Chapter 9

Thinking and Speaking A Dynamic Approach

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

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

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

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

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

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

The changes, even those in the mature mind, as thought realizes and develops itself in speaking are not merely momentary but, as Vygotsky states, "may be regarded as development in the functional sense." This would imply then that when we conduct interviews about conceptions the thought has to be considered as unfolding and changing in the process of the interview itself rather than as the result of a constant structure that is more or less directly made available, ex-pressed or, better, ex-pelled (from Lat. *ex*, out, + *pellēre*, to drive, thrust) by means of words. This is so even when we consider "mature minds," such as those of veteran professors giving lectures to undergraduate students on some introductory topic. Unless the person is reading from a paper or reproducing a memorized text, there are developmental aspects to thought, which therefore has to be considered as an emergent property of the situation rather than as the result of a fixed underlying structure. Vygotsky complained that, "no matter how they were interpreted, the relations between thought and word were always considered constant, established forever" (p. 254). He continues by suggesting that his own "investigation has shown that they are, on the contrary, delicate, *changeable relations between processes*, which arise during the development of verbal thought" (p. 254, emphasis added). And he concludes that all existing theories at his day had in common "their

antihistorical bias," studying thought and (living) speech "without any reference to their developmental history" (p. 255). This is also the main complaint of Bakhtine. Accordingly, language has to continuously evolve within situation to be able to evolve on ontogenetic and cultural-historical scales.

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

A Brief Episode from a Physics Lecture

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

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

The Set Up

The professor begins by announcing the topic, adiabatic demagnetization, and he also tells students that he has talked about it somewhat ("a little") before (turn 01). He continues by articulating that he already suggested "one possible way of looking"

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

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

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

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

```
Fragment 2
4   S::INCE:: WE=ARE:: [(1.95) doing an (0.34) [^iso:^thermal
    (0.90)
                       [[((gazes toward the end of abscissa
```

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

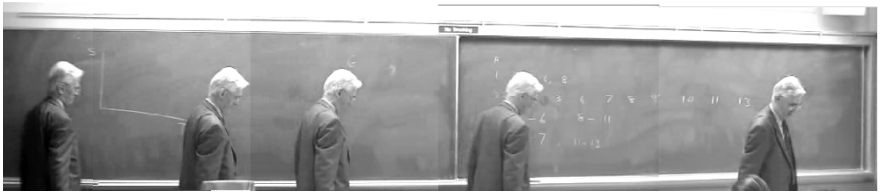


Figure 9.1. While producing utterances in a hesitating manner, the professor walks across the entirety of the front part of the lecture room. (Coincidence with talk is marked in transcript.)

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

collect a series of processes of the same kind into the same, more abstract category. It is as if the specific term or concept was unavailable and therefore denoted in an undeveloped, generalized form to be realized in a concrete way afterward. That there is time to come can be seen from the fact that the diagram is itself in embryonic state, existing at the moment only in its most generic state, the sketch of coordinate axes.

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

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

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

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

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

and only in its beginning stages, coming to be realized in the process of talking and writing/drawing.

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

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

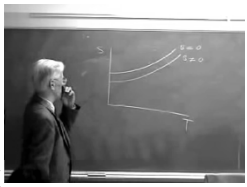
```
Fragment 3
11  [(1.50)
    [((walks back toward graph
12  an=i said the schematic is supposedly;
13  (2.18)
14  entropy varied with temp[erature;
                            [ 
15  (1.74)
16  [something like that,[
                                
    [((draws curve))        [
17  (2.11)
18  when there is [no field,
                  [((writes "B = 0"))
19  (2.95)
20  and uh:::; (0.39) [<<p>as the curve varied something like
    that;>](.)
                      [((draws a second, lower curve    ]
21  [when; (0.97) there is a field,
```

[

[((writes “B≠0”))

22 (2.48)

[((steps back to look at diagram))



[

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

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

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

interesting tension in that he orients to what is prospectively the frame of what will be the case after he completes the action, even though what the action precisely will be cannot be known until after it has been produced.

