of attention at that particular moment (Roth & Lawless, 2002a). That is, through his body orientation, the teacher shifts the focus of attention from the diagram of the heart on the chalkboard to himself, and consequently, to the gestures, speech, and other actions he performs at that time.

Episode 5.1:The top chambers.

01 The heart has four chambers (1.25) the top [ones are the receiving chambers] (0.60)
[*performs gestures in Figure 5.2*]

[1] The four chambers of the heart are named "right atrium" and "left atrium" for the top right and top left chambers, respectively, and "right ventricle" and "left ventricle" for the bottom right and bottom left chambers, respectively.

Figure 5.2. Gesture performed simultaneously with the bracketed words in Episode 5.1.

Once the teacher directly faces the students, the stroke of the gesture begins. It coincides with the uttering of the word *receiving,* and the first syllable of the word *chambers*. The second part of the word *chambers* is pronounced while the teacher returns to rest position (the retraction phase of the gesture), already turning back to the chalkboard. This particular gesture is performed towards the teacher's own body, that is, he brings his hands towards his chest, thereby assuming a referential position that implies his embodiment in the situation. Even though this gesture co-occurs with the utterance *the top chambers of the heart*, these receiving chambers are articulated in terms of their location in a human body, in this case, his own. The teacher's hands, moving towards his chest, embody the imagery of *bringing something into his heart*. To use the teacher's words, his heart, or more precisely, the top chambers of his heart are *receiving* something. As soon as this gesture is finished, the teacher retracts his hands, and turns towards the chalkboard again.

The shift in body orientation communicates the shift in attention: the diagram of the heart once more comes into focus. In fact, to be properly understood, the teacher's gesture in Episode 5.1 needs to be contextualized within the communicative meaning unit that includes the diagram as well. This communicative meaning unit includes the diagram on the board (which represents the heart, including its top or receiving chambers), the gesture, the words being uttered (*the top ones are the receiving chambers*), and the teacher's own body, as the speaker and gesturer's body. But it also includes a referential position for the gesture per se (as the gesture is performed towards the teacher's body), also functioning as a *pointer* through shifts of body orientation (i.e.,

the body was brought to the foreground through the shifting orientation from the chalkboard to the students). Moreover, this gesture's correspondent utterance is *top chambers*, and these are not available in the gesture or in the teacher's body, but in the teacher's words and in the diagram on the chalkboard, where they are represented as the top two compartments in the diagram of the heart (Figure 5.1). Therefore, through his body orientation, the teacher links the diagram and his words with his gestures and his own body, and thereby the entire communicative meaning unit makes available information that goes beyond what each one of the resources that constitute this unit could communicate when considered in isolation. The idea finds different expressions in each of these modalities that cannot be reduced to any single, isolated modality.

In the sequence, the teacher draws two red arrows on the diagram of the heart (Figure 5.3) simultaneously with the utterances in Episode 5.2. Here the teacher continues his explanations, introducing new information that, although new, is directly associated with the previous topic he has presented. He starts his sentence with *so*, which refers back to the previous utterance and connects it with the sentence that follows.

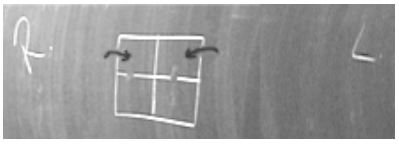

Figure 5.3. Diagram of the heart with the addition of two red arrows.

Episode 5.2:Blood flow.

02 so blood is going to flow [(1.19) in (1.09)] and blood is going to
[*draws an arrow in the left side of the diagram*]
03 flow [(1.75) in]
[*draws an arrow in the right side of the diagram*]

Previously, the teacher had identified the top two chambers of the heart as the receiving chambers; now, he identifies them as receiving blood. Thus, blood is flowing into the top chambers of the heart. The idea was not complete until this last bit of information was provided.

In fact, the use of a logical connector (*so*) literally implies that there is an implicative association between the idea of receiving and what is being received: The top two chambers of the heart (represented in the square diagram of the heart in the chalkboard) receive (an action articulated in words and in the teacher's gesture) blood (represented with two red arrows drawn on top of the diagram). Notice also that the color red the teacher chooses to draw the arrows with is perceptually related to the color of blood. Shifting attention from the diagram to the teacher and then back to the diagram enables the audience to associate all the visual and verbal information made available in concrete material form; and even this shift of attention is guided by the teacher's shifts of body orientation.

The Latin Meaning of Atrium: Introducing a New Idea

In this section, as the teacher continues lecturing, he turns to the audience again and he talks about the origin of the word *atrium*, defining the Latin meaning of this word.

Episode 5.3: The atrium.

04 (4.41) in uh Latin I think it is Latin there is the a name for the front room in the house (0.51) the place
05 [where people enter and arrive] and it is the (0.58) atrium (1.16) in churches we called it foyer (0.38) uh
[*performs the gesture in Figure 5.4*]
06 the front entrance in our school (0.99s)

Figure 5.4. Gesture that occurred simultaneously with the bracketed words in Episode 5.3.

Contrasting with Episode 5.2 (which was a continuation of the idea unit presented in Episode 5.1), Episode 5.3 brings forth a new idea. The teacher introduces a new topic, apparently disconnected from the topic articulated previously. He no longer provides information related to the chambers of the heart, but rather, he introduces the notion of atrium as a *place where people*

enter and arrive. This introduction of a new topic is marked by a long pause (4.41 seconds) and the occurrence of a gesture (Figure 5.4).

The gesture the teacher performs coincides with the uttering of the words *where people enter and arrive* (line 05). The stroke of this gesture is synchronized with the utterance of *enter*. This gesture is similar to the gesture in Episode 5.1, however, when performing this gesture, the teacher stands in a different referential position than when he was when performing that gesture; now he physically and metaphorically creates a space that lies right in front of him (the space *where people enter and arrive*), as opposed to including his own body into the space where the gesture is performed, as with the gesture in Episode 5.1. The synchronized gesture and speech constitute a growth point, that is, the exact moment when the concept of atrium is introduced in this lesson[2]. Before this moment, the teacher talked about the chambers of the heart and about how blood flows into the top two chambers. Now, however, he introduces a new topic, articulating the meaning of a new term that is brought into the idea unit, although not yet in association with the other ideas that already constitute this unit.

The Atria are the Receiving Chambers: Connecting Ideas Within the Same Idea Unit

To understand that semiotic resources across different modalities belong to and constitute the same idea or concept, lecturers have to provide yet other resources that allow the audience to connect them all. More so, if it takes different ideas to build a concept, these, too, need to be connected. How do lecturers achieve connections or produce resources for this purpose (i.e., connection) that have been used across the continuous flux of time?

[2] According to McNeill (2002), the concepts of growth point and catchment have also cognitive implications beside their immediately communicative aspects. However, I purposefully chose not to address the cognitive dimensions of these concepts in this study, as I am not interested particularly in the cognitive aspects of the teacher's discourse, but

The new idea the teacher just presented (Episode 5.3) has not yet been articulated in terms of the other aspects of the concept of blood circulation, which the teacher has already presented in Episodes 5.1 and 5.2. As the teacher continues, however, the connection between the new term (*atrium*) and the previous concepts is established. In the sequence, still talking about the atrium, the teacher performs a catchment for the gesture in Episode 5.1, that is, these two gestures present similar features, which enable the identification of the gesture in Figure 5.5 as being a repetition of the gesture in Figure 5.2.

Episode 5.4:A receiving area.

07 the word atrium [(0.39s) is (2.85s)] just means [a receiving area]or entranceway
[*writes* atrium *on the board*] [*performs the gesture in Figure 5.5*]

Figure 5.5. Gesture performed simultaneously with the bracketed words in Episode 5.4.

With this catchment and the associated words (line 07), the teacher establishes the connection between what he was communicating in Episodes 5.1 and 5.2, that is, the concept of blood flowing into the heart, and the idea of atrium introduced in Episode 5.3. Here, the teacher clarifies that the word atrium *just means a receiving area* (line 07). In Episode 5.1, the teacher had talked about the top chambers of the heart as being the receiving chambers; thus the recurrence occurs both in the word *receiving* and in the catchment. The novelty introduced in Episode 5.3 is the Latin word *atrium*; once the word has been introduced, however, it is then associated with the previous topic by means of a repetition of word and gesture that denote that the teacher is still elaborating and stabilizing the idea he has introduced in Episodes 5.1 and 5.2.

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rather, on how he publicly communicates the concepts to the audience, and how, communicatively, the various ideas

In Episode 5.4, however, two repetitions occur. The teacher actually repeats the gesture twice: First, synchronously with *receiving*, and then simultaneously with the utterance of *area*. The presence of a catchment already points to the existence of a recurrent idea being articulated, but the repetition of the same gesture in rapid succession brings forth another aspect of the concept of circulation of blood. That is, by repeating the same movement several times, the teacher is doing more than stabilizing the idea of the atrium as being a receiving area in the heart; he also introduces the idea of periodic movement, which is a particularly important aspect of the concept of circulation of blood (i.e., blood flows into the atria at regular intervals as opposed to a continuous or an intermittent flow). All the subsequent repetitions of this gesture are performed like this, with at least two gestures of the same kind in rapid succession. This constitutes further evidence of the iconicity of the gesture with the pulsating movement of blood circulation.

Finally, in Episode 5.5, all the resources that are part of the same communicative meaning unit (i.e., gesture, the word *atrium*, the idea of a receiving area in the heart, and the diagram of the heart on the chalkboard) are associated. The teacher turns towards the chalkboard and writes *RA* and *LA* inside the top chambers of the diagram of the heart, while verbally identifying them as the *right atrium* and the *left atrium* (line 08), respectively.

Episode 5.5:Right and left atrium.

08 and so this then becomes [the right (0.78) atrium and left atrium]
[*writes* RA *and* LA *on the chalkboard*]

Here, similarly to Episode 5.2, the teacher uses the particle *so* to connect the previous sentences to his following sentence. The introduction of the concept of atrium and its identification as a receiving area are associated with the diagram of the heart, and consequently, with the concept of blood circulation. Different aspects of the concept of atria have been

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are associated to one another within and across the lessons.

connected and this idea unit finally achieves stabilization: The top chambers of the heart are the ones that receive blood, and they are called atria.

The Ventricles in the Brain and the Ventricles in the Heart: Building an Analogy

Another way in which the teacher associates new ideas into the idea unit is through the use of analogies. By comparing two entities, both the similarities and the differences between these two entities become evident, and an association between the two is thus made possible. As the teacher continues lecturing on the circulation of blood, he introduces new information and moves the lecture forward with the presentation of a new concept (Episode 5.6).

Episode 5.6:Ventricles.

09 (3.14) there're (0.39) [empty spaces] in the brain (0.29) called ventricles (0.47s)
[*performs the gesture in Figure 5.6a*]
10 there're empty spaces in the [heart (0.26)] called ventricles (0.61)
[*touches the diagram on the board*]
11 and [this is the right ventricle (1.31)] and the left ventricle (2.21)
[*writes* RV *and* LV *on the diagram*]

Following a long pause (3. 14 seconds), which frequently signals that the lecture turns to a new topic or a new activity, the teacher starts talking about the ventricles. He compares the *empty spaces in the brain* with the *empty spaces in the heart* and associates both by using their name, *ventricles*. While uttering the first sentence in Episode 5.6 (line 09), the teacher performs the gesture in Figure 5.6a, synchronized with the words *empty spaces*, thus calling attention to this particular characteristic of the entities named ventricles. That is, the analogy between the ventricles in the brain and the ventricles in the heart works to emphasize the communalities of both entities: They are empty spaces, and they are called ventricles.

The teacher has already taught the unit dealing with the nervous system in this class. The term *ventricle* has already been introduced to students, but as a structure in the brain and not in the heart. Comparing both structures of the different organs (i.e., brain and heart) makes both

similarities and differences between the brain ventricles and the heart ventricles salient: The most obvious difference between these is that they belong to different organs; the similarity then is attributed to the fact that they are both *empty spaces* and they are both called *ventricles*, which the teacher emphasizes through the repetition of these terms (lines 09–10).

In the beginning of Episode 5.6, the teacher is turned towards the students. Simultaneously with the utterance of *heart* (line 10), however, the teacher turns towards the chalkboard and approaches the diagram of the heart, touching the bottom-left chamber in the diagram with his left middle finger and the bottom-right chamber with his left thumb. The teacher's body orientation functions once again as an index that the focus of attention has to be shifted to the diagram. The teacher then turns again to the audience when he utters *ventricles* (line 10), which functions as emphasis on the word *ventricle*, which is presented now as a new term in the idea unit. He turns back to the chalkboard once more to write *RV* and *LV* on the two lower parts of the diagram of the heart (Figure 5.6b), thus identifying them as the right ventricle and the left ventricle, respectively.

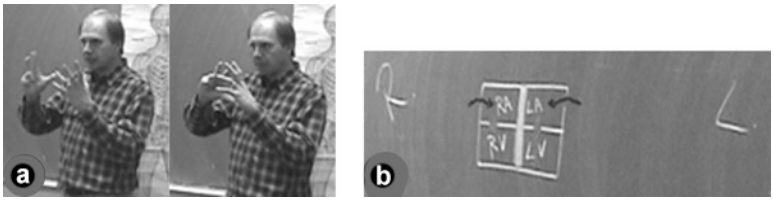

Figure 5.6. a) Still-frames of the gesture that is performed simultaneously with the utterance *empty spaces* in line 09 of Episode 5.6. b) Diagram of the heart with capital letters designating each one of the atria and the ventricles.

Here again, changing orientation signals a shift in the focus of attention and connects speech, gestures and diagram into the same communicative meaning unit. The heart ventricles, which are introduced through a comparison with brain structures also called ventricles, are related to the bottom chambers in the diagram of the heart, first by means of a pointing gesture, then through an abbreviation written directly on the diagram itself.

In Episode 5.7, the teacher continues to talk about the ventricles, introducing its function by means of another analogy, which he had previously introduced in this class. At the same time, the teacher also connects the concepts of atria and ventricles by succinctly establishing their differing functions in the circulation of blood.

Episode 5.7:The big pumps.

12 the vent- if the atria are (0.48) receiving areas the ventricles [are the big pumps] (0.65) these are the
[*performs the gesture in Figure 5.7*]
13 pumping chambers (2.00)

Figure 5.7. Gesture performed simultaneously with the bracketed words in Episode 5.7.

In line 12, when the teacher says, *receiving*, he performs another catchment for the gesture he did in Episode 5.1, which once more makes salient the (recurrent) idea of the atria being the receiving chambers of the heart. This time, however, the notion is contrasted with the function of the ventricles, which is introduced here as a new idea (the ventricles being the *big pumps* [line 12]) that coincides with (and thereby is identifiable through) the occurrence of a growth point. Simultaneously with the verbal articulation of the function of the ventricles (line 12), the teacher performs a gesture (Figure 5.7), the main feature of which is the short hand movement that is performed repeatedly. The imagery is powerful, insofar as it resembles the contracting movements of muscles, especially cardiac muscle. Thus, when the teacher utters *big pumps* simultaneously with the gesture in Episode 5.7, he is making salient in the communicative meaning unit an important aspect associated with the contraction of cardiac muscle, namely the fact that these contractions control the flowing of the blood in our circulatory system. These repetitions are part of the gesture, as opposed to consecutive repetitions, as in the case of the

catchment that occurs in Episode 5.4 (Figure 5.5), although in the context of the concept of blood circulation, one may think of the imagery associated with both repetitions as similar (i.e., periodic movement, equivalent to the periodic contractions of the cardiac muscle and flowing of the blood).

The stroke phase of the gesture in Episode 5.7 and the associated word *pump* constitute a growth point, which propels the development of the concept of blood circulation forward, introducing a new aspect of this concept. Previously, the atria were defined as areas that *receive* blood that was flowing into them; how the blood get there was not articulated yet. Now this aspect is made available with the introduction of the concepts of ventricle and contraction. The word contraction, however, has not yet been used. Rather, it is the imagery (the gesture) and the analogy (*big pumps*) that bring about the idea of contraction. The analogy of *pumps* is in fact recurrent, since the teacher has introduced the unit concerning circulatory system with an analogy between the fluids circuit in a car and the blood circulation in a human being, where the water pump was analogous to the heart. Later in the same lesson, as in subsequent lessons, the teacher did use the word contraction or variations of it (e.g., contracting, contracts) while at the same time repeatedly performing gestures similar to the one in Figure 5.7. In the next section, I focus on the occurrence of these catchments, from the first time the gesture appeared in Episode 5.7 to the end of the same lesson and throughout the remaining six lessons in the unit concerning the circulatory system. I focus on how new aspects of the concepts of contraction and circulation of blood are introduced to the class and associated with the ideas represented in this catchment, paying close attention to the integration of various resources within the communicative meaning unit.

The Development of a Scientific Concept Across Consecutive Lessons

Scientific concepts and ideas are complex, unfamiliar for most students, and abstract in most cases. Therefore, teaching (lecturing) them may take not only more than an instant, as I have shown in the previous section, but also more than a single lesson. Thus, how are concepts and ideas communicatively developed across consecutive lessons? How is the coherence between material sign productions belonging to the same concepts and ideas achieved when they occur in different lessons? In this section, I present answers to these questions by discussing the occurrence of various repetitions of the gesture that has been associated with the idea of contraction (Figure 5.7) as these occurred within and across lessons. Repetitions (i.e., catchment) of this gesture occurred several times in this same lesson and also in the subsequent lessons while the teacher talked about circulation of blood. To analyze the communicative development of this gesture in association with the concepts introduced or reinforced each time the gesture is repeated, I present here a microanalysis of gestures, speech, pitch, intonation, and material resources used by the teacher, which enables me to simultaneously focus on the integration of multiple resources in the communicative meaning unit and on the progressive development of the concept of circulation of blood, until it reaches its stabilization.

The gesture performed in Episode 5.7 first appeared concurrently with the uttering of the words *the ventricles are the big pumps*, which, as I have shown earlier, refers to an analogy the teacher had previously introduced in class. Through microanalysis, I synchronized gestures, words, pitch, and intonation, which are represented in the graph beside the photographs in Figure 5.8.

Episode 5.7: The ventricles are the big pumps.

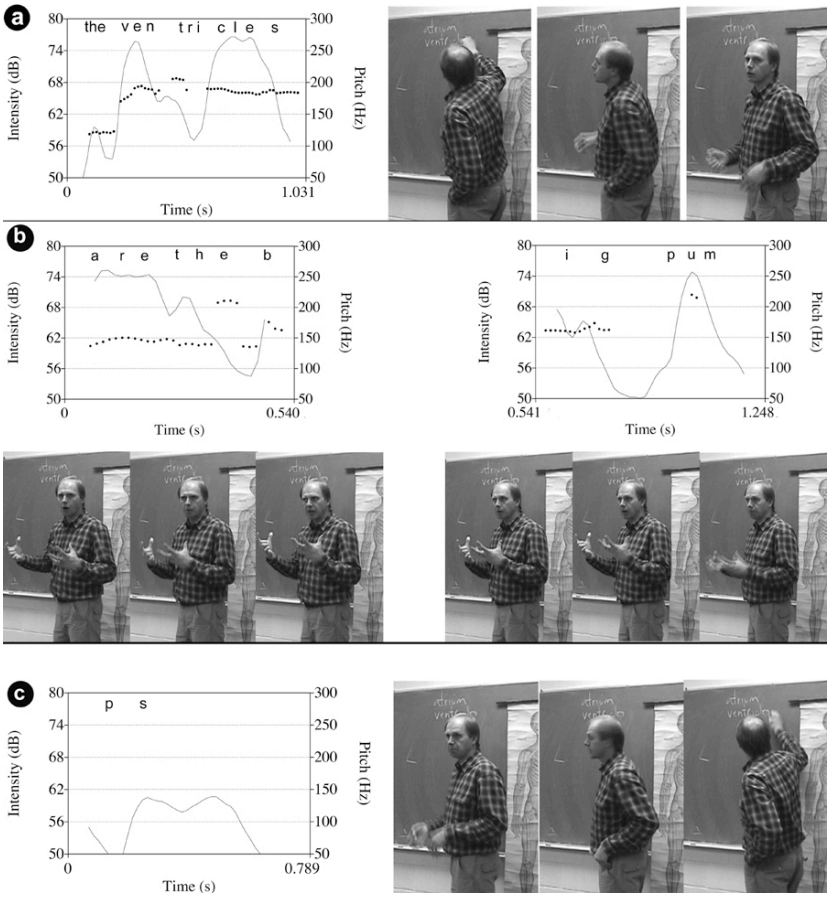

Figure 5.8. Graphic representations of pitch and intonation of utterances and still-frames of the synchronous gesture in Episode 5.7. a) Preparation phase. b) Stroke. The teacher performs the same movement twice within the same gesture. c) Retraction phase.

One notice that the short, repeated hand movements that constitute the gesture in Figure 5.8 are performed simultaneously with the words *are the big pum[ps]*. The subject of this sentence (the ventricles) is uttered during the preparation phase of this gesture (Figure 5.8a), when the teacher moves from the chalkboard, where he had written the word "ventricles" below the word "atrium," to the students. In this latter orientation, the teacher then performs the stroke of the gesture (Figure 5.8b), with higher pitch corresponding to the utterance of *[th]e* and *pum[ps]* and higher intonation at *are* and *pum[ps]* again. The body orientation allows for the

alignment of the gesture space (i.e., the area in front of the teacher) with the line of vision of the students. That is, by turning around and facing the students, the teacher positions himself so as to maximize the chances of the audience seeing his gesture. This also functions to shift the focus of attention from the chalkboard to the teacher's gesture. The emphasis placed on *are*, *the*, and *pumps* directly connects the gesture with these words, which in turn denote the action (verb *are*), and the fact that the ventricles are *the* part of the heart that functions as pumps (as opposed to, for example, the ventricles being *a* pump). Thus, the communicative meaning unit in this instance is constituted by the words (the ventricles are the big pumps), the gesture, the emphasis placed on certain words (are, the, pumps), the written word *ventricle* in the chalkboard, and the body orientation (towards the board, towards the students, and back to the board again during the retraction phase of the gesture [Figure 5.8c]).