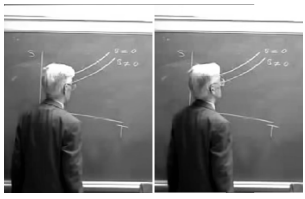
There is therefore little evidence to support that he simply was reading off a conception, opinion, or view on something, for example, from or based on a framework, which he was ex-pressing and externalizing using speech, gesture, and drawing. Rather, there are lots of indicators for the thought as forming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

A First Adiabatic Lowering of the Temperature

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

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

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



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27  when you; (0.30) PUT the material in a magnetic fie:ld at a
28  constant temperature (0.47) [its just] like 'that
                                [((draws downward line))
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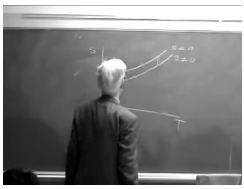
29 [(1.79)



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

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

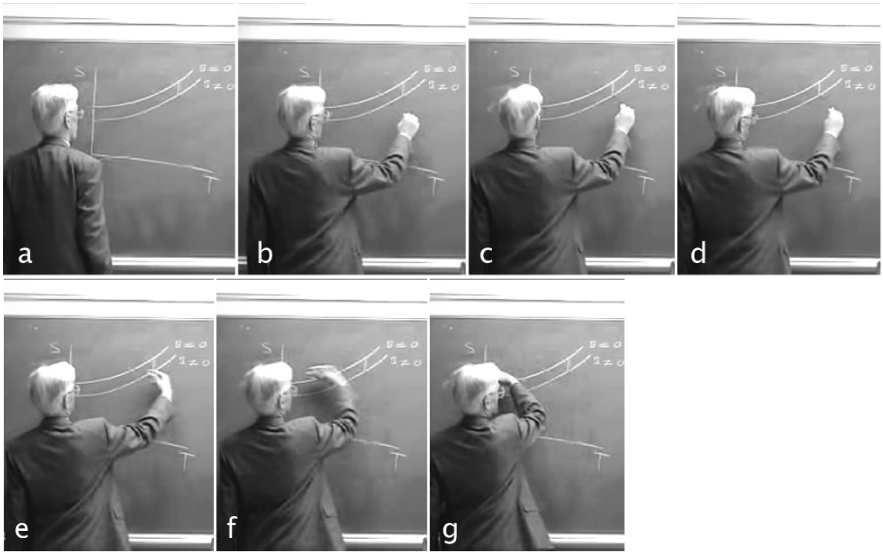


Figure 9.2. Video offprints corresponding to transcript lines 29–31.

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

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

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

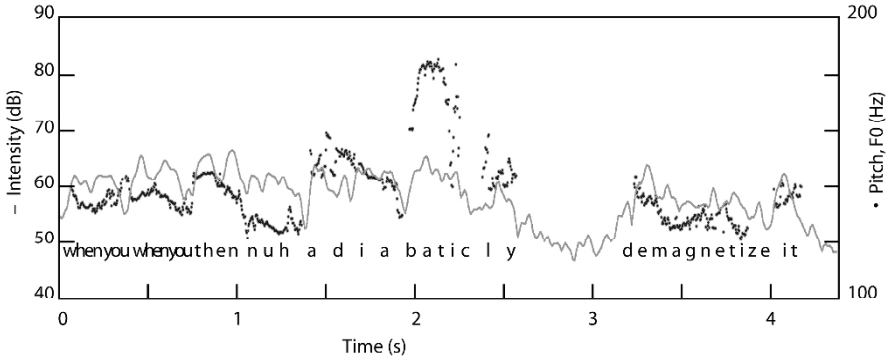


Figure 9.3. The pitch and intensity contours for a stretch of speech point to the psychological subject, which here is an adjective rather than the verb ("demagnetize") or the grammatical subject ("you").

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

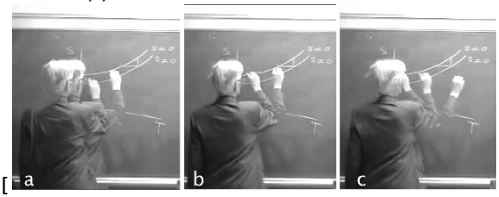
The filler (interjection) "uh" is at lower mean pitch (126.6 Hz) and intensity (60.47 dB) than the preceding talk representing a restart (137.1 Hz, 62.37 dB).

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

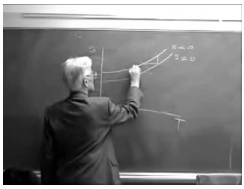
Going All the Way to There (Zero)

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

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




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



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

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

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

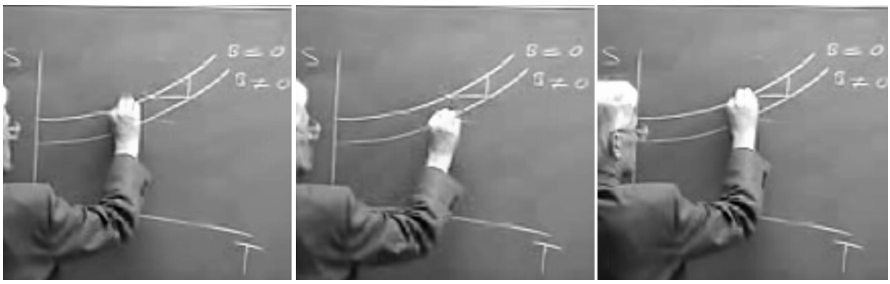


Figure 9.4. The hand and chalk move to different places, as if uncertain about where to put the next line.

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

Assessing the Thought as (Possibly) Wrong

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

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

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

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

Developments at Longer Time Scales

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

Individual Development

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

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

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

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

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

A Brief History of the Entropy Concept

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

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

Lectures on the topic of entropy likely changed already during the nineteenth century with the work of the Austrian physicist Ludwig Boltzmann. Whereas earlier approaches to the question of entropy were based on the phenomenological meanings, that is, as encountered in the laboratory—the heat engine—and observable quantities, Boltzmann expressed entropy in terms of the statistical properties of a system: a system is going to move to that state which is most probable and the entropy S can be expressed as the natural logarithm of the number of natural states Ω available to a system and some constant k, which has come to be called the Boltzmann constant ($S = k \ln \Omega$). Entropy now has come to be understood in a radically different way, which further changed when information theorists derived the same equation for the informational content of a message. At the beginning of the twentieth century (around 1917–1919), chemists were interested in the concept and determined the entropy for various pure substances as a function of temperature. The first entropy–temperature diagrams for substances other than H_2O (ice, water, steam), including the ones our professor used, emerged in the literature in the 1920s,

when Willard Gibbs pointed out that such diagrams graphically illustrate not only the work involved in a reversible cycle but also the heat. At the time, the discourse about entropy was being developed and certainly not yet suitable to be taught in undergraduate courses. But though thought to be suitable and insightful, my survey of about ten university texts shows that these graphs are not being taken up in undergraduate teaching, such as the temperature entropy diagram used in the lectures analyzed here, which appear only in very few textbooks in chapters on the second law of thermodynamics and entropy.

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

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

Emotion

Already in the 1930s, Vygotsky (1986) complained about the "weakness of traditional psychology," which derives from its separating intellect and affect. This separation "makes the thought process appear as an autonomous flow of 'thoughts thinking

themselves,' segregated from the fullness of life, from the personal needs and interests, the inclinations and impulses, of the thinker" (p. 10). This absence of emotion as a constitutive moment of thought continues to this day. Bakhtine (1977) had the same complaint and points out that the affective-volitional aspect of thought reveals itself in speech itself, in the form of intonational (i.e., prosodic) variations. Emotional qualities are available also in the lecture episode under study.

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

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

When we compare the voice toward the beginning of the lecture segment with the voice toward the end of the lecture segment, we notice marked decreases in pitch (F0) (between 160 and 190Hz to below 130 Hz), pitch variability (from 121–210 Hz to 88–153 Hz), and pitch contour (constant to downward). The speech intensity decreases considerably (around 65 dB to below 59 dB). The speech noise to harmonics increases. The speech rate has decreased from a normal 5.9 syllables per second to around 4.7 syllables per second and even slower rates. The voice repeatedly fades away into very low intensity. All of these changes are objective indicators of sadness/dejection (Scherer 1989), which we can actually hear in his voice at the mesolevel (ethnographic) analysis of the videotapes. A low level of pleasantness, high relevance, discrepant expectations, obstruction, and low urgency to resolution characterizes this emotion. Control levels are low to non-existent, and the level for adjustment is medium. We see the professor leaf through his

notes as if looking for an answer to the present situation, but when there is none, moving on to the next topic.