Analyzing this communicative meaning unit, one notices that the gesture is representative of the contractions of the ventricles, sending blood outside of the heart (either to the lungs or to the rest of the body); that is, this gesture is associated with the function of the ventricles, the particular contracting movement. Even though it has been used simultaneously with an analogy that refers to the ventricles as an entity, there is compelling evidence that this gesture is indeed associated with the contraction movement per se, not only because of the iconic representation of the movement (*squeezing* movement, with quick, consecutive repetitions), but also because the stroke of the gesture occurs synchronously with *are the big pum[ps]*and the emphasis is placed on *are the pump[ps]*. Another clue as to the reference of this gesture is given by the fact that a similar gesture is performed in association with a different entity (i.e., atria instead of ventricles) in Episode 5.8 (Figure 5.9). The gesture in Episode 5.8 presents the same main features of the

gesture performed in Episode 5.7; that is, it is recognized as a catchment. This time, however, the teacher is not talking about the ventricles, but rather, he is talking about the atria.

Episode 5.8: The atria have a fairly easy job to do they contract and pump the blood.

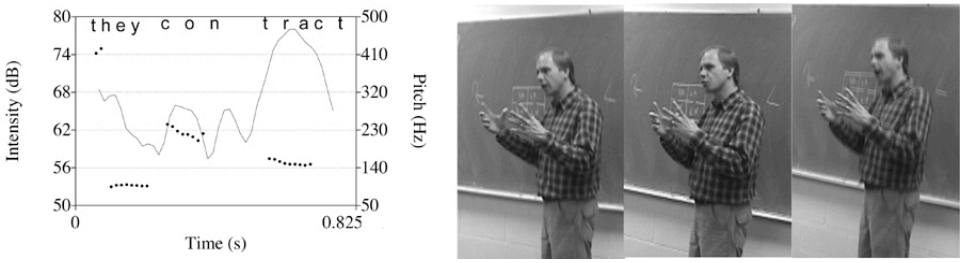

Figure 5.9. Graphic representation of the prosodic aspects of the utterance that is synchronous with the stroke of the gesture (represented in the still-frames) that occurs in Episode 5.8. The teacher repeats the same movement twice within the same gesture.

The stroke of this gesture occurs simultaneously with the words *they contract*. The hands movement is very similar to the one in Episode 5.7. Here, however, not only the subject of the sentence is the atria (a different entity then the ventricles) but also the verb associated with the gesture and which is emphasized through both pitch and intonation is *contract*. This corroborates the notion that this particular gesture, which was first performed in Episode 5.7 and is repeated here (and also various other times through this and the next lessons), makes reference to the contraction movement of the heart.

In Episode 5.7, the emphasis was placed on the analogy of the ventricles as pumps; here, although the word pump is uttered, it is related to the contraction movement of the cardiac muscle and how blood flows into other chambers of the heart. In both situations, however, the gesture presents the same referent. There is more evidence corroborating this interpretation of the reference of this gesture as I proceed to analyze the occurrence of the catchment throughout the other lessons dealing with circulatory system. During this lesson and throughout the following ones, the same gesture reappears, always in association with the contracting movement, although

with slight variations in form and content, which are directly related to the development of the concept of circulation of blood.

From Contraction to Systole, Pulse, and Pressure: The Association of Recurrent Ideas Across Several Lessons and the Communicative Stabilization of the Concept

During the remaining six lessons that constitute the unit concerning circulatory system, the teacher continues talking about the contraction of the cardiac muscle, and the circulation of blood. These concepts still need stabilization, as they are further and further developed, with the introduction of new terms and ideas that need to be associated with the previous ideas developed in class. The association of words and prosodic resources with other visual resources, such as gestures and drawings, provide coherence and the sequential characteristic of a multitude of different concepts that are intimately associated to each other in the broader unit concerning circulatory system. That is, whereas one aspect of the communicative meaning unit expresses the recurrence of the ideas being developed, other aspects introduce new and more complex ideas, which are associated with the previous ideas through the connection of all the resources that constitute this communicative meaning unit.

Throughout the next lessons dealing with the circulatory system, the teacher performs several catchments for the gesture in Episode 5.7. Although the main features of these gestures are very similar, they present variations that accompany the development in complexity of the concepts. Within the communicative meaning unit, the integration of gestures, words, and other resources (prosodic aspects of speech, drawings on the board) makes possible the association of different and new information with previous information within the same idea unit. For instance, in Episode 5.9, the teacher repeats certain information while also adding new information to the communicative meaning unit.

Episode 5.9: The heart muscle contract.

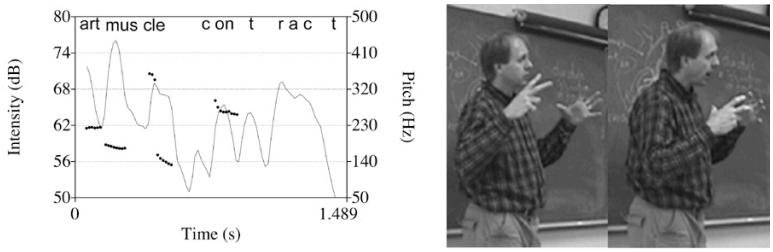

Figure 5.10. Graphic representation of the prosodic aspects of the utterance that is synchronous with the stroke of the gesture (represented in the still-frames) that occurs in Episode 5.9.

The gesture in Episode 5.9 (Figure 5.10) is also associated with the word *contracts* (in Episode 5.8, the teacher used the gesture with the same word combination). Emphasis is placed on both the words *muscle* and *contract*, which also coincide with the stroke of this gesture. In this situation, both the gesture and words represent repetitions of the previously enacted gesture|speech combinations. However, now the diagram of the heart in the chalkboard has become significantly more complex (Figure 5.11b). Compared to the square diagram of the heart (Figure 5.11a), this diagram presents more details and iconic features that render it more similar to a human heart (although, of course, it is still diagrammatic and two-dimensional). Now the diagram of the heart includes a representation of the four chambers, with the left ventricle (LV) larger than the right ventricle (RV) and these larger than the atria (RA and LA), and it also includes vessels, through which the blood flows, and their denominations.

The teacher now further develops the idea of circulation per se, an idea that had been briefly introduced in the previous lesson by means of a very schematic diagram of the blood circuit in the human body (Figure 5.11a). What before had been presented as undistinguishable vessels (or *tubes*) in a square heart, where all the chambers have the same size, and with blood circulation represented by arrows leaving from and coming back to the square heart, now is represented by more naturalistic drawings of the blood vessels, with their respective

denominations, which are connected to a diagram of a heart also more naturalistic, which the four chambers represented in proportional sizes. That is, the details of the circulation of blood are now being introduced, at the same time that the important idea of contraction of the cardiac muscle and the consequent blood flow is recurrent in words and gestures. Thereby, the concept of circulation of blood develops through the addition of new information that is connected to previous information within the communicative meaning unit by the enactment of catchments and the repetition of certain words associated with the gestures performed.

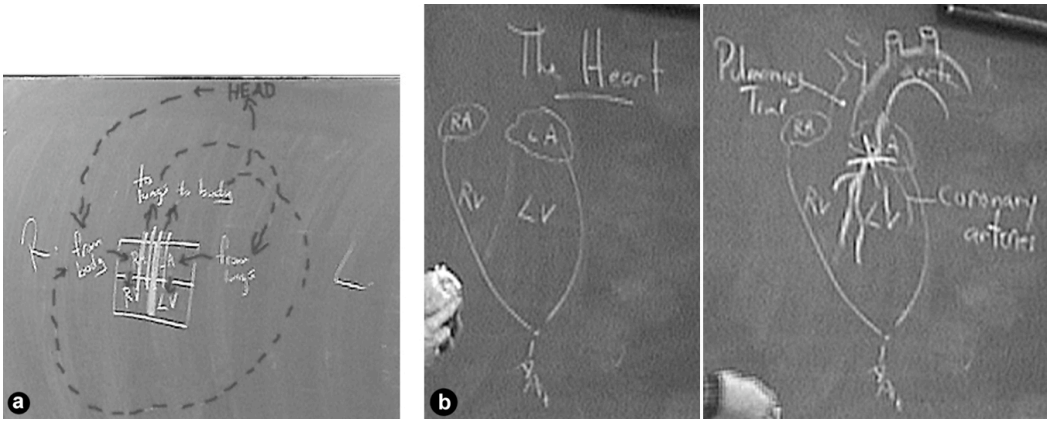

Figure 5.11 a) Square diagram of the heart as it last appeared in the first lesson dealing with circulatory system (compare with the one in Figure 5.3). b) Diagram of the heart in the second lesson dealing with circulatory system, as it was first drawn (left) and in its final presentation (right).

The next time this catchment appears (in Episode 5.10, Figure 5.12) the gesture is synchronous with the words *pumping action* of the heart muscle, which is another way in which the teacher refers to contraction and the consequent blood flow (in fact, in Episode 5.8 the teacher has already used the word *pump* as a verb with the connotation *to send blood out*). This catchment is a recurrence of both the concept of contraction articulated earlier, and the analogy of the ventricles as the pump (Episode 5.7). Through this gesture, the teacher associates these two ideas into one coherent unit: The contraction of the heart muscle generates the pumping action, which sends the blood through the vessels.

Episode 5.10: And that's the pumping action.

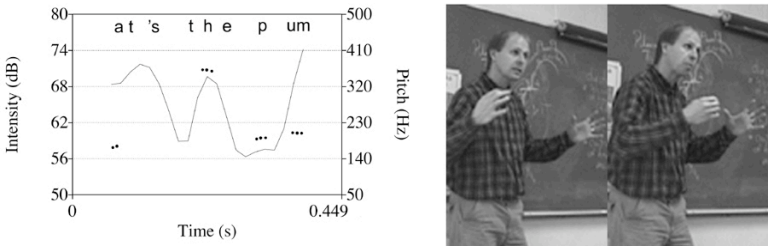

Figure 5.12. Graphic representation of the prosodic aspects of the utterance that is synchronous with the stroke of the gesture (represented in the still-frames) that occurs in Episode 5.10.

The emphasis here (as in Episode 5.7) is again placed on the words *[i]s*, *the* and *[p]um[ping]*, making salient the contraction movement of the ventricles. As the idea of circulation is further explored, the teacher keeps the idea of contraction and blood flow present, *tying* the new information to what has been previously taught.

Continuing with this lecture, two more repetitions of the gesture occur in Episodes 5.11 and 5.12 (Figures 5.13 and 5.14, respectively), both synchronized with the word *contracts*, as the teacher articulates further the idea of circulation of blood, by expanding on the trajectory of the blood through the different chambers of the heart and out to other body parts.

In Episode 5.11, when the teacher utters *heart*, he holds his hands ready for the gesture performance (Figure 5.13a), while he looks at the diagram of the heart on the chalkboard. The perfect synchronization of the stroke of the gesture (Figure 5.13b) with the word *contracts*, as well as the emphasis placed on this word (higher pitch in *con* and higher intonation in *trac*), function to create the dialectical meaning unit in which imagery and words together and in interaction generate the idea of contraction. The teacher's gaze orientation connects speech and gesture with the diagram (Figure 5.15), while the pre and post-stroke holds serve to place even more emphasis on the idea of contraction. In Episode 5.12, the stroke of the gesture is also

simultaneous with the word *contract* (Figure 5.14), but a slightly different configuration of the arms is noticeable. Here, the teacher's arms are higher than in the previous gestures.

Episode 5.11: The heart contracts.

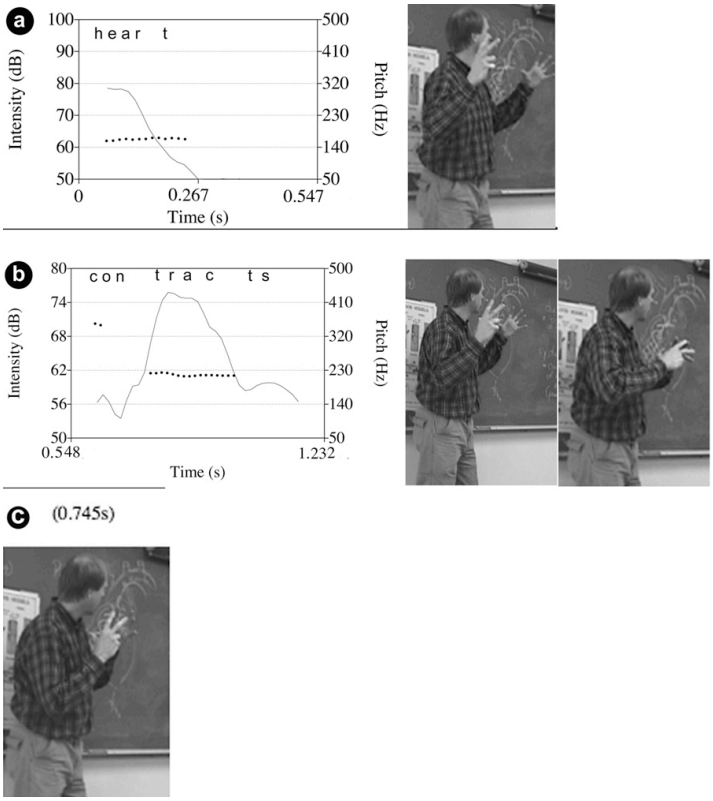

Figure 5.13. Graphic representations of pitch and intonation of utterances and still-frames of the synchronous gesture in Episode 5.11. a) Pre-stroke hold. b) Stroke. c) Post-stroke hold.

Episode 5.12: They both contract

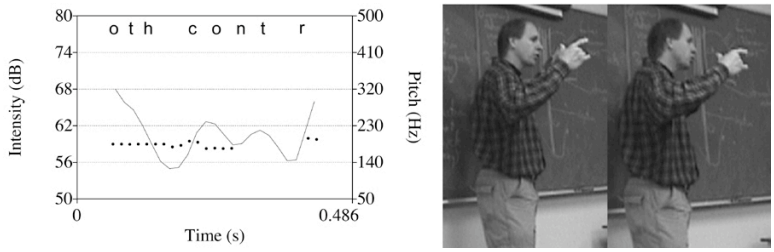

Figure 5.14. Graphic representation of the prosodic aspects of the utterance that is synchronous with the stroke of the gesture (represented in the still-frames) that occurs in Episode 5.12.

The diagram of the heart is also different (Figure 5.15), once again more schematic, presenting now the names of various vessels and valves. The teacher explains the contraction of the atria and how the blood flows from the atria to the ventricles. The atria are located above the ventricles, and this may account for the performance of the gesture of contraction with the arms slightly raised, as the contraction movement is actually happening in the upper chambers of the heart.

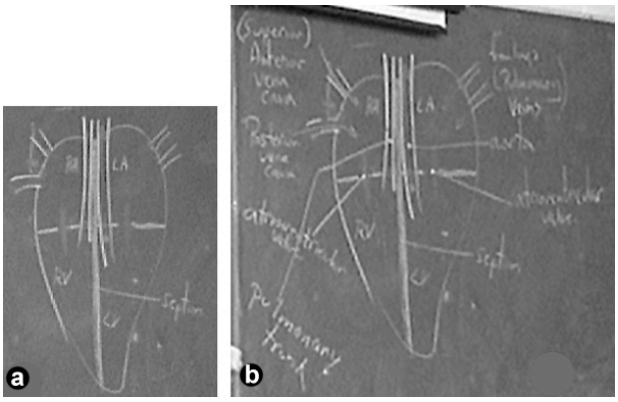

Figure 5.15. Schematic diagram of the heart. a) As it was first drawn. b) In its final appearance after the teacher added more information onto it.

In the sequence, concurrently with the gesture in Figure 5.16, a new term is introduced. The teacher repeats the gesture, but this time it is associated with the word *systole*[3]. At the same time that the concept is articulated in more complex terms, the recurrence of the catchment maintains the idea of contraction in the foreground. The gesture is performed with the arms slightly raised, as in Episode 5.12, which I interpret as an allusion to the fact that the contraction the teacher refers to occurs in the atria, the upper chamber of the heart. The term *systole* is a novelty, whereas the ideas of contraction and blood flow are recurrent. But both novelty and recurrence are expressed within the same communicative meaning unit, simultaneously. It is this

[3] The term systole refers to the contraction movement of either the atria or the ventricles, whereas the word diastole refers to the relaxation of the cardiac muscle. When the atria experience systole (i.e., contraction) the ventricles

novelty in recurrence that allows connections to be made across time and material resources; it is precisely the same kind of recurrence in the material productions (words, gestures) that allows the coordination and continuation of building concepts and ideas across different speakers (Roth & Bowen, 1995).

Episode 5.13: Experience systole at the same time.

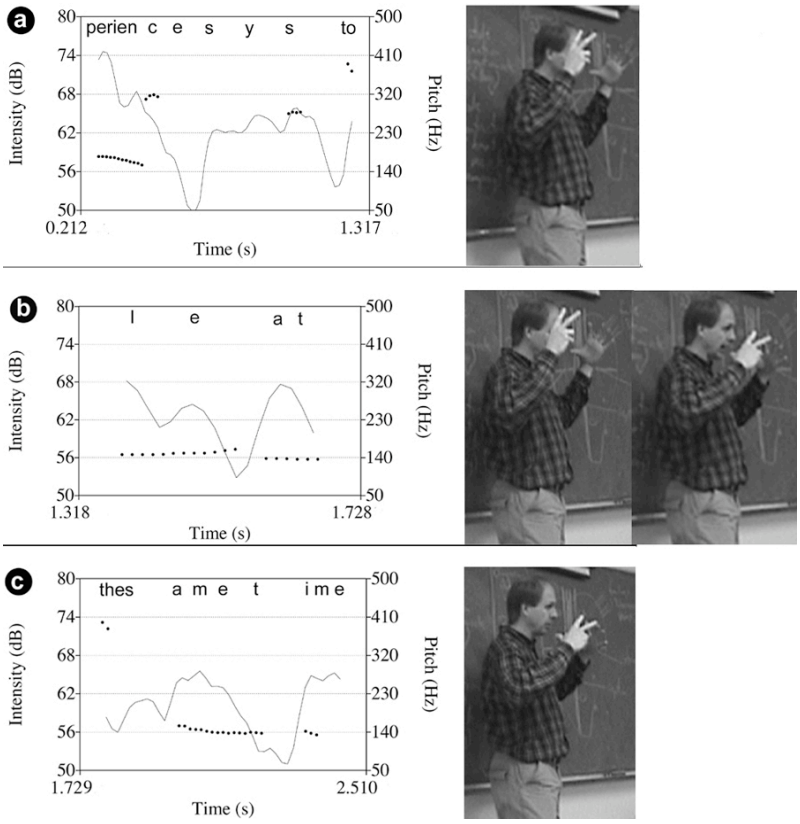

Figure 5.16. Graphic representations of pitch and intonation of utterances and still-frames of the synchronous gesture in Episode 5.13. a) Pre-stroke hold. b) Stroke. c) Post-stroke hold.

Similarly to the pre- and post-stroke holds of the gesture in Episode 5.11, here the holds (Figures 5.16a and 5.16c) also contribute to emphasize the contraction movement in association with the word "systole," as the stroke of the gesture (Figure 5.16b) coincides with the utterance

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experience diastole (i.e., relaxation), which permits the blood to flow from the atria to the ventricles. Thus, the double sound of the heartbeat is equivalent to the systole of atria, followed by the systole of ventricles.

of part of this word, while other words in the sentence are synchronized with the pre and post-stroke holds.

In Episode 5.14, the gesture again is slightly different than the previous performances of it: the teacher performs the gesture with both hands closed into fists (Figure 5.17). This gesture coincides with the introduction of the idea of heartbeat into the lesson. Once again, new information is added simultaneously with recurrent ideas, all integrated into the same communicative meaning unit: Whereas the word and general features of the gesture remain the same, and thus constitute a catchment with the gesture in Episode 5.7, some of the features of the gesture change in accordance with the novelty that is being introduced.

Episode 5.14: Ventricles contract.

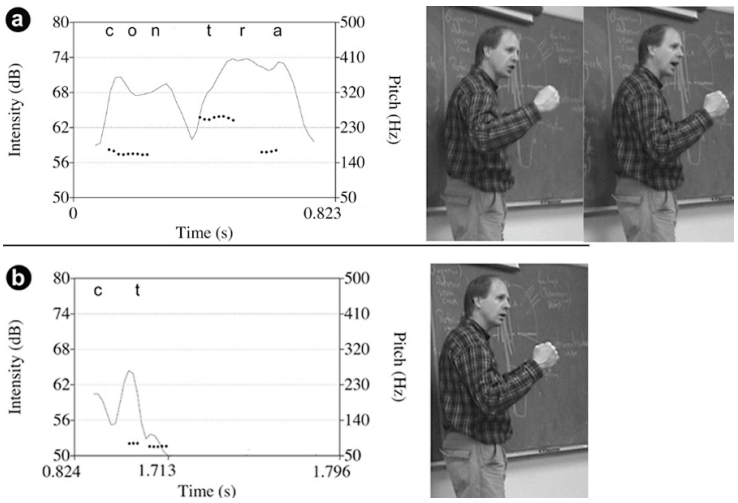

Figure 5.17. Graphic representations of pitch and intonation of utterances and still-frames of the synchronous gesture in Episode 5.14. a) Stroke. b) Post-stroke hold.

Moreover, with the differentiation in the performance of the gesture, the teacher also differentiates between the contraction of the atria and the contraction of the ventricles, which occur consecutively instead of at the same time. The teacher explains that the right and left atria contract at the same time, while the ventricles are experiencing diastole (i.e., relaxation), and that only afterwards the right and left ventricles contract. This sequence is important for the proper

functioning of the heart and also for the idea of heartbeat, which the teacher moves on to explain subsequently (Episode 5.15). In Episode 5.14, therefore, the teacher is again talking about the contraction of the ventricles; consequently, the height of the arms when performing the contraction gesture is again lower than when he performed the same gesture in reference to the contraction of the atria. The hands in fists constitute a difference in the imagery of the idea, which is congruent with the difference that is now introduced when the teacher develops the concept of contraction further, differentiating between systole in the atria and systole in the ventricles and the sequence of these events in the heart.

The next two repetitions, in Episodes 5.15 and 5.16, respectively are also performed with the hands shaped into fists, as the teacher continues lecturing on the topic of heartbeat. Both gestures (Figures 5.18 and 5.19) are performed while the teacher talks about the contraction of the ventricles, within the contexts of circulation of blood within the heart and heartbeat. Although the concept is still the contraction of the cardiac muscle and the circulation of blood, now a new idea is brought into the broader idea unit, that is, the idea that these contractions, which have been already associated with the term systole and the *pumping action* of the heart, are also what generate the heartbeat. Thus, since the first lesson, the concept has developed sequentially, with the introduction of more information, but always in association with the previous information provided. Coherence within the various resources that are dialectically related to each other within the communicative meaning unit is imperative to carry this conceptual development forward.

Episode 5.15: Inefficient heart beat.

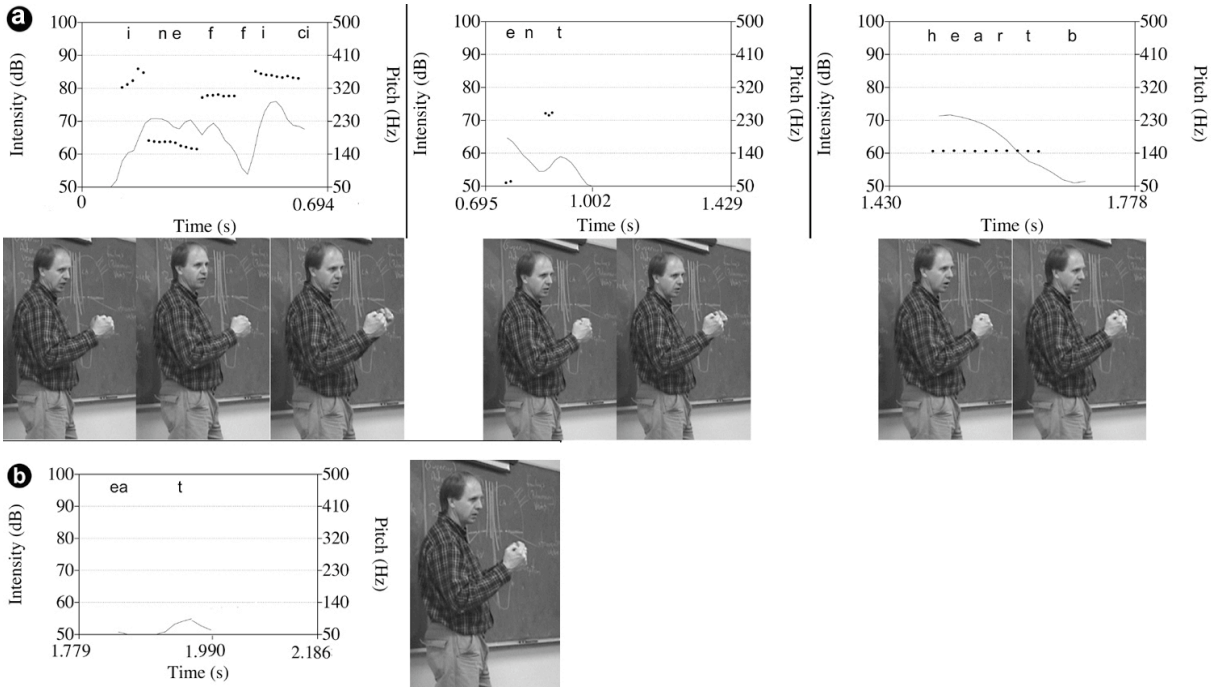

Figure 5.18. Graphic representations of pitch and intonation of utterances and still-frames of the synchronous gesture in Episode 5.15. a) Stroke. The teacher performs the same movement three times consecutively, within the same gesture. b) Post-stroke hold.

When performing the gesture in Episode 5.15, the teacher repeats the hands movement three times (Figure 5.18a), and holds the position for a little over one second (post-stroke hold [Figure 5.18b]). This gesture occurs right after the gesture in Figure 5.17, and the similarities between both gestures (hands in fists) attest for the continuity of the topic of heartbeat. Before, the teacher was talking about the contraction of the ventricles within the context of the sequence of events within the heart. Now, he considers the possibility of both atria and ventricles contracting at the same time, and concludes that this would be a very inefficient heartbeat. Continuing with the same idea, the teacher proceeds to explain that the right and left ventricles also contract simultaneously. He then performs the gesture in Figure 5.19. Once again, although this repetition presents the main characteristics of the other gestures which referent is

contraction, the closed fists are maintained as a special feature that distinguishes the contraction of the ventricles from the contraction of the atria, as this differentiation was introduced in Episode 5.13.

Episode 5.16: They contract at the same time.

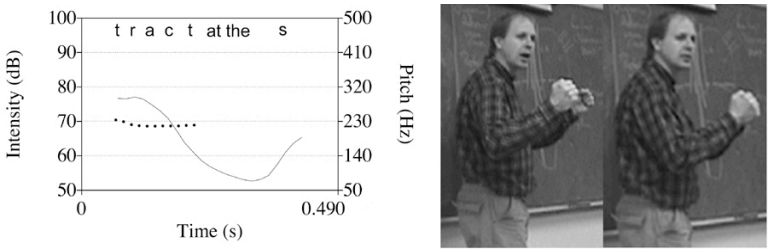

Figure 5.19. Graphic representation of the prosodic aspects of the utterance that is synchronous with the stroke of the gesture (represented in the still-frames) that occurs in Episode 5.16.

Through the next several lessons, as the teacher continues lecturing on the circulatory system, this and other catchments occur. In Episode 5.17, the catchment once more presents variation in shape (Figure 5.20), accompanying the development of the concept. While uttering *contrac[ting]*, the teacher gestures with elbows even higher than in the previous gestures, and with a greater distance between the hands. The main feature of this gesture is exaggerated. When one analyze the entire communicative meaning unit, the exaggeration of the arms movement to perform this gesture is congruent with the idea the teacher is introducing: blood pressure. The teacher is teaching about the pressure in the capillaries, veins, and arteries, and, in this context, the idea of ventricular contraction is crucial. Thus the recurrent idea of ventricles contracting is now presented to explain blood pressure in the various vessels.

Episode 5.17: Ventricle contracting.

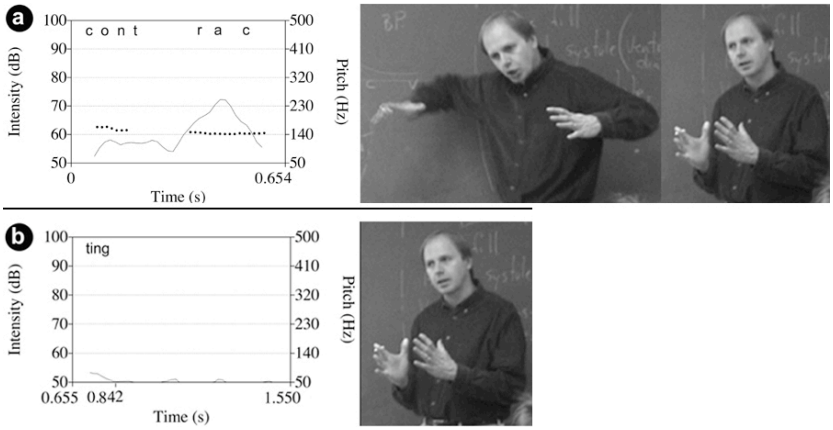

Figure 5.20. Graphic representations of pitch and intonation of utterances and still-frames of the synchronous gesture in Episode 5.17. a) Stroke. b) Post-stroke.

During this lesson, the teacher draws a graph on the chalkboard (Figure 5.21), representing the blood pressure on the different vessels. A diagram of a heart is also drawn, to which the teacher adds *LV* in the space equivalent to the left ventricle and a thick vessel coming out from it. These representations also convey the idea of the contraction of the left ventricle sending blood out of the heart, through the blood vessels, to other parts of our body, which contributes to the pressure in the vessels, which is represented in the graph. The exaggerated gesture in Episode 5.17 is therefore associated with the idea of a powerful ventricular contraction, which causes the blood to flow all through the body.

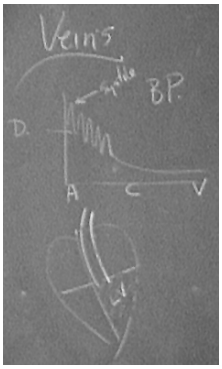

Figure 5.21.Graph representing the blood pressure (B. P.) in the different vessels: Arteries (A), capillaries (C), and veins (V). Bellow the graph, a diagrammatic representation of the heart.

The next two catchments, in Episodes 5.18 and 5.19 respectively, also present the same characteristics of the gesture in Figure 5.20, that is, an exaggerated *squeezing* movement with the arms. In Episode 5.18, the gesture is synchronized with the utterance *surge [of blood]* (Figure 5.22), which is a reference to blood pressure caused by the blood leaving the heart as a result of ventricular systole. The larger gesture provides a visual representation for the pressure with which the blood leaves the heart during ventricular systole (*as the ventricle contracts* [Episode 5.19]), which is the main idea the teacher communicates at this moment.

Episode 5.18: There's a surge of blood.

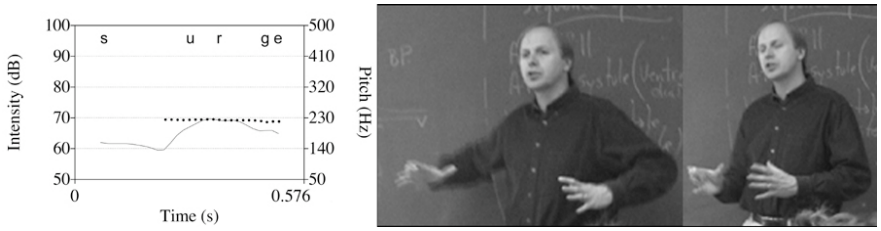

Figure 5.22. Graphic representation of the prosodic aspects of the utterance that is synchronous with the stroke of the gesture (represented in the still-frames) that occurs in Episode 5.18.

Episode 5.19: As the ventricle contracts.

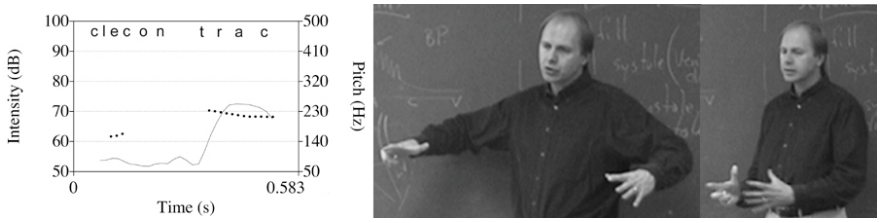

Figure 5.23. Graphic representation of the prosodic aspects of the utterance that is synchronous with the stroke of the gesture (represented in the still-frames) that occurs in Episode 5.19.

Episode 5.20 presents the next repetition (Figure 5.25), which occurs during another lesson dealing with the same topic. This catchment is particularly interesting, as the teacher performs it in silence, synchronized with a student's utterance. His hands are once again closed in fists, however in this particular case, he holds the chalk in his right hand and a piece of paper

in his left hand, which may account for the closed fists. He keeps his gaze on the student while gesturing and nods after the student has finished talking, which may be interpreted as agreement. Nevertheless, the teacher is still lecturing on blood pressure, this time focusing on the flow of blood within the blood vessels, and this gesture, although performed in synchrony with someone else's speech, is also associated with the concept of contraction movement.

Episode 5.20: Silence

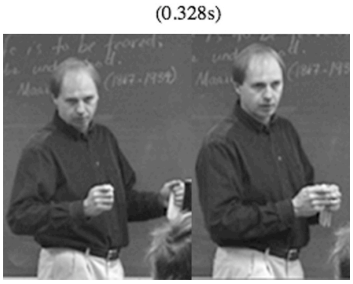

Figure 5.24. Still-frames representing the stroke of the gesture the teacher performs simultaneously with a student's utterance, as part of Episode 5.20.

Episode 5.21: It will continue to beat.

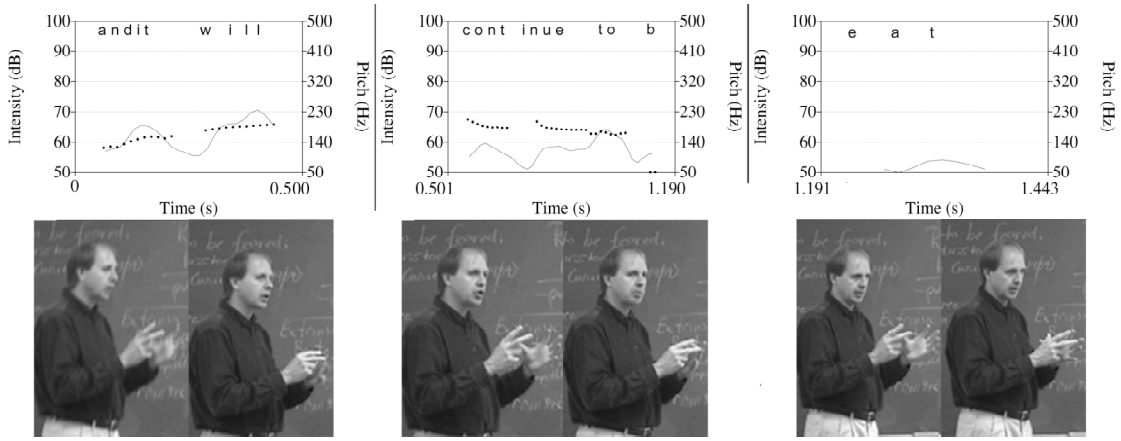

Figure 5.25. Graphic representation of the prosodic aspects of the utterance that is synchronous with the stroke of the gesture (represented in the still-frames) that occurs in Episode 5.21. The teacher performs the same movement three times consecutively, within the same gesture.

The last two repetitions for the gesture in Episode 5.7 occur while the teacher lectures on the regulation of the heartbeat. The teacher repeats the gesture in Episode 5.21 three times (Figure 5.26), whereas in Episode 5.22, the movement is repeated eleven times (Figure 5.27). These fast repetitions provide imagery for the concept the teacher is explaining: The rhythmically, periodic contractions of the cardiac muscle, which in this particular moment are associated with the idea of heartbeat. The particular features of these two repetitions are the hands movement, as opposed to the arms movement of the previous gestures.

Insofar as the teacher performs various repetitions, the synchronization of the stroke of the gesture in not with a particular word, but rather, the associated idea of heartbeat, and it is exactly these rhythmic repetitions, (both in gestures and in words in Episode 5.22 [Figure 5.26]) that make this idea available.

Thus, from an initial reference to the ventricle as the heart pump, to the idea of contraction of the atria and the ventricles and its sequential rhythmic occurrence, to the ideas of pulse and heartbeat, the recurrence of gestures provided a thread that connected all the new ideas added to the concept of circulation of blood within the communicative meaning unit, where the different resources available (words, pitch, intonation, diagrams, body and gaze orientations, and gestures) are dialectically related and contribute one-sided expressions of a whole that is indivisible.

Episode 5.22: That heart will continue to beat a normal rhythm bip bip bip bip bip.

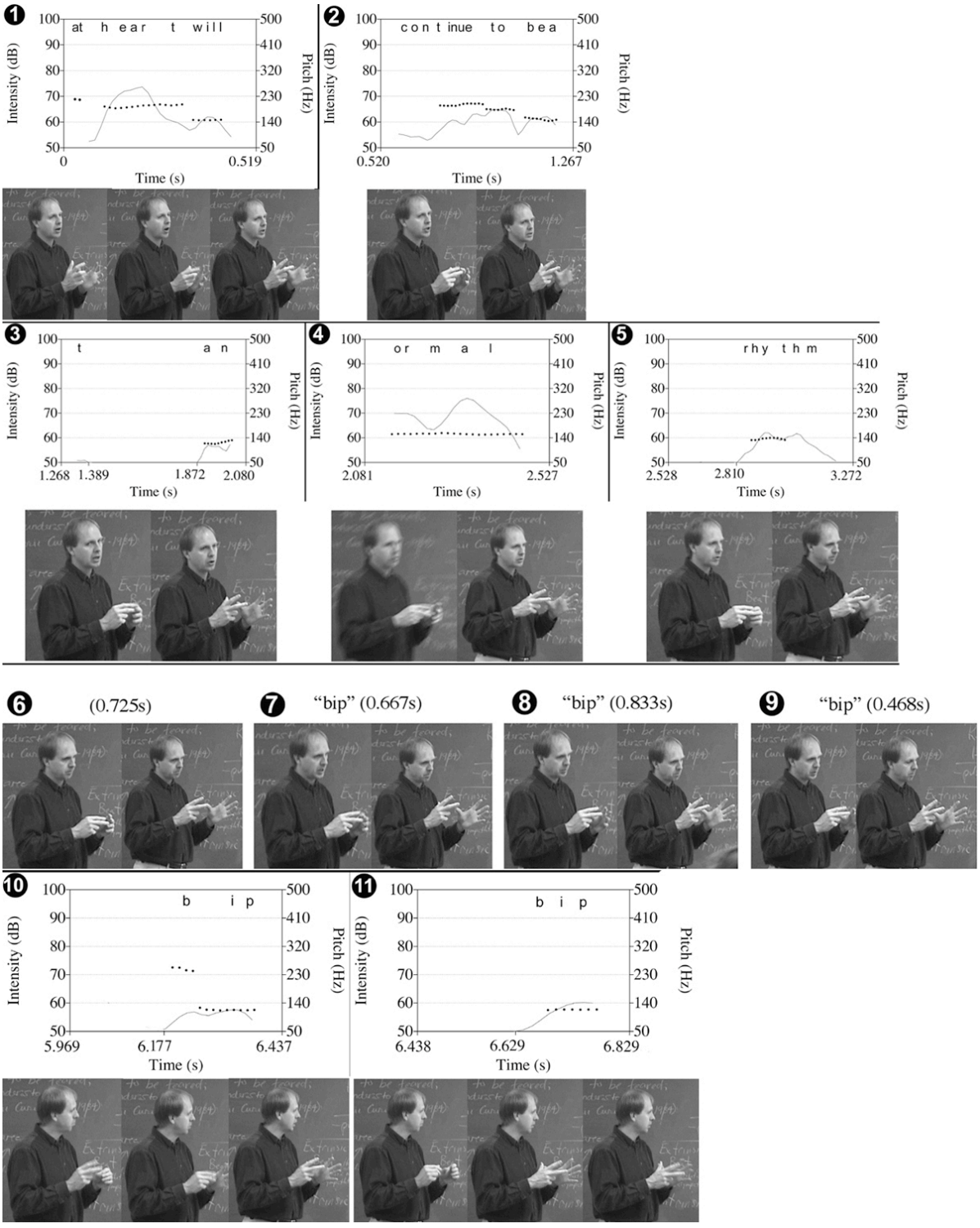

Figure 5.26. Graphic representation of the prosodic aspects of the utterance that is synchronous with the stroke of

the gesture (represented in the still-frames) that occurs in Episode 5.22. The teacher performs the same movement eleven times consecutively, within the same gesture.

During the next lessons, the teacher lectures on the lymphatic system, and this particular gesture no longer occurs. This is further indication that the teacher has achieved stabilization of the concept of contraction of the cardiac muscle, and is then ready to start lecturing on a new unit. Throughout his explanations of the circulation of blood from the heart to other body parts and back to the heart, the teacher made use of the same gesture over and over again, using it as a way to connect different words, diagrams, and ideas that together formed the concept he was teaching. Each time this gesture was performed, the teacher made available the recurrent idea of contraction, which was presented in association with different information; this association of novelty (growth point) and recurrence (catchment) within the communicative meaning unit made possible the development of the ideas in a sequentially manner, not only within the same lesson, but also across consecutive lessons.

Conclusion

In this study, I analyzed the development of a particular scientific concept within and across lessons through a communicative perspective, focusing specially on the integration of various different meaning-making resources that are dialectically related within the same communicative meaning unit. Adapting the concepts of growth point and catchment (McNeill, 2002) as a means of keeping track of the development of ideas during teaching, I uncovered how in a lecture new ideas are introduced into the communicative meaning unit and how they are associated with previously presented ideas. For instance, when the teacher first introduced the idea of ventricular contraction, he connected the imagery of the idea of contraction, expressed in the gesture, with the words *the ventricles are the big pumps*, at the same time making use of an

analogy and differentiating the function of the ventricles from that of the atria. This complex communicative meaning unit also included the diagram of the heart in the chalkboard and prosodic aspects of his discourse, which served to emphasize certain words in his utterances. As the teaching progressed, the teacher repeated the contraction movement in combination with different utterances, introducing new terms, such as systole, for example, but maintaining the idea of contraction within the communicative meaning unit by means of the recurrence of the gesture (i.e., catchment).

The novelty in the recurrence of words, gestures, and diagrams provides coherence within the idea unit, emphasizing both the similarities and the differences of each new idea introduced in relation to the previous ideas presented. Thus, differences in the features of gestures, for example, accounted for differences in the ideas introduced: When the teacher gestured while talking about the contraction of the atria, he performed the gestures with his arms raised above the position where he performed the same gestures when talking about the ventricles, in a direct allusion to the fact that the atria are the top chambers of the heart, which was also illustrated in the diagram of heart in the chalkboard. Therefore, within a multimodal communicative meaning unit, new ideas were added to recurrent ideas, resulting into a progressive and sequential development of the scientific concept within and across lessons. The integration of multiple resources, each presenting a part of the whole through a different non-reducible modality, constitutes the means through which the teacher *teaches a scientific concept*.

A clearer understanding of how scientific concepts are communicated (that is, *taught*) during science lectures is crucial for the advancement of studies in science teaching and learning. In this study, I provided a detailed analysis of the communicative development of scientific concepts during lectures, from the perspective of the teacher's speech, which resulted in a more

complex and thorough understanding of the integration of multimodal resources in the classroom.