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

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

Semantic, Pragmatic, and Syntactic Issues

Word Meaning: A Developmental Process

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

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

Here, the essence of word meaning comes to be found in "a *generalized* reflection of reality." The generalized reflection arises from the fact that words do not refer to single objects but to groups and classes of objects. Even in a simple utterance "This is a tree," we see the generalization at work, as whatever singular, definite thing (picture, photo, actual) the person indexes ("this") with or without

pointing is predicated to be something of a kind, as indicated in the indefinite article "a." Seeing is (the result of) a sensation; seeing something (specific) *as* something (class) constitutes a qualitative difference, is in fact a dialectical leap: "not only between total absence of consciousness (in inanimate matter) and sensation but also between sensation and thought" (p. 6). Because the essence of word meaning is the generalized reflection of reality, a form of consciousness (knowing together), meaning comes to be an "act of thought," a process rather than an attribute of a word. Thinking is singular, verbal thinking is not, because in making use of language, verbal thinking is already oriented toward the generalized other, from whom the language has come to the speaker, and to whom it returns.

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

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

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

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

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

On Syntactic, Pragmatic, and Psychological Subjects

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

```
1   i gave you a little bit about adiabatic demagnetization
    (0.22) but
```

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

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

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

that the professor (pragmatic subject) takes with respect to the diagram that is itself developing.

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

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

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

"A true and full understanding of another's thought is possible only when we understand its affective-volitional basis" (p. 252). But we have no access to the affective-volitional basis of the thought other than through what the Other makes

available to us with the resources at hand. “To understand another’s speech, it is not sufficient to understand his words—we must understand his thought” (p. 253). But we cannot understand another’s thought unless we take an external perspective on our own thought. Knowing that a particular expression is that of a specific emotion requires us to take an external perspective on ourselves. And this perspective on ourselves we can only take when our Selves have been constituted by the Other. This interlacing of Self and Other makes a pure representation impossible, each auto-representation of my body to myself is interconnected with a re-presentation, which in turn requires it to be a presentation of the Self. To understand thought, we need to understand the motive of the activity. For Vygotsky, therefore, verbal thought takes its course “from the motive that engenders a thought to the shaping of the thought, first in inner speech, then in meanings of words, and finally in words” (p. 253). Each of these levels constitutes a plan that cannot be derived directly from the other, each standing in a constitutive relation to and with the next plane, each being on its own trajectory.

Units of Analysis

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

Towards the Analysis of Units

Vygotsky proposes the use *unit analysis* in place of an analysis in terms of elements. Unit analysis takes into account the social reality toward which thinking is oriented and for which language is produced in the way it is and can be anticipated to be intelligible, reasonable, and fruitful. “The primary function of speech is communication, social intercourse” (p. 6), which requires us to study the dual function of speech: being for the speaker and the audience, realizing intellectual (development of thought) and interactional purposes (sharing of thought). Unit analysis is of interest, because “units are capable of retaining and expressing the

essence of that whole being analyzed" (p. 211), which, in the case of the lecture excerpt presented here, is the historical situation of culture generally, physics more specifically, and this university and its undergraduate student population, and the level of the course being delivered concretely and singularly.

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

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

Extending Vygotsky's Unit

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

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

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

I maintain with Vygotsky—and with Bakhtine/Volochinov and other cultural-historical psychologists and philosophers—that thought specifically and consciousness generally each constitutes a (non-mirror-like) reflection of the social and

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

Reflexive Comments

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

This chapter is a first attempt to better understand *Thought and Language*. But it constitutes only a first step in the development of thought concerning language, language development, speaking, and speech activity. The chapter therefore constitutes a moment in the development of thought concerning the topic of thought, language, speech, and their relation to collectively motivated societal activity. Some aspects of the work of Vygotsky may remain the same, whereas others may

change. But even if everything were to change, the ultimate product of my thinking about language, thought, speaking, and speech activity cannot be dissociated from its cultural-historical roots. Disconnecting it would constitute an antihistorical bias.

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

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Appendix: Transcription Conventions

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

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