Chapter VI:

Catchments, Growth Points, and the Iterability of Signs in Classroom Communication

Preface

My analysis in this study is focused on the repetitions of a gesture throughout various lessons dealing with the same conceptual unit (i.e., circulatory system) using the concepts of *catchment* and *growth point* and relating them to Derrida's idea of the iterability of signs. To exemplify my points about the use and function of iterated signs—which emerge during growth points and are repeated in catchments, as I demonstrate here—I focus on fourteen repetitions of the particular gesture used to convey the specific idea of contraction of the cardiac muscle. This gesture was first performed during a lesson dealing with the circulatory system, as I have presented in chapter V, and then was repeated throughout this lesson and during consecutive lessons on the same topic. In this study, however, I analyze the signifier-signified relations in each instance of repetition and articulate these repetitions as a special case of the iterability of signs that helps establish the signified for each instantiation of the sign. This particular study derives from my previous analysis of this catchment (presented in chapter V), but here the same phenomenon is analyzed through different lenses, aiming a different contribution to a different community. Whereas both analyses (in chapter V and here) could be presented together as part of a single study in this dissertation if I had chosen to do so, this same treatment would not be feasible for publication purposes, due to the complexity of the concepts and theories presented and the length of the resulting manuscript. Thus, I prepared a different version of this study for submission to Semiotica, where it has been recently accepted.

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Catchments, Growth Points, and the Iterability of Signs: Meaning in the Making During Lectures on Circulatory System

In this study, I focus on the occurrence of a particular catchment related to the contraction movement of the cardiac muscle. My analysis is centered on the semiotic value of the gestures and words unit, and the relation between catchments and growth points (McNeill, 2002) and iterability of signs (Derrida, 1988). Within the dialectical communicative unit, the gesture that is repeated throughout the lessons on circulatory system and the synchronous words accompanying it constitute a double signifier, verbal and visual at the same time. The repetitions allow and embody the presentations of different associations of verbal and imagery content that encompass diverse aspects of the conceptual unit the teacher is teaching. During the teacher's discourse through various lectures, a variety of different scientific terms and ideas are presented, which must be interpreted within the context of the overall conceptual unit. That is, within the unit on circulatory system, diverse concepts are communicated, all connected to one another to form a (discursively and scientifically) coherent unit. Through the microanalysis of the recurrent gestures, considered as one part of a double signifier, I was able to identify these connections.

Because similarities and differences in the words used by the teacher could be identified more easily (for example, pumping, contract, contracting), I chose to group the occurrences of signs according to similarities in the gesture movements. Grouping the gestures that are similar to each other also made it easier to identify the differences in the various gestures that I identified as constituting the *same* or *repetitions of the same* gestures. Within the communicative unit comprised of gestures and words, these

differences become meaningful, as the specific way in which a gesture is performed is constrained only by specific aspects of the imagery itself (McNeill 2005). That is, constraints were imposed by the nature of the signified itself. Thus, to reinforce the notion of *sameness* and repetition of each occurrence of the gesture, making explicit the particular features that reoccur in each instance, I keep the letters identifying each image in sequence (from *a* to *n*) even within differently numbered figures. In the following, I illustrate how catchments and growth points allow us to link studies of everyday communication to the concept of the iterability of the sign.

The Case of the Contraction Sign

During the lessons dealing with the circulatory system, the teacher repeatedly produced the sign I henceforth refer to as the *contraction sign*. This sign is identifiable through both gesture and word(s), which thus constitutes a double signifier, visual and verbal at the same time. The visual part of the signifier is represented by a gesture performed with both hands, arms folded at the elbows, and hands initially apart and then approximating, in a *squeezing* movement (e.g., Figure 6.1a). In all the various instances in which this gesture occurs, it is accompanied by words, some of which are repeated more than once. The various repetitions of this gesture constitute a catchment that presents a recurrent idea available through the particular movement that, in turn, carries meaning *in conjunction with* the words synchronously uttered. Semiotically, the signifier is composed of the unit constituted by gesture and words, whereas the signified, as I make evident in my analysis, is the *recurrent idea* that is made thematic in the repetitions of the gesture and that is identified as the *squeezing* movement, which, within this

particular context (i.e., teaching about circulatory system), represents the contraction of the cardiac muscle.

Following McNeill's (2002) speech and gestures dialectic, both the hand and arm movements that visually constitute the gesture and the utterance that is constituted by sound comprise the indivisible dialectical unit that I identify here as signifier. In the various occurrences of this sign represented in Figures 6.1 and 6.2, the gesture is performed with fingers opened, but each gesture is performed with the hands raised to different levels. Both characteristics of this gesture constitute variants of this movement, as I will show. However, the main features of this gesture, that is, the use of both hands, with arms folded at the elbows, and hands approaching each other in the central gestural space, are constant, thereby permitting the identification of the various occurrences of this gesture—considered as repetitions—throughout the lessons that deal with the same conceptual topic.

Ventricles. The gesture in Figure 6.1a corresponds to the very first time the teacher performs this gesture, and, therefore, it is also the first time this gesture is performed within the series of lessons that deal with the human circulatory system. It introduces another variant of the gesture: the movement may be performed only once or may be repeated *within the same gesture*. In Figure 6.1a, the teacher performs the movement twice as part of the same gesture.

The stroke of the gesture synchronizes with the utterance *are the big pum[ps]*. The reference to the contraction of the cardiac muscle is not immediately available through this sentence. Rather, one needs to interpret this sentence as an analogy between a pump and the ventricles in the heart. The teacher started this lesson with an analogy

between the fluid circuit in a car and the circulation of blood in a human body. The heart was then said to be analogous to the water pump in the car's fluid circuit. Thus, the situated meaning of *pump* had already been established. In Figure 6.1a, however, this term assumes a new meaning as the teacher differentiates between the different chambers of the heart (i.e., ventricles and atria[1]). In this sense, this gesture and word ensemble constitutes a growth point. The ventricles are larger than the atria, thus the use of *the big*; the ventricular contraction sends blood outside of the heart, thus the analogy between the ventricles and a pump.

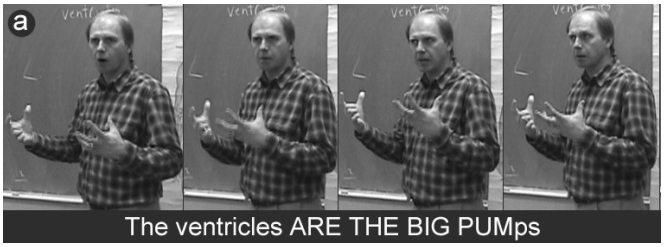

Figure 6.1. Still-frames representing the stroke of the gesture and synchronous utterance (in capital letters). (a) The first occurrence of the contraction sign. Here, the movement occurs twice within the same gesture.

The newsworthy information in this case is the function of ventricles as the *big pumps* of the heart. Whereas *pump* refers to the function of the ventricles, the adjective *big* not only presents a characteristic of the ventricles in relation to the atria, but also brings forth another aspect of the concept of ventricular contraction. The ventricles are not pumps; they are *the* pumps, that is, they are the chambers of the heart responsible for *pumping out* the blood from the heart. Further yet, because they are bigger than the other two chambers of the heart (i.e., the atria) and send blood to other parts of the body (as opposed to sending blood *within* the heart only, as is the case with the contraction of the

[1] The heart is divided into four chambers. The two upper chambers are denominated *atria* (plural form of *atrium*), while the lower chambers are called *ventricles*.

atria), the ventricular contraction is responsible for the circulation of blood[2] in the blood vessels. Indeed, the pulse we can feel in our wrists results from the ventricular contraction, and that is how we can estimate the rate of our heartbeat by feeling this pulsation in our blood vessels. This differentiation between the function of the ventricles and that of the atria in regards to the circulation of blood is made explicit in other occurrences of the gesture. But it is already present here in the form of a characteristic of the ventricles (they are big) in direct association with their function (they pump blood).

The words *are the big pumps* are just a one-sided expression of the entire meaning unit, that is, they are just one part of the signifier whole. The other part, which is indivisible (and yet, distinguishable) from them, is the gesture. Taken together, therefore, the meaning of this word and gesture ensemble is different than the meanings we can make out of the words alone; thus, word and gesture *together* constitute the meaning of the sign. The particular feature that is repeated through all the repetitions of the gesture performed within and across lessons and that constitutes the catchment is the movement of both hands coming together at the central gestural space. This particular movement invokes an image, an analogy, of the contraction of the cardiac muscle, inasmuch as it embodies the idea of *squeezing*; that is, the concept of *contraction* is intrinsic to the teacher's articulation of the *squeezing* movement of the ventricles that occurs once the contraction of the musculature of these chambers of the heart causes the blood to flow. This interpretation is validated in the iterations of the sign, which include the repetition of the gesture (with slight alterations of form) and the accompanying words, which vary according to the aspects of the concepts that are being emphasized at the moment the

[2] Contractions of the muscular tissue around the blood vessels also contribute to the circulation of blood,

teacher performs the gesture. That is, one sees new meaning possibilities that emerge in repetition, which never is identical (Deleuze, 1968/1994) but *constitutes signification*. Thus, while the recurrent idea of *squeezing* appears in every performance of this gesture, particular features of the gesture vary, as do the words accompanying the gestures, in accordance with the introduction of newsworthy information at each moment (i.e., the occurrence of growth points).

In Figure 6.1a, the gesture also contributes an important characteristic of the cardiac contraction movement, its periodicity. The rhythmical contraction of the cardiac muscle is represented in the repetition of the movement within the gesture. In this sense, the gesture is iconic both qualitatively and quantitatively; whereas its form refers to the *squeezing* movement of the chambers of the heart, the repetition of the movement establishes the rhythmical property of the contraction. The repetition of the movement within the same gesture constitutes a growth point, which introduces the periodicity of the contraction of the cardiac muscle. Thus, within the same gesture and word(s) unit, different and interconnected ideas are introduced: (a) the functional differentiation between the ventricles and the atria, (b) the differentiation of the size of ventricles and atria, (c) the notion of contraction of the cardiac muscle as cause of the circulation of blood, and (d) the notion of periodicity of this contraction movement. All of these are included within the same growth point, represented by both gesture and words.

Systole. Figures 6.2b to 6.2g present iterations of the sign presented in Figure 6.1a. These, as well as the other gestures I identify as being *the same* here*,* constitute a catchment. In Figures 6.2b, 6.2d, 6.2e, and 6.2f, the verbal reference to contraction is

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but unarguably, the contraction of the ventricles is the primary cause of it.

explicit, as the stroke of the gesture synchronizes with *contract(s)*. The entity that contracts, however, is not fixed; in Figures 6.1a, 6.2f, and 6.2g the teacher verbally refers to the ventricle*s*, whereas in Figure 6.2b, the pronoun *they* refers to the atria. In this instance, the teacher presents new information, which complements the information already presented at an earlier moment. The growth point here refers to the contraction of the atria (as opposed to the contraction of the ventricles about which the teacher talked earlier). The gesture that the teacher performs, however, is to be taken as the same. The recurrent idea present in the catchment is that of *squeezing* the chamber of the heart and sending blood out. This is a result of the contraction movement, both in the case of ventricular and atrial contractions.

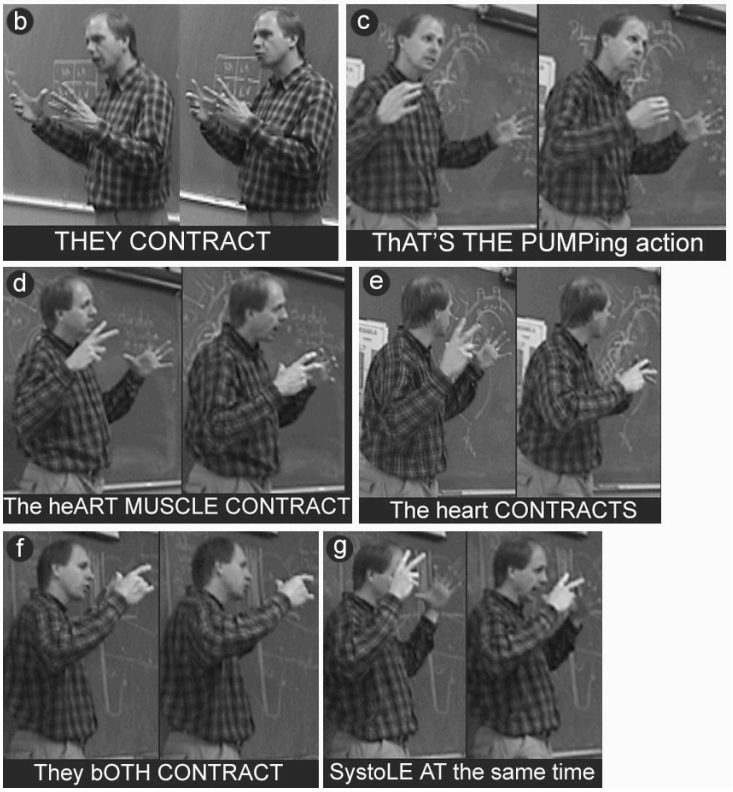

Figure 6.2. Iterations of the contraction sign.

In Figure 6.2c, similarly to Figure 6.1a, the words refer to the pumping action, in reference to a previous analogy the teacher has used. Here, however, *pumping action* is a more direct reference to the *squeezing* movement. That is, once words and gesture are analyzed together as dialectical moments of the same unit, the meaning of this unit is the action of squeezing blood out of the heart through contraction (*pumping action* + *squeezing* gesture). The same meaning can be attributed to the other instances in which the gesture is repeated, even though the words vary. In Figure 6.2d, the teacher refers to *the heart muscle*, and in Figure 6.2e, simply to *the heart.* This variation in the words used validates the claim that the recurrent idea is the contraction movement, irrespective of the entity that is contracting.

Figure 6.2g presents a synonym with contraction: The term *systole*. Here, the introduction of the term also constitutes a growth point. Previously, the contraction movement was introduced as *pumping action* (Figure 6.2c), and now it is articulated in scientific terms, with the introduction of the word *systole*. That is, the repetition of the gesture allows the audience to see a continuity of the content whereas a new scientific term is introduced, which in essence translates the earlier *contraction*. Here, a possible response may be found to the following and perennial question in science education (Roth in press): How is it possible to learn a new scientific language if all students bring to class is their vernacular language? The translation, which occurs between two languages, grounds the required equivalence (sameness in the face of difference) in the repetition of one part of the sign, the gesture.

Whereas in all these instances the catchment brings forth the theme of *squeezing* the heart chambers, within the meaning composed of gesture and words, *contraction*

becomes the recurrent idea, the signified of this sign. Whether we refer to the entity contracting as *ventricle*, *atrium*, *heart*, or *heart muscle*, and whether the *squeezing* movement is referred to as *contraction*, *pumping action*, or *systole*, the signified of this sign remains the same. This is possible both by the recurrence of the idea embodied in the catchment, and by the iterability of the sign, that allows it to be repeated in different contexts while still maintaining the same meaning. The very possibility of the sign to be iterated, repeated in different contexts and yet with the same meaning, permits one to consider the various gesture and word ensembles to *mean* the same thing, to share a signified even when there is differentiation and variations in the signifier, due to the introduction of new ideas (growth points). That is, it is the iterability of the sign that allows the gesture and accompanying words to be identified as repetitions in the first place, but it is through their identification as repetitions that one is able to get at the meaning that is recurrent in all these iterations, and, therefore, to identify the recurrent theme that is the catchment and the newsworthy information that is the growth point.

Heartbeat. The gestures presented in Figure 6.3 introduce other variations in the performance of the catchment. In all three instances, the gesture is now performed with hands in fist, but one is still able to identify the catchment, insofar as the main features of the gesture are repeated here as well. Figure 6.3h presents the movement enacted three consecutive times, which, as I have discussed earlier, constitutes a reference to the periodicity of the contraction movement. This gesture is performed in the context of talking about *heartbeat*, which, as with the term *systole* (Figure 6.2g), represents yet another way of referring to contraction of the cardiac muscle. The introduction of the term *heartbeat* marks the existence of another growth point, when the teacher introduces

this idea into his discourse. The teacher is lecturing about the sequence of contraction of the chambers of the heart, explaining that the contraction of the right atrium occurs simultaneously with the contraction of the left atrium, and synchronously with the relaxation (diastole) of the right and left ventricles. That is, the atria contract while the ventricles relax, and they relax at the same time that the ventricles contract. This sequence of events allows the blood to flow from the atria to the ventricles. The teacher then conceives of the possibility of the contraction of both atria and ventricles occurring at the same time, and concludes that this would be a *very inefficient heartbeat* as the blood being expelled from the atria at the moment of their contraction could not flow into the ventricles if these latter chambers were contracting at the same time. Thus, the concept *inefficient heartbeat* in combination with the *squeezing* gesture introduces the idea of heartbeat as a result of the contraction of the cardiac muscle.

The term *heartbeat* connects to the *contraction* catchment by way of particular characteristics of the contraction of the cardiac muscle: (a) the periodicity, which, as pointed out earlier, is represented in the immediate repetitions of movement within the gesture, and (b) a particular rhythm that results from the sequential contraction movements of atria and ventricles, and which is identified as a *heartbeat*. Thus, at the level of signification, the term *heartbeat* as a signifier is associated with other signifiers, such as the rhythmical pulsation that we can feel and a particular sound that we can hear when a heart is beating, which are essentially experiential attributions we give to the sign. Once the unit comprised of gesture and word(s) is considered altogether, the meaning of

heartbeat + gesture becomes connected to the contraction of the cardiac muscle, which is a rhythmical movement that indexes *heartbeat*[3].

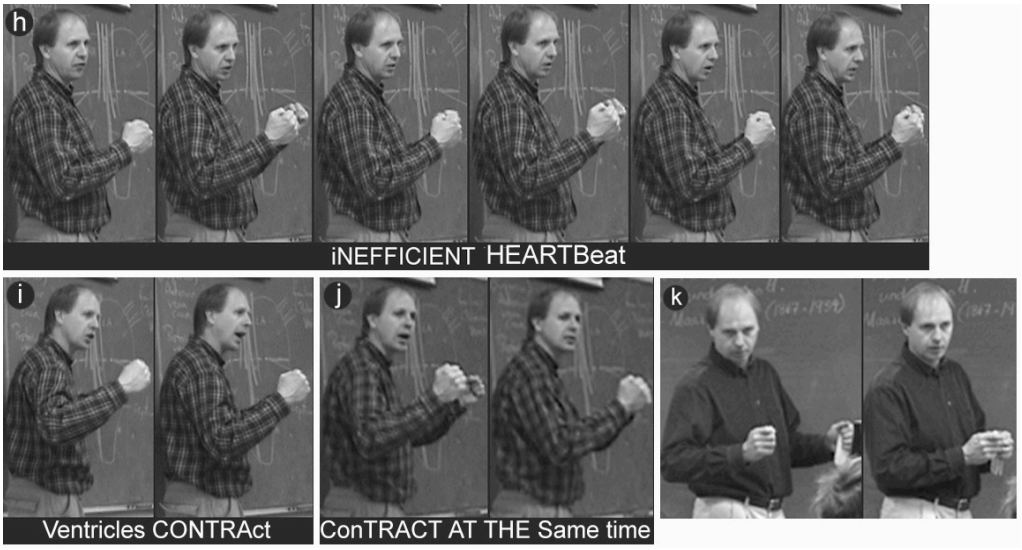

Figure 6.3. Further iterations of the contraction sign. Here, the gesture is performed with hands closed in fists. (k) the teacher performs the gesture in silence.

Figures 6.3i and 6.3j present words that are exact repetitions of those used in earlier appearances of this sign and that make direct reference to the contraction movement, which is the recurrent idea in the catchment. Figure 6.3k, on the other hand, represents a peculiar instance of this catchment. The teacher performs the gesture in silence, while a student is talking, thus synchronizing the stroke of his gesture with the student's words (which are inaudible in my data sources). Although one can still identify the repetition of the gesture (the iconicity is still available), meaning in this situation is attainable only once one considers this instance as yet another iteration of the sign originally produced in Figure 6.1a. The possibility of this sign to be iterated within different contexts, even in the absence of the words that are an integral part of it, allows

[3] Given the context within which this sign is used, the meaning we can make out of the word and associated gesture is confined to the actual heart contraction as a physiological phenomenon, as opposed to, for

the interpretation of it as a repetition, thereby identifying the catchment and the recurrence of the idea of contraction.

Circulation. The three gestures represented in Figure 6.4 are similar in the exaggeration of the movement, with elbows initially held high and far apart from the body and coming down and closer to the body as the movement unfolds. Whereas Figures 6.4l and 6.4n present the word *contract*, as in earlier occurrences of this gesture, in Figure 6.4m the stroke of the gesture synchronizes with the term *surge*. Here, the teacher talks about how the contraction of the ventricles causes the blood to flow out of the heart, to either the lungs or other parts of the body, depending on which ventricle is contracting (the right ventricle or the left ventricle, respectively). The shape of the gesture is iconic to the contraction that causes the flowing of the blood, a reference that I have identified earlier as the recurrent idea present in the imagery of the *squeezing* movement.

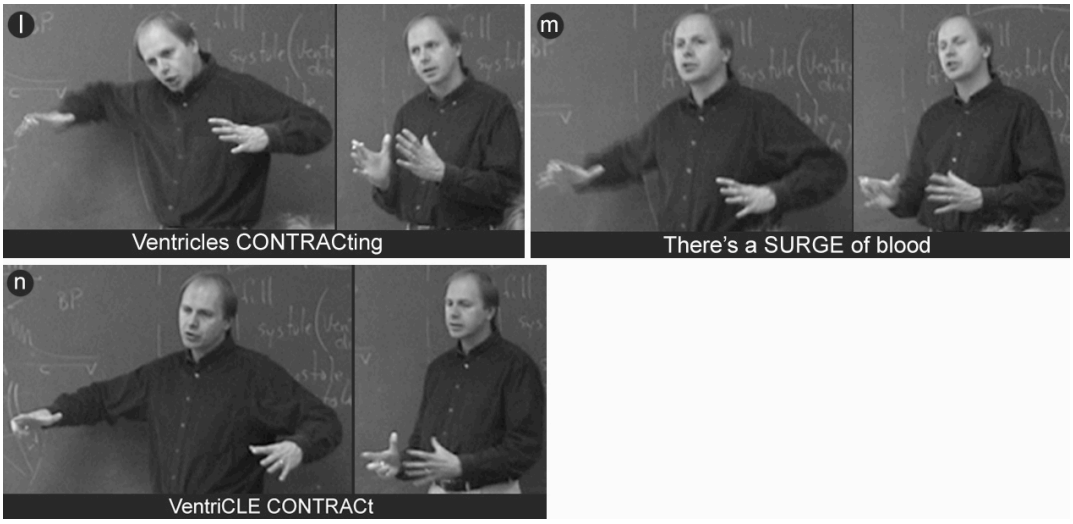

Figure 6.4. In these three further iterations of the contraction sign, the hands are opened again, but the gesture stroke starts with the elbows far apart from the body.

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example, the meaning we can attribute to heartbeat in the sentence *this can be done in a heartbeat*.

However, to send blood all over the body, the contraction must the powerful, and the exaggeration of the movement conveys this meaning; thus, the variation in the performance of the gesture, as well as the noun *surge* synchronized with it, constitute another growth point, where the idea of the pressure with which the blood flows out of the heart and through the blood vessels in our body is presented. The association between contraction of the cardiac muscle and circulation of blood is available in both gesture and word(s) in Figure 6.4m: *Surge of blood* is the primary result of the movement represented in the gesture, and this combination of *contraction* and *sending out blood* is the recurrent idea in the catchment. However, within the context of blood pressure, which is the topic of the teacher's discourse at the moment, this same gesture and word ensemble introduces a new idea, which connects to the idea presented in Figure 6.1a, when the teacher talked about the ventricles as being the big pumps.

Therefore, each iteration of the sign during the lectures dealing with circulatory system constitutes an instance of repetition, in the form of a recurrent idea present in the catchment, but, at the same time, the variations in the shape of the gesture and in the words that accompany it mark the presence of the growth point, when newsworthy information is brought into the teacher's discourse. This variation in the repetitions, which renders the gesture and word ensembles to be *the same* and *not the same* simultaneously, I refer to as a special case of the iterability of signs. This iterability has at least one specific function: providing resources for establishing sameness in the face of difference, which is encountered in the translation of two languages (students' vernacular and the teacher's scientific discourse). The gestural moment of the communicative unit constitutes something like a *basso continuo* that—not unlike in music—provide the

harmonic (meaning) structure in the communicative event. The basso continuo provides the structure upon which other instruments may improvise harmony *above* them. The present examples show that the hand and arm gestures provide the continuo upon which the verbal part may constitute its themes, variations, and translations.

Conclusion

In my database, among the abundant signs the teacher produce when lecturing, the uttered words and accompanying gestures, especially of the gesticulation type, are predominant. These words and gestures constitute an indivisible, dialectical unit, as I have argued in earlier chapters. When teaching a particular concept, within and across consecutive lessons, the teacher repeats (parts of) signs the meaning of which is established from the combination of word(s) and gestures within this unit. That is, word and gesture constitute a *double signifier*, visual and verbal at the same time.

In the fourteen repetitions of the *contracting* sign I have shown here, both the visual (imagery, gestural) and the verbal components of the signifier vary according to particular constraints imposed by the context within which the gesture and word ensemble is produced. However, within the unit comprised of gesture and word, the signified remains constant, with the invariant part of the signifier (the catchment, the recurrent idea) *carrying* the same meaning forward throughout all the iterations of the sign. The identification of the recurrent features of the *squeezing* gesture (i.e., the catchment) allows one to interpret the various gestures as being *the same*, thereby identifying recurrent themes in the discourse; on the other hand, one is also able to identify variations either in the gesture performance or in the associated words, and this identification of the gesture and words as *not the same* corresponds to the moments in

which new information is added to this unit (the indivisible, dialectical unit, a minimal unit of analysis in Vygotskian terms, which is composed of both gesture and words), and which constitute the growth points.

This dialectic of identity of non-identical things (signs), within the same unit, constitutes a special case of iterability of signs. I take iteration here in the sense of an ontology of difference, which not only takes a repetition to be different from its original but which, to be consistent, takes the thing as non-identical with itself (Deleuze, 1968/1994). Iterability, which is based on substitutability, constitutes the very possibility of signification (Derrida, 1988; Roth, 2006b). That is, the possibility of the sign (with signifier composed of gesture and word) to be identified as a repetition of the same sign even when the gesture is performed differently and the words vary is a property and requisite of its non-identical identity as sign. Its iterable nature allows the sign to be repeated within the same context (lecture on circulatory system) and by the same subject (teacher). But, within the identity of the sign, there exists non-identical components that nonetheless carry the same meaning and refer to the same referent; that is, the signified can be taken as remaining constant in the face of difference. This aspect therefore is an essential component in establishing topical cohesion generally and topical cohesion in moments of translation particularly (as these occur daily in science or mathematics classroom lessons, where students are confronted with forms of discourse radically different from the vernacular ones that they bring to school).

The variations in the words used (*contraction*, *systole*, *pumping action*, *heartbeat)* correspond to growth points in the teacher's discourse, when new conceptual ideas are introduced. However, in this instance these terms are *synonyms,* thus sharing the same

signified. Similarly, the gestures present differentiations in form that, although identifiable, still maintain the gesture *self-identity*, allowing one to identify each occurrence as a repetition of the same gesture. The invariant part is recognized as a catchment, with a recurrent idea that corresponds to the signified, whereas the variant features of the gesture are consistent with and constrained by the conceptual aspects introduced as novelty in the teacher's discourse (i.e., growth points).

Thus, within the indivisible dialectical unit, the gesture-word ensembles constitute *iterations of the same sign*, thus legitimizing their meaning in relation to the *signified*, which remains constant despite variances in the *signifier*. Gesture and word(s) constitute, in this sense, a double signifier, which, with each iteration, produces and reproduces the meaning of the signified and of themselves as signifiers, thereby *making* the sign *meaning(ful)*. Put differently, the unit of gesture and word(s), as it is repeated within and across the lessons, makes meaning at the same time that it becomes meaningful.

Chapter VII:

How Do We Know He Is Not Talking About Himself?

Demonstrations in Science Classroom

Preface

My starting point for this study was my interest in knowing how are we able to unproblematically interpret demonstrations and quotations as such in everyday communication events. I have observed in my database various instances in which the teacher talked and acted as someone or something else. One particular case was especially intriguing, and I presented it here in the introduction of the study. I showed this episode to my husband one day and asked him *what is happening here?* When he readily answered that the teacher was demonstrating something, I decided to find out what are the clues we have to make sense of this situation so straightforwardly. Thus, in this study I focus on demonstrations during science lectures, conducting microanalysis to identify the markers that allows us to disambiguate reference (to other people, other places, other times) from self-reference. This study is perhaps the one I enjoyed most, as I was really curious to obtain the answers to my motivating question. I also had the opportunity to discuss some of the early episodes I have selected for analysis in a course taught by Dr. Janet Bavelas, from the Department of Psychology at the University of Victoria, who provided me with very insightful and intriguing remarks about the phenomena, which influenced my approach to this topic. A different version of this study has been accepted for publication in Journal of Pragmatics.

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How Do We Know He Is Not Talking About Himself?

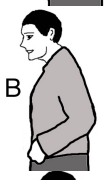
In everyday conversation, people make reference to places, objects, other people, and time. They also refer to themselves and to the direct interlocutor(s) during the

conversation. Besides verbal reference—achieved through using pronouns such as *I* and *you*—and demonstrative terms (e.g., *this* and *there*), one can also use gestures to refer or point to something. In fact, gestures may contribute to disambiguate crucial aspects that help us to understand what the person is trying to communicate (e.g., Pozzer-Ardenghi & Roth, 2005). Another way through which reference can be made is in the form of a *demonstration*[1], when a person speaking performs and therefore *quotes* someone else's actions, gestures, or speech. In these situations, a person may gesture with his or her own body when actually referring to someone else's actions. Direct quotations are examples of these instances (Clark & Gerrig, 1990). The differentiation between the narrator of a story and the character the narrator quotes is possible due to markers that allow us to understand the quotation as such. In some situations, however, the disambiguation is not easily accomplished, and reference and self-reference may be conflated. For example, consider the following episode:

Episode 7.1: The ovaries.

01 Because there's (0.95) events happening (0.35)
02 [in the brain with pituitary] (0.30)
[*performs gesture in 7.1a*]

03 [in the ovaries]
[*performs gesture in 7.1b*]



04 [in the uterus]
[*performs gesture in 7.1c*]

05 one asks (0.57) where did it start?

Figure 7.1. Drawings produced from video still-frames showing the teacher gesturing.

[1] I use the following definition of demonstration: "A practical exhibition and explanation of how something works or is performed" (Dictionary, Apple Computer, Inc.).

The excerpt is part of a lesson on human physiology, in which the teacher links events happening in the brain (pituitary), ovaries, and uterus. As the utterance *in the brain with pituitary* (line 02) unfolds, the audience can observe a two-handed gesture to the temples (Figure 7.1a). The teacher moves on to talk about the ovaries, whereby the utterance *in the ovaries* occurs simultaneously with a two-handed gesture to the approximate location of the ovaries in a normal female body (line 03 [Figure 7.1b]). Similarly, the utterance *in the uterus* (line 04) is accompanied by a deictic gesture to the region of the body where there normally is a uterus in a woman's body (line 04 [Figure 7.1c]).

Here, in using pointing gestures, the teacher is providing a frame of reference for the approximate location of the brain (line 02), the ovaries (line 03), and the uterus (line 04) in the human body[2]. However, whereas every human being has a brain, only women have ovaries and uterus. Thus, because the teacher points to the ovaries and to the uterus when talking about these organs, one might think that the teacher ought to be a woman. But the teacher in the videotape actually is male. The interesting aspect of this episode lies in the fact that a male teacher points to his body while talking about ovaries and uterus, pointing to locations where they might be located in a woman's body but which are definitely not present in his own body.

Here, as self-reference is conflated with reference, a contradiction is created: the speaker points to a particular male body but treats it as a generalized female body. I

[2] Because these are internal organs, they obviously cannot be pointed at from the outside of our bodies; thus, any pointing gesture would only refer to the approximate location of such organs, from an *outside of the body* perspective.

thereby ask what are the semiotic resources that allow the audience to make sense of the lecture despite the apparent contradictory message articulated at that moment?

When the teacher in the episode above was pointing to himself while talking about the ovaries, the students in the class did not laugh. In fact, upon reflection there is nothing funny or awkward in everyday conversation about a male teacher pointing to himself while talking about the ovaries. One understands that he was pointing to the approximate location of the ovaries on a female human body rather than to *his* ovaries. The interesting aspect is that we are able to disambiguate the teacher and his male body from the body that constitutes the referent of his pointing gestures; that is, the teacher *is* and simultaneously *is not* pointing to his own body, and the body that is pointing *is* and at the same time *is not* the body being pointed to. This potentially confusing situation is in fact unproblematically understood in real time as a case of *demonstration*; that is, the teacher is demonstrating the approximate position of feminine organs using his own (masculine) body as a background for this demonstration. Thus, my questions include: What is he doing? What resources is he making available, which enable us to interpret this situation as a demonstration? The teacher does not cease to exist as a teacher; that is, it is still the teacher who talks and points. His words and his pointing hands are perceived as the teacher's words and hands, but the parts of his body to which he is pointing are perceived as someone else's body parts. How does the audience distinguish between what is the teacher, and what is not? In other words, how do lecturers mark that they are doing something that corresponds to verbal quoting? What are the clues we have to disambiguate *the teacher* and *the teacher's body* from *not the teacher* and *not the teacher's body*?

The purpose of this study is to identify the verbal and nonverbal markers made available during lecture situations, which allow us to interpret demonstrations as such. To do this, I analyze instances in which the teacher demonstrates someone else's actions, paying particular attention to the various semiotic resources the teacher makes available while lecturing, which are integrated into the communicative meaning unit, and may come to the foreground, thus becoming markers. Included in these instances of demonstrations are some cases of direct quotations, which I consider as a special case of demonstrations, following Clark and Gerrig (1990). I analyze speech, gesture, posture, and prosodic aspects in the search for the semiotic resources that are made available to the audience to make sense of these demonstrations. I argue that the various semiotic resources co-deployed during the lectures I analyze render these lectures more dynamic and complex, but at the same time these semiotic resources are integrated to form a unit (meaning unit), and the constitutive elements of this unit cannot be comprehended or analyzed in isolation. Hence, I consider these various semiotic resources as potential markers that help to organize spatially and temporally the communication encounter, thus facilitating disambiguation during demonstrations. I explain these markers in terms of the shifts between figure and ground, elaborating on the dynamic aspect of the communicative meaning unit and how the various semiotic resources that constitute the meaning unit are brought at times to the foreground so as to become markers.

Disambiguating Referents in Demonstrations: Identifying Communicative Markers

In this study, I identify communicative markers that allow us to disambiguate aspects of demonstrations. In other words, how do we recognize a demonstration? What are the semiotic resources available and how do they interact so as to become markers that enable us to interpret a particular part of the teacher's discourse as a demonstration? I argue here for the existence of a communicative meaning unit constituted by diverse semiotic resources, both verbal (linguistic) and nonverbal (imagery, material), which are simultaneously and differentially co-deployed. That is, although the meaning unit may include, for example, words, gestures, material artifacts, and prosodic aspects of discourse, these different semiotic resources exist in a dialectical and dynamic relationship that enables some of these resources to come to the foreground, whereas others remain in the background. When a teacher is lecturing, all the invariant aspects of the communicative meaning unit become ground against which the variant aspects become salient. These variant aspects are articulated here in terms of *markers*, which are then used to disambiguate otherwise ambiguous communicative forms including, for example, teachers' demonstrations. Here I discuss (a) positional, (b) verbal, and (c) prosodic markers. I present an exemplary episode that illustrates the interplay of verbal and nonverbal semiotic resources from which markers are created. These markers establish the beginning and the end of the demonstration and they come to exist from a dialectical relation of non-identical resources that in fact are part of the same meaning unit.

Episode 7.2 is representative of many other episodes[3] in which the teacher used a demonstration to communicate a scientific concept. It was culled from a lesson on nervous system, in which the teacher is positioned beside the projector and points and gestures over a transparency, also writing on it occasionally.

Episode 7.2: The doctor's office.

Teacher:	01	These particular proprioreceptors (0.47), if you're sitting in the doctor's office (0.31),
	02	sort of dangling your leg here and the doc hits with his funny little rubber hammer
	03	(0.55), what does your leg do?
Students:	04	(INAUDIBLE)
Teacher:	05	It jumps up like that right? Is this conscious thought are you thinking okay he hit me I
	06	guess I'd better lift up my leg (0.82), in fact the doctor doesn't want you to use
	07	conscious thought (0.90), the doctor says just relax (0.80), and he knows when you
	08	are faking it or she knows when you're faking it right? So they hit you right in the
	09	right spot and you sort of feel it underneath that bone there give it a little whap with
	10	the rubber hammer and your leg jumps (0.57), why does your leg jump? Because of
	11	this built in reflex arc.

At the beginning of Episode 7.2, the teacher has projected an overhead entitled *The Reflex Arc* containing a black-and-white diagrammatic representation of the leg and knee, showing the muscles and joint, and a magnified cross section of the spinal cord, with nerves connecting the spinal cord with the muscles on the leg and joint (Figure 7.2). Episode 7.2 begins with the final, unfinished utterance (*These particular proprioreceptors* [line 01]) concerning the existence of receptors connected to the cerebellum and responsible for coordinated body movements. After a brief pause, the teacher apparently changes topics in mid-sentence. He moves away from the projector and towards the opposite corner of the desk where the projector stands, while beginning a story about someone sitting in the doctor's office, subjected to a test of the knee reflex arc. As part of his presentation, the teacher enacts a demonstration in which he uses his

[3] Throughout my database, the teacher demonstrated other persons' actions in 16 different lessons. These episodes varied in length and sometimes the same demonstration was repeated in different moments of the same lesson, and at times, mentioned afterwards, to remind students of what the teacher had demonstrated.

own body to illustrate what is happening in the story to someone else (*you*). How do students know that the teacher is now demonstrating someone else's action at a place different than the classroom where he and the students stand at the moment? In other words, how do these students in particular and human beings more generally disambiguate three possible situations: (a) a speaker points to his or her body as his or her body, (b) a speaker points to his or her body to stand for the specific listener's body, and (c) a speaker points to his or her body to stand for a body in general?

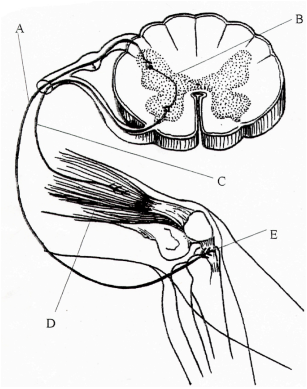


Figure 7.2. The image projected by the teacher onto the screen during the lesson analyzed here.

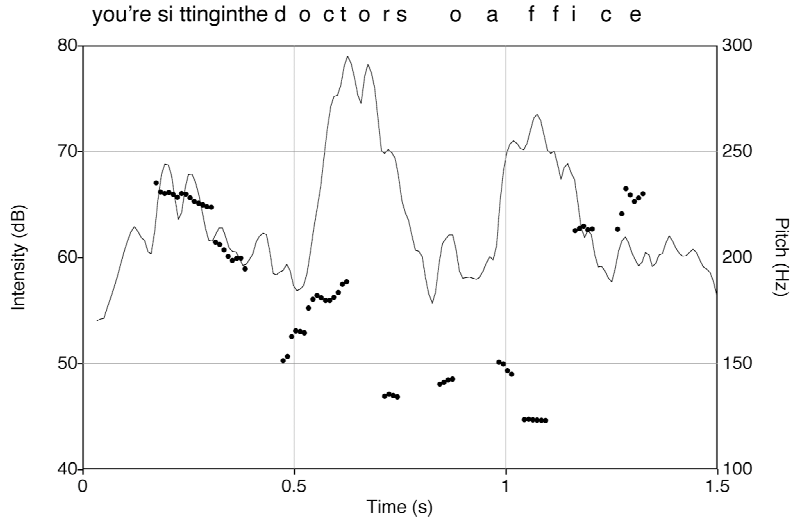
Body Position as Marker for Narrative Shift

The teacher marks the beginning of the demonstration by using both verbal and nonverbal resources that are brought to the foreground of the communicative, meaning unit from which they are a part of. For instance, he changes his physical position as he changes his narrative perspective: He had talked about receptors responsible for coordinated body movement, but then physically moves towards a different space in the room (Figure 7.3c), while also explicitly, verbally presenting a new situation. This first sentence *if you're sitting in the doctor's office* (line 01) is therefore coupled with the

teacher's change of position in the classroom, marking the beginning of the demonstration.

a) [If you're sitting in the doctor's **office** (0.31)]

b)



c) [The teacher retrieves his right hand from the top of the projector and starts moving towards the opposite corner of the table.]

Figure 7.3. (a) Transcription of the teacher's utterance. Words underlined (for intensity) and on bold face (for pitch) represent emphasis placed on these words when the sentence was uttered. (b) Graphical representation of pitch (darker speckles) and intensity (curves) levels. An increase in on one or both of these levels is identified as emphasis. (c) Still-frames of the teacher's movements while uttering this sentence, accompanied by a verbal description of these movements (between brackets).

Initially, therefore, the teacher distances himself from his role *as teacher*, by moving away from the position associated with the immediately preceding lecture position. He moves to a new position where he now demonstrates a person in the doctor's office. By moving to a different place, the teacher not only finds an appropriate setting

where he can sit and enact the actions of the patient in the doctor's office, but he is also bodily *marking* the space (both concrete and abstract) of the demonstration.

Once the demonstration is finished, he stands up and returns to his earlier position at the side of the projector, resuming the talk over and about the image projected on the screen. This latter transition occurs simultaneously with a transitional utterance *why does your leg jump?* (line 11), which followed a brief pause (0.58 seconds) after uttering the final sentence pertaining to the demonstration. From the position taken while producing the final utterance of the narrative in the doctor's office (Figure 7.4a), the teacher moves into an upright position (Figure 7.4b) and turns around (Figure 7.4c), steps back (Figure 7.4d), and then moves forward again to his original position next to the overhead projector (Figure 7.4e).

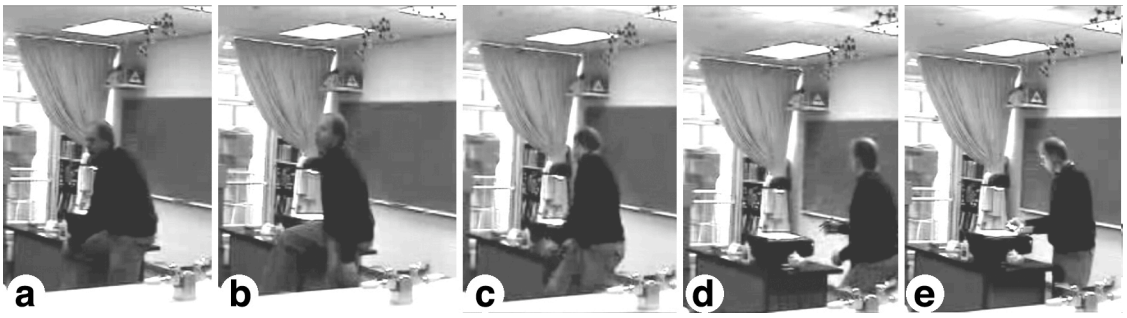


Figure 7.4. The shift between two narrative and epistemological spaces was marked by a change in body position, which occurred simultaneously with an utterance that marked the transition from practical understanding to theoretical explanation of an aspect of the world.

Here, the positions and body movement clearly mark different *narrative spaces* and movement between them. The physical transition occurs simultaneously with an utterance that bridges two situations. On the one hand, there is the narrative describing a visit to the doctor's office. This is a concrete situation from the everyday lifeworld that every listener is expected to have had; the narrative appeals to a practical *understanding* of the world. On the other hand, there is the science lecture situation, in which theories

are taught and *explanations* are provided for the physical world generally and here the experienced world in particular. These two forms of narrative, one appealing to understanding and the other one providing explanation, are, from a hermeneutic perspective on texts, dialectically related (Ricœur, 1991). They are very different, but also identical: they constitute a meaning unit.

In shifting his body and moving to different locations, therefore, the teacher marks the shift between two very different forms of consciousness: practical understanding of the world and theoretical explanations of experience. The question *why does your leg jump?* that ends simultaneously with Figure 7.4c, constitutes the textual transition point, because it appeals both to practical understanding of a leg reacting to the tap of a rubber hammer in the doctor's office and the scientific explanation of this experience. In this situation, therefore, very different textual forms and the appeal to different forms of consciousness (cognition) are associated with different positions in the classroom and shifts between them.

Similarly, in the introductory episode, the teacher, who was pointing to the chalkboard and standing sideways between the board and the students, turns towards the audience when he starts pointing to his body. This shift in position affords more than a narrative shift; by turning to students, the teacher makes his body, now used as a material resource, visible to all students. The brain, the ovaries, and the uterus are referenced by means of pointing gestures to a *generalized* body, in the same way as they could be pointed at in a model or a diagram of a human torso, for example. Although this shift in body position is subtler than the one I describe in Episode 7.2, it also marks a different narrative space, insofar as the teacher shifts the focus of attention from the chalkboard to

the body parts he is pointing to. Other markers, however, helps us disambiguate *his* body from *the generalized* human body he is making reference to.

Verbal Markers of Narrative Shift

Simultaneously with the shifting in position in the classroom, the teacher utters the sentence *if you're sitting in the doctor's office* (line 01). Here, the teacher uses *you* as the agent of the actions he performs. That is, the use of the pronoun *you* announces that the teacher's actions at the moment should be interpreted as the actions of someone who is *not* the teacher in the classroom, but, instead, *you*, which in this particular case signifies *the students* as *patients in the doctor's office*. From a detailed analysis of various other instances in which the teacher uses the pronoun *you* as he has done in Episode 7.2, I came to understand that *you* means the group of students, both male and female, that constitute the audience of the teacher's lectures. The teacher excludes himself from this group, and the group seems to be characterized primarily by the students' age (e.g., the teacher explicitly talks about babies, children, and elderly people at other occasions, which are all people who belong in a different age group than the students in his class). References are also made to various professionals (e.g., school secretary, athletes), which are clearly conceived as not pertaining to the same group as the students.

In this situation, therefore, the teacher directly appeals to students' prior experiences in a doctor's office, where they have had the kind of test that the teacher is going to talk about. In line 02, the teacher elaborates on the actions the students would be performing in the doctor's office by saying *sort of dangling your leg here*. The use of *here* indicates the proximity (Hanks, 1992) of the teacher (now *student* in the *doctor's office*) to the demonstration space he has just created. In this sense, the teacher *is* the

student/patient dangling his or her leg in the doctor's office. The indexical term *here* is a direct reference to the site of the demonstration. That is, the teacher created a *perceptually conspicuous site* or PCS (Clark, 2003), which is shared by both the teacher and the students but that is different than the actual setting where they are located at the moment (i.e., the classroom). A combination of verbal (e.g., use of *you*) and nonverbal (e.g., shifting his position in the room) resources established this site (i.e., the doctor's office), and now the teacher stands within this space, which makes it legitimate for him to use *here* to refer to the demonstration site. However, the teacher can step out of the demonstration site and resume his role as teacher, without physically moving away from this site.

When the teacher asks students a direct question (*What does your leg do?* [line 03]), he is in fact resuming his role as teacher by verbally stepping out of the demonstration site, within which he is still bodily present. This question is pertinent only in relation to the demonstration setting. When the teacher asks the students *what does your leg do?* he is asking each of them what his or her leg would do if he or she were sitting in the doctor's office, dangling their leg, and the doctor were to hit their knee with a rubber hammer. That is, this question is a direct reference to the demonstration site or PCS that the teacher and the students now share, and the students are expected to answer this question from *within* this site. The teacher neither wants students to tell him what their legs do in general, on an everyday basis, nor he wants them to describe what their legs are doing at that particular moment *in the classroom*. The question and its answer are contextualized within the demonstration space. However, the specific actions of questioning and answering to this question take place *outside* of the demonstration site, in

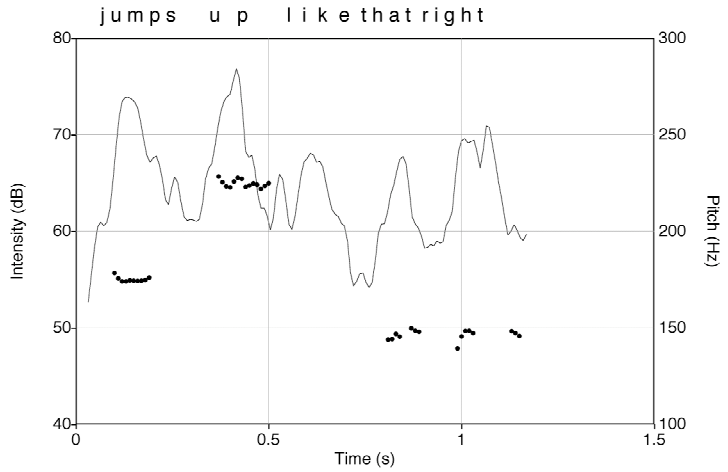
the actual classroom setting. These two different settings (i.e., the doctor's office and the classroom) are marked by the simultaneous use of dialectically related resources, verbal and nonverbal, that are employed differently to mark different communicative spaces, that is, they mark narrative shifts.

After the students have answered his question, the teacher answers it himself (*It jumps up like that* [line 05]), but he seeks confirmation from the students by adding, *right?* Synchronously with *it* the teacher lifts his right leg. *Like that* in this sentence, therefore, makes reference to the movement of the leg. Moreover, the choice of words (*jumps* instead of *kicks*, for example) is coherent with the main concept being articulated, denoting the involuntary character of the knee reflex movement. Even though jumping is still an action, the leg, as inanimate entity, is imbued with action possibilities that are independent from the person's voluntary control (differently than kicking, for instance, which presupposes a conscious will to move the leg up), which is an important aspect of the concept of '*reflex movement*' that is to be articulated. With this sentence, the teacher gets to the point of the demonstration, that is, he shifts narrative forms again and *explains* particular aspects of the scientific concept (knee reflex movement). The teacher attempts to ascertain students' understanding of this issue by asking questions and by seeking confirmation for his statements, which are actions recognizably performed in the classroom setting. At the same time, however, through the deployment of other semiotic resources (position in the room, gestures, previous speech, and so on), the teacher marks the existence of the demonstration setting in relation to which these questions and statements make sense. The following sentences (lines 06–11) make this intention to *explain* phenomena explicit, as the teacher then elaborates on the *unconscious* (i.e.,

involuntary) aspect of the reflex movement. Here, demonstration space and classroom space merge, as the teacher attempts to explain a concept (i.e., involuntary nervous control of the knee reflex movement) while at the same time making reference to the particular situation he is demonstrating (i.e., the visit to the doctor's office).

a) [It] <u>jump</u>s **<u>up</u>** like that right?

b)



c) [Kicks his right leg up, with left hand touching right knee]

Figure 7.5. (a) Transcription of the teacher's utterance. Words underlined (for intensity) and on bold face (for pitch) represent emphasis placed on these words when the sentence was uttered. (b) Graphical representation of pitch (darker speckles) and intensity (curves) levels. The intensity level is highest on *jumps* (74dB) and *up* (76dB). The pitch on *up* is also the highest, reaching 225Hz. (c) Still-frame of the teacher's movement while uttering this sentence, accompanied by a verbal description of this movement (between brackets).

Throughout Episode 7.2, the teacher emphasizes a particular movement of the leg, within a particular context, all of which is part of the demonstration he performs.

Emphasis is placed in the demonstration setting and in the knee reflex movement through the use of different semiotic resources, both verbal and nonverbal, which the teacher brings to the foreground at different moments in time, relying on the dialectical relation between foreground and background, variance and invariance. In line 10, the teacher asks another direct question to students, *why does your leg jump?* This time, however, the teacher does not wait for an answer from the students, and he immediately stands up and returns to the side of the projector, where he was standing at the beginning of Episode 7.2, while already verbally providing an answer to this question. Although this question was still tied to the demonstration setting, the answer to it was not. The change in location that functioned to mark the beginning of the demonstration is now repeated in the opposite direction, marking the end of the demonstration. Concomitantly, the answer the teacher provides to this last question refers back to the projected image he was manipulating before, and helps to re-establish the teacher as *the teacher in the classroom setting* once again. Therefore, the interplay of different semiotic resources (speech, gestures, image projected on the screen, and location on the room) creates different communicative spaces (the demonstration space and the classroom space) from which the teacher can walk in and out as he communicates with students the contents of his science lesson and which allows him to relate the demonstration he just did with the topic he was teaching previously and to which he now returns.

In Episode 7.1 verbal markers also help us disambiguate the teacher's body from the generalized human body he is making reference to. For instance, the teacher refers to *the* brain, *the* ovaries, and *the* uterus—differently than in Episode 7.2, for example, when he refers to *your* leg. That is, the generalization occurs at the verbal dimension already,

marking these body parts as *stand alone* and not belonging to any body in particular, neither the teacher's nor the students', neither male nor female.

Prosodic Markers Indicating Change of Narrative Forms

Prosody has been identified as a semiotic interactional resource. For example, children playing hopscotch, though of different culture, display sharp increases in pitch when they express disagreement (Goodwin, Goodwin & Yaeger-Dror, 2002); teachers in multicultural classrooms coordinate their pitch with that of students, thereby decreasing the risk of conflict and increasing the probability of constructive interactions (Roth et al., 2005); and interviewers in research situations indicate willingness and unwillingness to respond to an interviewee's question by adjusting or not-adjusting their pitch with that of the questioner (Roth & Middleton, 2006). Certain words are emphasized over others, through changes in pitch and intensity (volume) levels, and by altering the speed of speech as well.

A peak in speech intensity (Figure 7.3b) occurs at the beginning of the words *doctor* and *office* (79 dB and 74 dB, respectively). The first syllable of the word *doctor* is uttered with a rising pitch, as is the word *office*, which rises to almost twice the normal pitch. These two additional aspects of the communicative meaning unit also constitute semiotic resources made available during the communicative encounter. Here we may hear the peaks in speech intensity and pitch as *emphasizing* the corresponding sounds, themselves normally heard as words. That is, both words *doctor* and *office* are emphasized in this sentence.

Associated with the changing position and narrative form, there is also a dramatic shift in speech rate. Moreover, Figure 7.3b also shows that these two words are uttered

much slower (1.9 words/second) than the previous words in this sentence (11.6 words/second), and about half of the average speed of the discourse during this episode (3.5 words/second). Thus, by varying the pitch, speech intensity, and speech rate coinciding with the sounds heard as *doctor* and *office*, the teacher marks these words as salient against all the other invariant aspects of the communicative meaning unit. Therefore, *doctor's office* becomes the most salient part of this sentence.

In line 06, the teacher's alterations on pitch and intensity levels place emphasis on key words that are associated with the knee reflex movement. When uttering *it jumps up like that right?* the teacher kicks his leg up (Figure 7.5c), demonstrating the result of the knee reflex. Moreover, the word *jumps* is uttered with higher intensity level (74dB) and the word *up* presents the highest pitch in the sentence (225Hz), with intensity of 76dB. Here, the teacher uses prosodic resources to emphasize the particular topic of the lesson, that is, the knee reflex movement; the leg *jumping up* becomes the salient aspect to pay attention to in this part of the lecture.

Similarly, in Episode 7.1 we can identify prosodic markers that allow us to make sense of the teacher's pointing gestures. When the teacher utters *brain* (line 02) he does so with an increasing pitch that reaches over 230Hz, and with a higher intensity level (82dB). In the sequence, *pituitary* (line 02) is also emphasized (pitch at 210Hz and intensity at 83dB). Moreover, the words *ovaries* and *uterus* (lines 03 and 04) are also uttered with increasing pitch (216Hz and 240Hz, respectively) and intensity levels (84dB and 76dB, respectively). Therefore, not only the teacher's gestures (pointing to the location of these organs), but also the use of *the* and the emphasis placed on the words *brain*, *ovaries*, and *uterus mark* these body parts as the focus of the communication, thus

shifting everything else (including the teacher's own body and his masculinity) to the background. His body in this instance is nothing more than a material resource, much like the chalkboard; however, as a material resource used in the background of the communication, it still plays an important role in the communicative meaning unit and must be taken into consideration for us to interpret the teacher's message appropriately.

Dialectical Relations of Semiotic Resources

At the same time that *doctor's office* in Episode 7.2 is verbally emphasized through variances on pitch, intensity, and speed levels, the same place is marked nonverbally by the teacher's changing position in the room. Although the students continue to find themselves in the same classroom, the semiotic markers ask them to follow a shift in narrative frame and to imagine themselves in a different place. These are two opposing modes of cognition—verbal and imagery (McNeill, 2002)—that complement each other inside the communicative, meaning unit, thus substantiating the *doctor's office* within the classroom. I understand these different semiotic resources, which mark the beginning of the demonstration, as standing in a dialectical relationship—they are very different expressions marking the same overall change: shifting narrative form.

Thus, communication during lectures also occurs through a dialectical (and inherently dynamic) process, which includes as part of the same communicative, meaning unit a variety of verbal (e.g., words uttered, prosodic and semantic aspects of the speech), nonverbal (e.g., gestures, location in the room), and material (e.g., image projected on the screen, table on which the teacher sits down) semiotic resources. To create meaning, and thus communicate something, some of these resources shift from the background to the

foreground (Roth & Pozzer-Ardenghi, 2006) by means of variance (against everything else that is invariant, and therefore, remains in the background), thus constituting *markers* that help us to interpret what is being communicated.

Using a dialectical approach is useful because it allows researchers to postulate movement to occur because of the contradiction that exists between concurrent expressive forms. Here, for example, the second part of the question *why does your leg jump?* clearly refers back to the doctor's office narrative. The interrogative *why* on the other hand, is related to a query and therefore explanation—scientific or otherwise. Concurrent with the interrogative, the teacher begins to move out of his demonstration position. That is, at this point, the intention to shift narrative frames is already visible, though not yet achieved. The shift will have been completed when the teacher has returned to the overhead projector and returned to his teaching of scientific theory. Here we see that everyday practical action involves taking a position—knowing is very much an embodied phenomenon, expressed, as this episode showed, in taking position (cf. Merleau-Ponty, 1962) in the world. The change in position taking is announced in the body movement, but this produces an inner contradiction in the communicative unit, which simultaneously is about changing position (bodily) but remaining in the previous narrative (*does your leg jump?*). In the present instance, the contradiction is a force that pushes the communicative event forward (McNeill, 2002). The contradiction will be removed and talk can continue only when the teacher has taken the original position again.

Similarly to the establishment of communicative markers, the interplay of verbal and nonverbal semiotic resources creates different communicative spaces, allowing the

teacher to move through these spaces in an unambiguous manner. That is, while one communicative space is held secure by a set of semiotic resources that at that moment stand for that particular space, another communicative space can be created and entered through the use of a different set of semiotic resources, all of which are part of the same communicative, meaning unit.

Conclusion

In this study I presented and analyzed two exemplary instances of demonstration, from which I identified some verbal and nonverbal markers that allow us to interpret a demonstration as such, that is, as a reference rather than as a self-reference. The markers include body position, verbal markers, and prosodic markers. The body position markers were related to the position of the teacher in the room. Moving from one location to another tends to delimit the narrative space that is different than the classroom setting. In my example, the teacher moves toward new locations in the room, thus marking the demonstration space of the doctor's office. Once a demonstration is completed, the teacher moves back to the position he has held before (e.g., next to the projector), and resumes the talking about the scientific concept he is teaching. This analysis sheds light on the issue of the ambiguity of reference and self-reference, which is inherent in demonstrations. How do we know when the teacher is not talking about himself? How do we distinguish between the teacher's actions and someone else's actions *demonstrated* by the teacher? My analysis of the various resources made available during this episode made it evident that there are specific markers that allow the audience to disambiguate—likely without attending to given the rapidity with which we normally

recognize the difference between reference and self-reference in everyday conversations—between the different narrative forms that are employed during teaching.

Verbal markers include the words uttered, which also differ between the normal narrative space and those taken up during self-reference that is to count as reference in general. Thus, for example, when the teacher starts demonstrating a patient's visit to the doctor's office, he makes use of the pronoun *you*, which in this case refers to someone, including these students, as patient in the doctor's office rather than *these* students specifically; the ambiguity in the *you*, which both appeals to the specific other and the general and generalized other, allows students to bring their own relevant experiences, if they have such, to bear on interpreting or understanding the demonstration. Other words, such as *here*, for example, stand for the demonstration space rather than the classroom setting where teacher and students are located at the moment and also function as markers to help disambiguate between different narrative spaces. Variations in pitch and intensity levels, as well as differences in the speed rate of speech, function as prosodic markers; they are constitutive parts of the current meaning unit and therefore also are resources for disambiguation.

In addition to identifying the markers that allows us to interpret demonstrations, I also elaborate on the relation of the various semiotic resources that constitute the communicative meaning unit. This unit, following Vygotsky (1986), is irreducible and therefore cannot be analyzed in terms of independent elements. Thus, the different semiotic resources produced as part of a communicative act and, in fact, all the semiotic resources available at a single moment in time, mutually presuppose one another: they stand in a dialectical relationship. In this study, I extend an earlier formulation, according

to which the dialectic includes speech and gesture, to include other semiotic resources, such as, for example, pitch, intensity, and material objects present in the room. In everyday situations, such as teaching biology lessons, we are always situated in a larger activity setting, we always already find ourselves in a world embedded in and with reference to which we act and interact. These settings include interaction participants (audiences), artifacts, structures, spatial organizations, and the various prosodic and other body-based resources that speakers, and interaction participants (audiences) make available to each other.

Some of the resources available in the situation are highlighted in the communicative act—though others are taken for granted by interaction participants and therefore have to be accounted for during the analysis (Roth, 2004). In the example I provided here (Episode 7.2), the teacher marks the beginning of the demonstration by simultaneously emphasizing the words that refer to a specific location (i.e., the doctor's office) and by moving towards a different location in the classroom. To emphasize certain words the teacher varies the pitch and intensity levels and the speed with which these words are uttered. This variance makes these words salient, shifting them to the foreground on the communicative meaning unit. Similarly, when the teacher changes location in the room he is bodily (nonverbally) marking the existence of a communicative space, which is different than the classroom setting.

Here I understand meaning as the intuitively and practically constituted coherence of familiar everyday situations; any sign, word, and other semiotic resource *accrues* to this existing meaning whole (Heidegger, 1996). Thus, the pragmatic aspects of the communicative act simultaneously produce and frame the existing semiotic resources to

constitute the meaning unit. There is an interplay of a variety of different semiotic resources, some existing in the setting others being produced, all of which nevertheless mutually presuppose each other *within* and *constitutive of* what we know as meaning. To understand what a person is constituting as communicative figure, that is, to articulate meaning, we need to take into consideration all the resources that constitute the unit in its entirety rather than focusing only on its *one-sided* expression in speech, gesture, or other resource. In the examples provided here, the communicative meaning unit includes the words uttered, the way in which these words were uttered (pitch, intensity, and speed), the movement in space, the gestures performed, and even the table where the teacher sat. What the teacher is *saying* makes sense only when we attend to all of these resources, because these *are* the means through which the teacher articulates his message. The fact that other resources could have been used to frame and articulate a similar message attests to the dynamic aspect of the communicative unit. That is, at different times, different resources are used; and whereas some are emphasized and brought to the foreground, others recede in the background. This dynamic process is what creates markers, which allow us to disambiguate the referents of demonstrations.

In everyday situations, therefore, participants engage in this dynamic and dialectical process of communicating with each other, establishing and recognizing markers, interpreting and creating meaning, in an unproblematic manner. That is, my analysis helped unveil the complexity of communicative encounters. But it is important to emphasize that on an everyday basis people engage in communication of various forms, including teaching and learning at school, without being consciously aware of each and every resource they are making available to each other during this process.

Unless a breakdown in communication occurs, people talk and interact *straightforwardly*, do not articulate that which *goes without saying*, and we are able, for example, to *understand* a person's actions as an instance of demonstration without necessarily taking notice of what allows us to arrive at this understanding. However straightforward and unproblematic, it is still crucial that researchers investigate, analyze, and ultimately theorize this process, insofar as successful communication is key to teaching and learning processes.

Chapter VIII:

Action and Interaction in the Classroom: Teacher's Movement and Associated Pedagogical and Discursive Practices

Preface

This final study was in fact the fourth one I produced (the most recently study in order of production is the one presented in chapter VI, which was also the most theoretically challenging for me). The topic emerged from my realization, when I was still collecting the data, that the teacher had his *preferred spots* in the classroom, where he would stand almost always in the same position. Though I was not able to tell then if these body positioning and locations in the room were connected in any way to the pedagogical and interactive practices that unfolded, I paid attention to this phenomenon and decided to investigate it more carefully. Initially, I planned to analyze all the 26 lessons, looking for the locations where the teacher stood, how much time he spent in each location, how many gestures and of what type he performed in each location, and what he was talking about. I soon realized I would need another four years to complete this analysis. I settle then for the analysis of one lesson, which I randomly selected from my database, making sure, of course, that it was representative of other lessons as well. Because the analysis is less micro and more social in nature here, I submitted a different version of this study to Research on Language and Social Interaction, where it is still under review process.

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Lecturing as Communicative, Social Activity

Without doubt, teaching includes more than producing words, sentences, and texts. Few educators, however, investigate whether non-textual aspects in teacher actions are meaning-making resources for students in the process of learning. To introduce my

topic in this study—the non-textual aspects of teaching (science)—consider the following episode: A teacher positions himself in front of the leftmost corner of the chalkboard and starts to write on it, silently. He finishes writing a few sentences, turns towards the students, steps back and away from the chalkboard, and then points to the area on the chalkboard where he has just finished writing, at the same time that he starts to talk.

This situation is typical for many classes, and at first glance does not seem to provide relevant information about the multimodal and interactive nature of lectures. A closer look, however, brings forth a myriad of issues that are directly connected to teaching as a recognizable and stable form of social activity. For instance, the teacher starts the writing on the leftmost corner of the chalkboard, which is a culturally and socially given in western society (we read and write texts from left to write, top to bottom, and here the chalkboard is seen as an oversized notebook, on which the teacher starts to produce and record the day's lesson). The teacher's strategic position on this side of the chalkboard and his writing on it are aspects that are repeated many times within and across lessons. In this sense, they have become characteristic of teaching; that is, one takes for granted what this action is communicating to students, what meaning-making resources it makes available, and how it is used to structure the lesson. For example, one study revealed how by means of his positioning with respect to two chalkboards, a university professor emphasized the contrast between Aristotelian and Galilean physics, in the way these are conducted (natural observation vs. scientific experiment) and in the outcomes/concepts they produce (Roth & Tobin, 1996). Another study concerning teacher positioning in the classroom and the types of discourse also shows significant relationships between group size (whole-class versus small group), physical

arrangements, focal artifacts, and the participation patterns and contents of the discourse (Roth, et al., 1999).

In the present instance, when the teacher stops writing and turns towards the students, his movement away from the chalkboard is seen together with his turning to the students and the gesture he subsequently performs. All these movements are also part of a socially negotiated and historically constructed teaching strategy: The teacher silently requests students' attention by turning towards them (that is, he communicates a change in the activity), while his distancing from the board and the pointing gesture to it signal where the focus of attention should be (that is, he establishes the focal area). The chalkboard is no longer the teacher's notebook; it becomes a resource available to the students and transparent in the sense that only what is now recorded on it is of importance at the moment. The teacher points to it, directing students' attention, and simultaneously starts lecturing. These events mark the beginning of a lesson, and the students, recognizing it as such, present the expected, culturally negotiated, appropriate behavior to the situation (that is, they stop chatting with their colleagues and pay attention to the teacher).

Lectures are social activities; they present a "pattern of organization, a structure" (Lemke, 1990, p. 2), which requires the participation of both teacher and students to realize it. In this sense, therefore, lectures are interactive events, even when we take into consideration the primacy of the teacher's actions over the students' in organizing the interactional space of the lesson. In fact, this primacy is itself an outcome of teacher' and students' actions and interactions, because for lectures to unfold in the way they do, students have to collude, that is, actively produce certain behaviors.

Traditionally, lectures have been investigated solely or primarily from a linguistic perspective, in which spoken and written language constituted the means of acting and interacting in the classroom. Although a lecture may be equivalent to a monologue in certain situations, it always involves a variety of nonverbal actions and material resources that also constitute meaning-making resources and that are all integrated into the same meaning unit. In this study, I shift from this traditional linguistic approach to teaching and learning and propose to investigate lectures focusing primarily on the teacher's movement in the room. That is, I identify the various different locations in which the teacher stands during any given lecture and analyze them and the movements back and forth between them in terms of the pedagogical, interactive, and discursive practices that are associated with these movements and locations.

My focus in this study resides on the teacher's physical movements in the classroom, analyzed as actions that give structure to and are structured by the lesson. Thus, the teacher's body positioning in various different locations in the room are associated with pedagogical, discursive, and interactive practices that unfold during the lesson and constitute semiotic resources for students in making sense of and participating in the lesson in socially appropriate ways.

Locations in the Classroom, Movement Between Locations, and the Associated Pedagogical, Interactive, and Discursive Practices: Action Structured and Structuring a Lesson

In this study, I analyze, from a multimodal approach to language and communication, the different pedagogical, interactive, and discursive practices associated

with the teacher's movements and location in and around the classroom. Thus, the teacher's physical positioning in different areas of the classroom and his movements from one location to another constitutes a starting point for my analysis. In this study, I show that, although each location represents a physical space where the teacher physically (bodily) stands at the moment, a location also represent a teaching space, which is structured and structures the activity of lecturing. That is, particular pedagogical, interactive and discursive practices unfold within each location, as part of the teacher's action of moving to and from or standing in different locations. The actions performed in each location are constrained by physical aspects of the setting; yet, within the socially constructed lecture, each location is a semiotic resource that may, through time, come to signify the very actions performed in this location, whereby the organization and structure of the lecture is established and becomes stabilized. I begin my analysis with the identification of these different locations and the description of associated practices.

Teacher's Locations in the Classroom and the Pedagogical, Interactive, and Discursive Practices that Unfold During the Lesson

During the lesson I analyzed, the teacher moves around the room and positions himself in various different locations where he remains for different amounts of time. From the five different locations I identified (Figure 8.1), Location 1 is where the teacher spent the most time (see Table 8.1). This location is equivalent to the area in front of the chalkboard, which extends from one side of the room to the other (approximately 5 meters in length [Figure 8.1]).

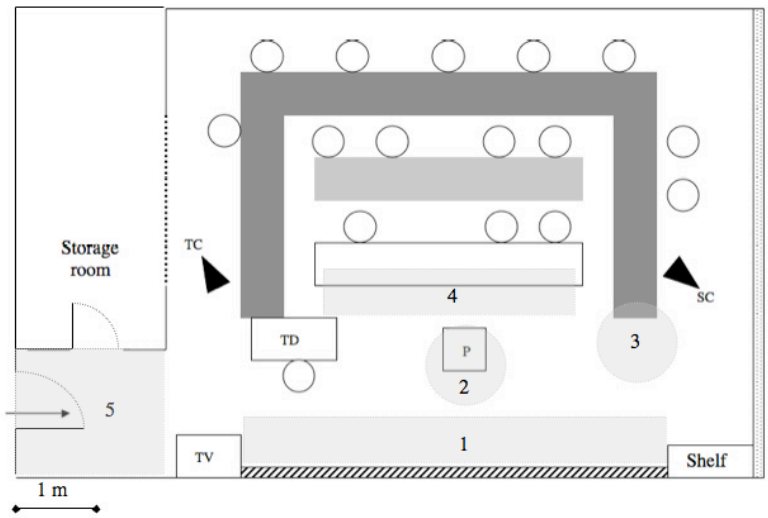

Figure 8.1. Diagram of the floor plan of the classroom. Each light gray numbered area represents one location where the teacher stood during the lesson analyzed. For complete legend for this figure, please refer to Figure 3.1 in chapter III: Methods.

The teacher remains in Location 1 for over 70% of the total time of the lesson, where he makes extensive use of the chalkboard (Figure 8.2). In fact, the chalkboard is the material resource that delimits this location, also providing the constraints and affordances that determine the pedagogical and interactive practices associated with this location. Thus, pedagogical practices in Location 1 are related to the chalkboard, with actions either performed *on* the board or *towards* the board. Location 1 is also the physical space where most of the gestures occur (over 97% of all gestures performed during the lesson), which is directly related to the fact that most of the lecturing also happens in this location, as discussed later.

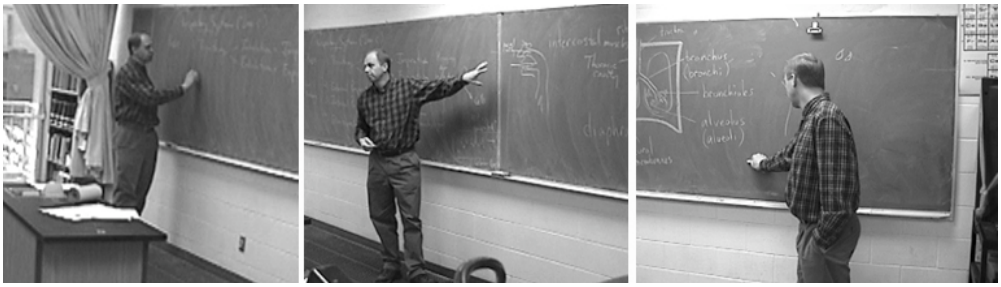

Figure 8.2. Teacher's body positioning at Location 1, the area in front of the chalkboard.

The teacher spent a little over 10% of the total time of the lesson in Location 4, which is equivalent to the area in front of the first student bench (see Figure 8.1). In this location, the teacher's proximity to the students (Figure 8.3b) affords a new physical configuration that is reflected in the type of pedagogical and interactive practices associated with this location. However, this physical configuration also constrains the lecturing possibilities available to the teacher. That is, the physical arrangement of the room, as much as the teacher's body positioning and the resources he uses to lecture either facilitate or make it more difficult for the teacher to employ certain pedagogical or interactive practices.

Table 8.1. Total time spent in each location and the associated pedagogical, interactive, and discursive practices, including the number of gestures performed.

Location (total time spent)	**Total number of gestures**	**Pedagogical practice**	**Interactive practice**	**Discursive practice**
1 (53min25sec)	471	Erasing the board Drawing/writing on the board Waiting for students to copy		(In silence)
		Writing on the board and reading out loud Completing diagram/ equation/ sentence on	Q&A (both teacher- and	Lesson content

		the board and lecturing Lecturing and writing/ drawing on the board	student-initiated)	
		Lecturing		Lesson content
2 (26sec)	zero	Consulting notes		(In silence)
3 (44sec)	3	Waiting for students to copy Lecturing	Asking questions	Lesson content Lesson content
4 (6min54sec)	11	Discussing projects/assignments Supervising students' work	Q&A (both teacher- and student-initiated) Answering questions; Manipulating objects together	Other Lesson content
5 11sec	zero		Opening door for student	

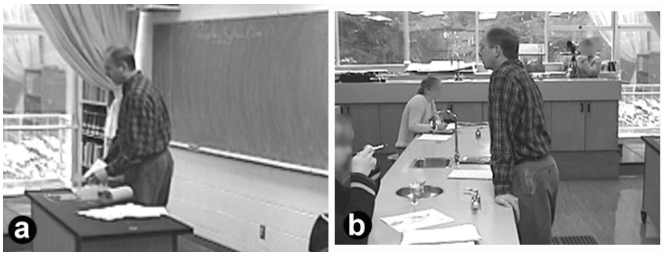

Figure 8.3. (a) Location 2, the area around the projector table. (b) Location 5, equivalent to the area in front of the students' first bench.

The teacher spent less than a minute in Locations 2, 3 and 5. Location 3 represents the area in the leftmost corner of the classroom, near the chalkboard and beside the C-shaped student bench (see Figure 8.1). Always arriving from location 1, the teacher usually leans against the side of the student bench in Location 3, either resting his right elbow on it (Figure 8.4a) or placing his right hand on it (Figure 8.4b). Location 2 represents the area around the table where usually the overhead projector rested on

(although not in this particular lesson). Even though the teacher spent only few seconds in Location 2, this location (Figure 8.3a) is associated with very specific pedagogical practices that help structure the lesson. Finally, during this lesson, the teacher only once entered the area equivalent to Location 5, which represents the area in front of the classroom door (Figure 8.1).

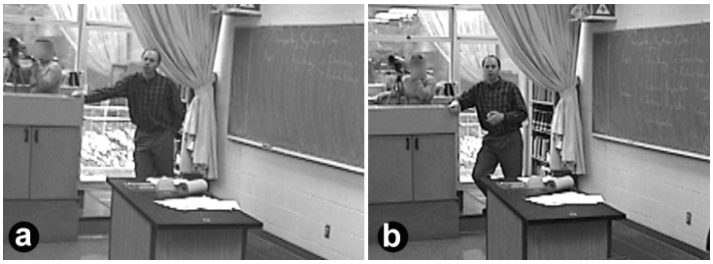

Figure 8.4. Teacher's body positioning at Location 3.

Each of these five locations in the classroom is the site of different pedagogical, interactive, and discursive practices (Table 8.1). During this lesson, I identified precisely 10 different pedagogical practices, most of which are related to the use of the chalkboard. This is not surprising given that most of the lesson unfolded in front of the chalkboard, in Location 1. Thus, *erasing the board*, writing/ drawing on the board, *writing on the board and reading out loud*, *completing diagram/ equation/ sentence on the board and lecturing*, and *lecturing and writing/ drawing on the board* constitute five different pedagogical practices, all related to the chalkboard. Except for *erasing the board*, all the other four practices include writing or drawing something on the board. The difference between these latter four practices resides in the way in which content matter is articulated (written or drawn). For instance, *writing/ drawing on the board* always occurs in silence and with the teacher's back turned to students, much like while he is erasing the board. The teacher engages in this practice at the beginning of the lesson and repeatedly during the lesson, but always as a preparation phase for a new segment of the

lesson. The drawings produced are large scale diagrams, already relatively complex by the time the teacher finishes drawing them and engages in some other pedagogical practice; but the diagrams become even more complex as more information (drawings or written words) is added to them in the unfolding lecture about the topic represented. The content of the teacher's writing on the board in this situation are mostly titles or subtitles that help organize the scientific content presented. At the interactional level, while the teacher writes or draws on the board in silence, students write down content previously written or drawn on the board. Only in rare instances do students ask questions to clarify particular words written on the board, to which the teacher promptly answers.

Writing/ drawing on the board differs from *writing on the board and reading out loud* primarily because of the presence of speech in the latter practice. When *writing on the board and reading out loud* the teacher writes on the board and simultaneously reads out loud what he is writing, keeping his back turned to students. The primary activity is the writing, and the reading is slow, perfectly synchronized with what the teacher is writing. The teacher engages in this pedagogical practice when writing long sentences on the board or when writing terms that are considered to be difficult to spell, to pronounce, or both. This practice is usually preceded and followed by *lecturing*, and students and teacher interact by means of questions and answers (Q&A) sessions initiated by the teacher (i.e., the teacher asks the questions, the students are invited to answer, individually or as a group).

Completing diagram/ equation/ sentence on board and lecturing and *lecturing and writing/drawing on the board* constitute two other pedagogical practices in which the teacher writes or draws on the chalkboard while speaking. When engaged in the first one,

the teacher writes or draws only a single word or object at a time, slowly adding information to the diagram, equation, or sentence, and always requesting the help of students through Q&A sessions. Even though the interaction between students and teacher is mostly verbal, these are the moments when students are more actively invited to participate in the lesson. Alternatively, when engaged in *lecturing and writing/drawing on the board*, the teacher lectures about the topic represented in the diagram, equation or sentence, and occasionally draws, labels or writes something else on the board, completing the diagram, equation or sentence as he lectures. Students only on occasion are invited to answer questions, but they actively participate by paying attention to the teacher, taking notes, and sporadically asking questions. These also constitute the moments when the teacher gestures most.

The pedagogical practice I designated as *lecturing* includes the teaching that occurs when there is no direct contact with the chalkboard (i.e., the moments when the teacher is lecturing without writing or drawing on the board). However, while lecturing, the teacher constantly uses gestures to refer to the content on the board, and most of the lecturing occurs in Location 1, in front of the chalkboard. This pedagogical practice is the most similar to a monologue, when only the teacher speaks and the students, as audience, listen and watch. Interaction between teacher and students, therefore, is limited to the more traditional roles of teacher as speaker and students as listeners in the classroom. However, students are *active* participants in the lesson as it is realized, for other behaviors might disrupt the lecture, leading to different interactional practices and lessons. In the entire lesson, *lecturing* occurs interspersed between other pedagogical practices, such as, for example, *lecturing and writing/drawing on the board* or

completing diagram/ equation/ sentence on board and lecturing, which are practices associated with a greater degree of students' verbal participation.

After long periods of *lecturing* or *lecturing and writing/drawing on the board*, or immediately after *writing/ drawing on the board*, when the amount of information available on the chalkboard is large and the students require some time to copy everything before the teacher proceeds with the lesson, the teacher waits for students to copy. This pedagogical practice happens in Location 3 for a few seconds only. In other moments when the students are copying information from the board, the teacher may erase another area of the board and start writing or drawing something on it.

Finally, the teacher supervises students' work, always from Location 4, standing closer to the students and intermittently posing or answering questions about the work the students are doing. This work frequently involves exercise sheets or textbook research, and the teacher gestures on these textual materials when talking to students about them. Moreover, teacher and students manipulate these textual materials together, as when, for example, they flip pages of the textbook back and forth searching for a particular illustration.

Despite the predominance of the chalkboard in this lesson, each location in which the teacher positions himself is associated with differing pedagogical and interactive practices that are both afforded and constrained by the material resources and physical arrangement of the location. Furthermore, movement between locations is triggered by movements in pedagogical and interactive practices, while simultaneously bringing about movement between different practices. I now turn to the analysis of the interrelations of

physical movement, and pedagogical, interactive, and discursive practices, as these constitute cause and consequence of the teacher's movements.

Action and Interaction: Movement and Physical Location as Semiotic Resources for Organizing and Structuring the Lesson

From a social semiotic perspective (e.g., Hodge & Kress, 1988), the teacher's movements around the room constitute a meaning-making resource to which, presumably, students do pay attention to make sense of and participate in the lecture in socially recognizable ways. This movement, however, happens as part of a larger activity (the lecture), and is associated with various other meaning-making resources, such as, for example, the teacher's speech, gestures, and the diagrams and words or sentences in the chalkboard. The meaning of the teacher's movements, therefore, is attained only from a holistic, multimodal approach that considers within the same meaning unit all the resources available and employed by the teacher simultaneously with his movement from one location to the next, within the context of the lesson.

At time zero in the videotape, the teacher's initial position is as shown in Figure 8.5. The teacher and students are reading from a sheet that outlines upcoming events and news at the school, and which is given to all teachers and students at the start of the very first class of the day. One of the topics in the sheet relates to a forthcoming province-wide final examination, which all students must take. Here the teacher and students talk about this test.

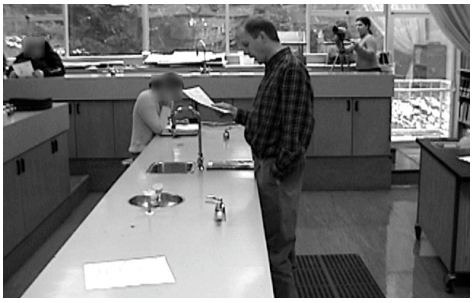

Figure 8.5. Teacher's position in Location 4 at the beginning of the lesson.

The teacher is in Location 4, in front of the first student bench, a place that brings him closer to students. This spatial configuration not only decreases the physical distance between teacher and students (and therefore allows them to hear each other more easily), but it also represents a different social configuration as well, with repercussions on the way in which interaction is structured (Roth et al., 1999). The apparent uneventful move from the traditional positioning of the teacher near the chalkboard to this location, closer to students and away from the chalkboard, moves the centre of attention from the teacher *solely* to the *teacher and students* as a group. Consequently, interactions with students at this location are informal and unstructured, that is, students may talk all at once, and parallel conversations may occur while a student is talking to the teacher, particularly at this early stage of the lesson, *before* the actual lesson start (Lemke, 1990); in fact, not all students have arrived in the classroom yet at this point, and part of the purpose of reading the day's school information sheet is to allow students to arrive and settle down before the teacher starts the lesson proper.

Thus, the interactive practices that take place in this location constitute an affordance (Gibson, 1979) of the spatial configuration of teacher and students. At the same time, this spatial configuration also constrains the possible pedagogical practices in this location; for instance, the teacher's distance from the chalkboard renders it

impossible to engage in various pedagogical practices that make direct use of the chalkboard, which greatly limits the number and types of gestures performed in this location and the resources available for teaching scientific concepts. While in front of the chalkboard, the teacher can write, draw, or gesture on or towards it, and use what he wrote or drawn on the chalkboard in various different ways; however, free-standing in front of the bench in Location 4, the teacher is limited to speaking and gesturing. These limitations imposed by the spatial configuration in Location 4 account for the relative scarcity of gestures and pedagogical practices performed here. However, just by standing in this location, the teacher communicates that a new social configuration is present, and that alternative interactive practices and students' ways of participating in the lesson are called for.

The first time the teacher moves from one location to another occurs within the fourth minute of the lesson. The teacher starts to move away from Location 4 while uttering the sentence *provincial exams are set by the government we just sort of uh put the rest of the test into that framework* in response to a student's question. Synchronously with the utterance of *put the rest of the test into that framework* the teacher withdraws from the bench where he is leaning on (Figure 8.6a–b) and moves his left leg backward, turning his head and torso to the left (Figure 8.6c) in preparation for walking to the door (Location 5).

The teacher's movement from Locations 4 to 5 is triggered by the need to open the door for a student who arrives late. The teacher is careful to finish the sentence he is uttering in response to students' questions before completely turning his back to students and walking towards the door. Thus, both finishing the verbal utterance and turning his

back to students constitute aspects of the moving from one location to another that contribute to the signaling of the movement between interactive and pedagogical practices that accompany the physical movement between locations.

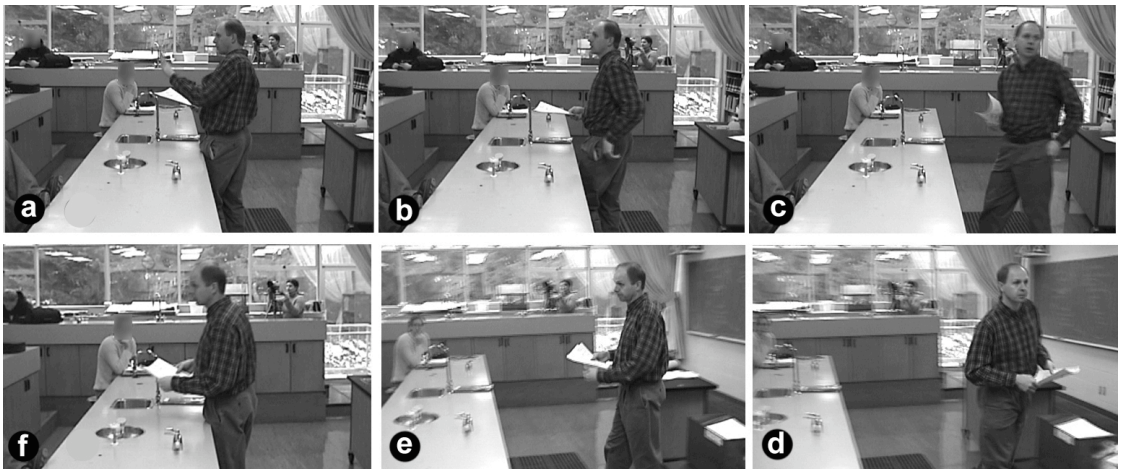

Figure 8.6. Clockwise from top left: Teacher's movement from Location 4 (a–d) to Location 5 and back to Location 4 (e–f).

Figures 8.6e–f presents the teacher coming back to Location 4 from Location 5. Although the teacher returns to Location 4, the previous conversation is not restored. Clearly, the movement from one location to another, irrespective of the reason for this movement, is associated with a movement from one pedagogical practice to another and also from one interactive practice to another. The teacher only remains in Location 4 for a few more seconds, while he hands text material to the student that arrived late, and then moves on to Location 1, where he starts erasing the board. Meanwhile, students chat with each other and occupy themselves with papers, pens, and other school materials.

Erasing the board at the beginning of the lesson is an already conventionalized preparation phase for the actual lesson start. The students respond to this action in appropriate (expected) ways, which are also conventionalized (that is, students may take out their notebooks, write the date on the top of the page, seat straighter in preparation for

taking notes, etc.). However, students do not stop chatting until the teacher starts talking again after erasing the chalkboard and writing the title of the day's lesson on it. As the teacher starts formally teaching about respiratory system, the students gradually quiet down. There is still a considerable amount of noise in the classroom from students' setting up their workspaces (opening and flipping pages on their notebooks, taking pens and pencils out of their backpacks, etc.). At this early moment in the lesson, the teacher talks slowly, pausing constantly between uttering consecutive sentences. He writes a couple sentences in the board, in silence, and then moves to Location 3 (Figure 8.7), where he briefly comments on what he has just written on the board.

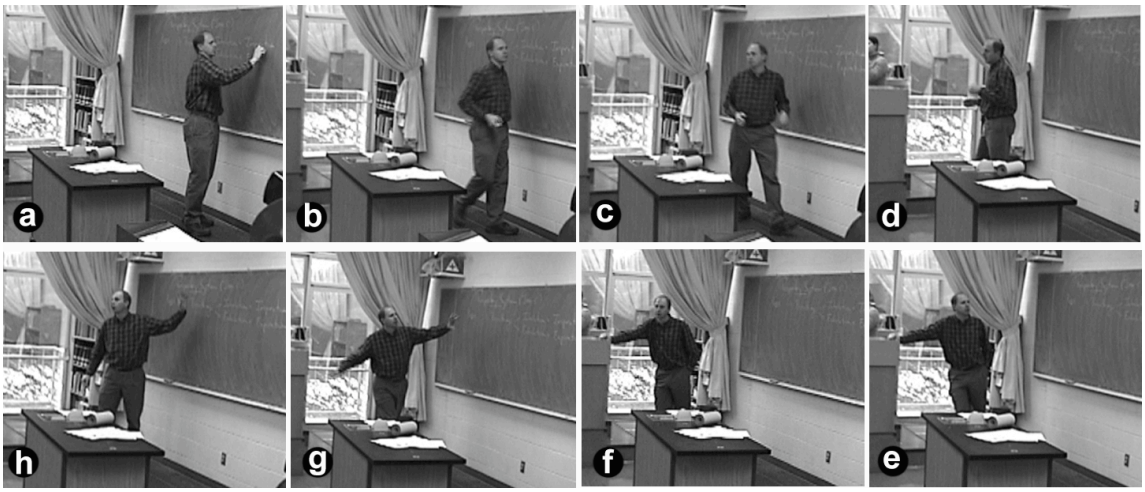

Figure 8.7. Clockwise from top left: Teacher's move from Location 1 to Location 3 (a–d), where he looks back and forth between the chalkboard and the students repeated times (e–f), and his movement back to Location 1 (f–h).

While in Location 3, the teacher orients his gaze back and forth between the chalkboard (Figure 8.7e) and the students (Figure 8.7f) repeated times. These head and gaze movements function to connect what the teacher has written on the board with his audience (i.e., the students), to whom his speech is directed. At the same time, the teacher is able to follow students' movements and pace the lesson accordingly, waiting for

students to get ready to fully and exclusively focus their attention on him before he starts lecturing. Location 3 affords the teacher an ideal positioning for both reading content from the board and seeing all the students in the room without blocking the students' view of the chalkboard. Thus, the teacher usually stands in this location while waiting for students to finish copying content from the chalkboard.

The teacher moves back to Location 1 with a sudden gesture towards the board (Figures 8.7g–h), synchronous with the utterance *the mechanism of breathing is fairly complex*, after 3.6 seconds of silence. From then on, the teacher continues lecturing in Location 1. Moving from Location 3 to Location 1 is associated with a gesture towards the chalkboard, which was performed simultaneously with a verbal reference to what was written on the board. Thus, both the teacher's speech and gesture and his movement from one location to another referred to the information available in the chalkboard and coincided with (and indeed caused) a movement in the sequential structure of the lesson, which itself constituted an aspect of the emerging structure. That is, after this movement from Locations 3 to 1, the lesson *really* started, with the teacher speaking faster and gesturing and interacting with the board more actively, and with students quietly paying attention to the teacher and taking notes. Therefore, the teacher's action of moving from one location to another, which, in this case, also entailed the performance of a gesture synchronous with his speech, organized the lesson and constituted a meaning-making resource that students can rely on to understand and participate appropriately in the lesson. The closer the teacher is to the chalkboard, the more he interacts with it in its function as the focal artifact (Roth et al., 1999); and the more the teacher *teaches* in Location 1, the less students talk, unless invited by the teacher. In the same way that the

teacher organizes scientific content in the board by writing titles, subtitles, and numbering sentences, he also structures the lesson through his action of physically moving in the space and speaking and gesturing. Each segment of the lesson becomes distinctive for the participants of the lesson by means of an ensemble of diverse semiotic resources, including speech, gestures, physical movement, body positioning and conventionalized practices that communicate what is happening at each given moment in the lesson.

The teacher's first attempt at starting the lesson in Location 1 is delayed by the students' actions (i.e., their focus of attention was divided between the teacher and setting up their workspaces). The teacher then moves away from the chalkboard and surveys students' actions, waiting for them to settle down, then he moves back to Location 1 and starts lecturing. The movement in location is associated with a movement in pedagogical and discursive practices, and the teacher's strategic positioning at Location 3 allows him to adapt his actions (thereby structuring the lesson) to the actions of the students. In this sense, students' actions also contribute to the organization of the lesson. In fact, each moment of social interaction could be otherwise so that the entire activity of schooling is understood as being enabled by the participation and interactions of students, teacher, and other stakeholders. Even lecturing as a teacher's monologue requires the students' participation to make this part of the lesson a lecture.

Subsequently, the teacher moves again to Location 3, this time simultaneously with the utterance of an *addendum* to the scientific concepts he is articulating in his speech and on the board. In Location 1, the teacher says *and the fourth part of respiration is cellular respiration*." Then he writes *cellular respiration* on the board in silence, and

moves to Location 3. In this location, the teacher utters *which is a part of grade eleven biology but strangely enough is not part of grade twelve course so*, and then he moves back to Location 1 where he continues the previous sentence with *we assume you understand a little bit about cellular respiration*. While uttering, *assume* the teacher gestures towards the chalkboard (Figure 8.8), pointing at the area where he wrote *cellular respiration*.

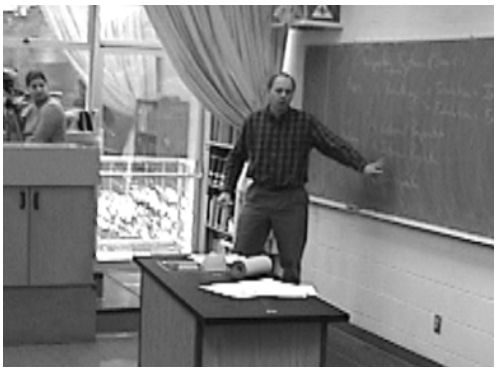

Figure 8.8. Teacher's gesture toward the chalkboard immediately after moving from Locations 3 to 1.

This movement from Location 1 to Location 3 and back, therefore, occurs simultaneously with a movement in the teacher's discursive practice, as he shifts from talking about the subsections of the larger unit on respiratory system to point out a fact related to the biology curricula. Although the topic of the teacher's speech still is centered on *cellular respiration*, this topic is approached from two different perspectives in Locations 1 and 3. Thus, the teacher's movement in this instance from one location to another accompanied a movement in the way in which he dealt with the topic of his speech, that is, a movement in the teacher's discourse. As semiotic resources, these movements can be interpreted to help understand what the teacher is saying and doing during the lesson. For instance, as a student in this lesson, one would take note of the teacher's spoken words in Location 1 and what he writes on the board, but one would

know not to copy down what the teacher says in Location 3. Part of what allows someone to *know* what is relevant and what is not within the context of a lesson is exactly this movement from one location to another, from one form of discourse to another, from one pedagogical or interactive practice to another. By physically moving away from the chalkboard and into Location 3, which is at the periphery of the central teaching stage delimited by the chalkboard, the teacher also removes himself from the shared focal area (i.e., the chalkboard and the scientific content written on it), allowing his discourse to be interpreted as separated from the previous and proceeding sentences uttered.

Later during this lesson, the teacher moves from Location 1 to 2 and then to 4. In Location 1, the teacher lectures positioning himself towards the students, as shown in Figure 8.9a. Then he stops talking, looks at the board, grabs the eraser, puts it down still looking at the board (Figures 8.9b–d), and then moves to Location 2 (Figures 8.9e–h). In this situation, the teacher's initial movement occurred after a pause in the lecture, which indicates a moment of hesitation that is evident in the teacher's actions (he is silent, looks at the board, grabs and drops the eraser and then turns and looks at the table in front of him, where his notes are located [Figures 8.9a–d]). This pause already communicates an interruption in the flow of the lesson; attuned to the teacher's actions, students can be understood as waiting for guidance, for directions about how the lesson is to proceed. In traditional lectures, the teacher's actions structure the lesson, and even without explicit instructions, students are able to understand what is happening and what is expected of them, that is, how they should act based on the teacher's actions. Thus, when the teacher stops talking and looks at the board, apparently unsure if he should erase something or not, students watch in expectation, presumably trying to make sense of the teacher's

hesitation (in fact, *seeing* it as hesitation is already a possible meaning that is attributed to the teacher's actions).

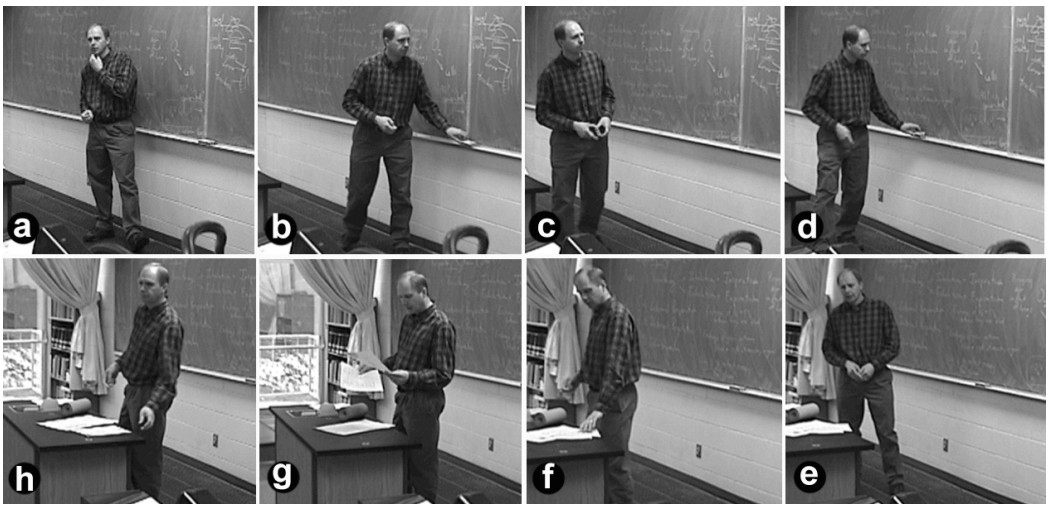

Figure 8.9. Clockwise from top left: The teacher moves from Location 1 (a–d) to Location 2 (e–h).

After gazing at the table in front of him (Figure 8.9e), the teacher utters *okay so flip it over*, simultaneously with his movement towards Location 2. The moment of hesitation has passed; the teacher now clarifies the nature of what is to happen next. The use of *okay* constitutes a verbal mark for summing up one classroom segment and starting another, as does the teacher's movement between locations and his shift of focus of attention (from the chalkboard to the sheets of paper on the table). The instruction *flip it over* is uttered before the teacher grabs the sheet from the table in front of him; however, the teacher's gaze already is on the table and as he speaks he moves towards the table, and then grabs the sheet, flipping it over and saying *at the back of the sheet I'd like you to label, from memory*. The teacher then continues this utterance with *see if you can do that*, and moves away from Location 2 in the direction of Location 4 (Figure 8.10).

Figure 8.10. From left to right, the teacher's movement from Locations 2 to 4.

At Location 4, the teacher supervises students' work, gazing at one of the students' worksheet and eventually gesturing on it while talking to the student. By standing in Location 4 while students work on their worksheet, the teacher makes himself available to students; he is not busy doing anything else, he is closer to students, and the lesson now is centered on the work students are performing. The teacher's positioning and apparent inaction in this location communicate the teacher's availability. And students do take advantage of this configuration, as they begin questioning the teacher. In this situation, the teacher position at Location 4 not only structures a new segment in the lesson, but it also reinforces the teacher's verbal instructions to shift to another task, as he positions himself closer to student, from where he can easily supervise students' work. This supervision is, on the one hand, a reinforcement of the teacher's request (he makes sure students are indeed working on their sheets, for example) and, on the other hand, it is an offer of help, as the teacher makes himself available to students. Thus, once again, the teacher's movement from one location to another within the classroom provided resources for students to make meanings and understand what is happening in the lesson and what their actions should be. In this sense, the teacher's movement structures the lesson and the students' action, thereby organizing interaction in the classroom.

Conclusion

In this study, I analyze the teacher's physical movements as actions that are associated with pedagogical, interactive, and discursive practices in lessons and that structure lessons temporal-sequentially and interactively. The teacher's physical movement from one location to another is equivalent to a discursive movement and also to an abstract movement from one pedagogical or interactive practice to another. Thus, the same interrelation existent between the physical and the pedagogical, discursive, and interactive spaces during the entire lesson exists in the movements the teacher performs: Each movement between locations occurs in the physical, pedagogical, discursive, and interactive spaces simultaneously. In these movements, a variety of semiotic resources are integrated to communicate sense associated with the organization of the lesson as an interactive, socially constructed and structured event. At the same time, these movements also constitute *teaching* strategies, as they provide new meaning-making resources for understanding the concepts the teacher is teaching.

Through my analysis of the teacher's movements during this lesson, it is possible to understand the nature of science lectures beyond the analysis of the content of the lesson and the identification of teaching strategies employed by the teacher. This understanding also requires the microanalysis of the multiple resources used in lecturing and its association and integration, as well as an analysis of the occurrence of these multimodalities and how they are socially, culturally, and historically associated with teaching as a social activity, which is evident from a macro-perspective. Thus, different levels of analysis are required to unveil the intricacies of classroom teaching, even when we consider traditional lectures, where most interaction is verbal. Moreover, within each

level of analysis different aspects of teaching become the focus of investigation, even though all modalities are part of the same meaning unit and cannot and should not be analyzed in isolation from each other.

During lectures, interaction participants (i.e., teacher and students) negotiate their actions and re-actions or inter-actions by orienting themselves to the shared object of the activity. Alignment between participants promotes the *smooth* realization of the activity, whereas misalignments cause disruptions that need to be immediately dealt with if the activity is to continue. Thus, when the teacher tries to start the lesson and is confronted with the students' lack of attentiveness, as they are still organizing their workspaces, the teacher re-orients his actions (physically, discursively, interactively) to allow students to both perceive that the lesson is starting and prepare themselves for it. This constant negotiation of joint action within the socially structured event of the lesson is what constitutes lectures as activities and what permits teaching and learning to occur. Thus, my study shows that within the multitude of resources employed in various settings of social interaction, including classroom teaching, physical movement takes on a special role when considered as action that helps structure the activity and is associated with other practices that unfold during the lesson.

Chapter IX:

Conclusion

In this dissertation, I present five studies that investigate teaching as a multimodal event, where a variety of semiotic resources are employed to communicate scientific concepts to students, that is, to *teach* science. Together, these five studies show the integral co-dependence of the different semiotic resources and modalities of communication, which we cannot understand independently of the others. I theorized this mutual dependency here as integrated within a dialectical unit that cannot be reduced to any one of these resources. The conceptualization of a dialectical communicative meaning unit, within which all these resources are integrated, is essential for future studies on teaching and learning from a communicative and interactional perspective, insofar as these resources constitute a one-sided expression of the whole that is the communication. An analysis that isolates any one of these resources would be methodologically incongruent within a sociocultural and communicative perspective, such as the one I take in this dissertation. For example, rendering gestures by verbally describing them not only changes modality but also belies their essentially visual aspect.

The analysis of meaning units is congruent with modern takes on multimodality that focus on the *complete action* (Sidnell, 2006) instead of the role of individual, isolated modalities within social interaction. A communicative action thus includes everything that is produced and made publicly available for interaction participants to interpret and make sense of what is communicated. Therefore, understanding the concrete details of communication during lectures is important because this is the very material students use to evolve their own understanding, insofar as all that students have to make sense are these concrete details that a teacher bodily and verbally articulates in the lectures.

My results also have implications for research on conceptions, particularly in science education. The traditional approach to research on conceptions in science education—exclusively centered on the spoken and written word (e.g., Atwood & Atwood, 1996; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002; Limon, 2001; Palmer, 2001; Vosniadou & Brewer, 1992)—is incongruent with a multimodal approach to research on teaching and learning. Researchers can no longer rely on word-centered approaches to research on conceptions and conceptual change once we take into consideration the results of the studies that comprise this dissertation, which show that resources other than words play an important role in teaching science.

I have shown here that during teaching sessions there are many other resources used beyond words, even in lecture style format. Within a multimodal perspective, conceptions are not intra-psychological knowledge that is *expressed* into words; the multimodal discourse the teacher produces when teaching is, as I have shown, a *performance of concepts*, an aspect of the teacher's taking up a position in the world of significations (Merleau-Ponty, 1962). During lectures, the communication of scientific concepts occur along trajectories driven by the dialectical relation among the various semiotic resources a lecturer makes available that together constitute a unit—the idea, the conception. Dialectical here means that entities, which appear to be in opposition, really are one-sided expressions of an integrative, higher-order unit: Speech, gesture, and other nonverbal resources are but one-sided expressions of a higher order communicative meaning unit. It is only within this unit that we can understand and investigate science teaching and learning.

My trans-disciplinary research also contributed important theoretical and methodical aspects to the investigations on the development and communication of scientific concepts, both within the same lesson and across lessons. For instance, the use of the concepts of *catchment* and *growth point* (McNeill, 2002) as theoretical and analytical frameworks to analyze the integration of verbal and nonverbal resources during teaching over time seems promising. Thus, I have shown that as new semiotic resources are integrated into the unfolding communicative meaning unit and repeated, the latter is stabilized, develops, or changes. When the teacher lectures on a scientific concept throughout several lessons, he does not in fact precisely (identically) repeat the same thing over and over again. Rather, the scientific concept, concretely available in the teacher's bodily performance and talk (as seen in chapters V and VI), develops within the unit constituted by the various resources used. New information is introduced into this unit *integrated with* previous information, which is iterated in both gestures and words. That is, at the same time that we are able to identify a recurrent idea or theme, carried forward from one moment to the next in the lecture by means of iterations in some features of a gesture, we are also able to notice the novelty in this recurrence, available through a new combination of (same) gesture and (new) words, or even within the recurrence of the gesture per se (for example, an exaggerated gestural movement that retains properties of a previously enacted gesture but that, in its exaggerated form, brings with it the signification of the strength of the process to which it refers).

Moreover, this dialectic between figure and ground, novelty and recurrence also provides answers to questions related to scientific literacy and how students are able to translate between the vernacular discourse with which they come to school and the

discipline-specific discourses that they encounter in science lectures. As I have shown in chapter VI, the iterable nature of signs permits, supports, and encourages the repetition, variation, and translation of ideas, themes, and languages and therefore permits, supports, and encourages conceptual development at the boundary between the mundane and discipline-specific cultures that students (have to) traverse in learning.

Teaching, as other forms of communicative interaction among people, include the interplay of verbal and nonverbal, existing and newly produced resources, all of which stand in a dialectical relationship. The variety of different resources, including gestures, body positions, verbal, prosodic, and material resources that interact to create and communicate meaning also are useful to help disambiguate between different narrative spaces and discursive practices the teacher may use while lecturing—also helping in the organization and structuring of science lessons. Although this dynamic and complex process of interpreting various resources to make meaning of information and situations occurs seamlessly and unproblematically in everyday communication, it is of crucial importance to better comprehend how people communicate, particularly in teaching and learning contexts, and how these various resources are integrated with each other. It is this integration of multiple resources within the same meaning unit (some coming to the foreground while others recede into the background and become context) that allows us to understand complex events such as, for example, quotations and demonstrations.

Similarly, physical positioning in the room and body orientations provide clues that help us differentiate between different pedagogical and interactive moments in the lessons, and, therefore, could presumably become a means through which interaction

between teacher and students is purposefully structured, particularly in situations where interaction and communication is problematic or challenging.

Furthermore, a multimodal approach to teaching and learning has implications for science teaching education inasmuch as, by focusing the attention on nonverbal aspects of communication as much as on the written and spoken words produced in class, may provide would-be and novice teachers with new resources that will enhance their teaching. This is particularly important, for even seasoned teachers' and professors' gestures may communicate scientifically imprecise information (Roth & Welzel, 2001). A further implication is that once teachers are aware of the multimodality of teaching and learning processes, they will be able to adapt both curriculum and assessment practices to the way in which they teach; that is, teachers themselves could implement activities that would involve students in exploring various verbal and nonverbal modes for communicating their scientific understandings.

Curriculum planning could also be enhanced by focusing on the multimodality of science lectures through the implementation of classroom activities and teaching strategies that encourage students to make use of the nonverbal resources the teacher makes available to them, and also to provide opportunities for students to explore some of these nonverbal resources when they are communicating with teachers and peers. From a multimodal and situated approach to concepts and knowing, students' assessment ought to include a variety of activities other than written and oral examinations. Students may be able to better articulate their conceptions and understandings when a multitude of resources other than speech or writing are available. For example, there is evidence that students' articulation of concepts changes from situated multimodal to verbal modes

when they talk and from concrete to abstract pictorial ways if they are allowed to express themselves through drawings on written tests (Roth, 2003b). When both teaching and learning processes are viewed as multimodal, complex, and dynamic events, methods of evaluating learning ought to provide students with possibilities of articulating their understanding in ways that go beyond the use of words exclusively. I therefore suggest that future research should focus on how the students perceive and make use of these various multimodal resources, either in naturally occurring settings or in regards to explicitly designed curricular materials and teaching strategies.

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