

Lev Vygotsky as Muse to Complex Learning/Teaching

A Response to Ton Jörg's Programmatic View

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Before we go any further here, has it ever occurred to any of you that all this is simply one grand misunderstanding? Since you're not here to learn anything, but to be taught so you can pass these tests, knowledge has to be organized so it can be taught, and it has to be reduced to information so it can be organized do you follow that? In other words this leads you to assume that organization is an inherent property of the knowledge itself, and that disorder and chaos are simply irrelevant forces that threaten it from outside. In fact it's exactly the opposite. Order is simply a thin, perilous condition we try to impose on the basic reality of chaos...

William Gaddis (1975, p. 25)

At the foundation of efforts to understand the significance of non-linear dynamic complexity is a disturbing reality. The smoothly connected (differentiable) functions of classical mathematics are “almost nowhere” present within the class of continuous functions. Technically, this means the infinitude of the classical functions is swallowed up in the much vaster uncountable infinitude of fractal (continuous and nowhere differentiable) functions. The spotlight of classical mathematical rationality shines narrow indeed, giving us a perfect view of a disembodied reality lost in the vastness of something else, something only dimly perceived, something complex.

Ton Jörg (this issue) urges us on to found a science of learning and a practice of teaching that is rooted in this larger, complex, reality: “To enable such a reinvention we need to stop thinking linearly. . . . We need to take the complexity of reality as reflecting the real” (p. 2). His motive? To escape “the surprising inefficiency of individual learning, of learning alone, and become more aware of the generative power of learning through social interaction as a generative process, with unexpected potentialities for the partners in that interaction” (p. 6).

Jörg’s vision for the possibilities of education restructured and reconceived is inspired first and foremost by complexity theory itself, including the central features of recursivity, unpredictability, and self-organization. These are familiar elements that curriculum theorists—including many of those contributing to this special issue of *Complicity*—have been looking to for at least fifteen years as source for a new foundation for educational practice (Davis & Simmt, 2003; Doll, 1993; Doll, Fleener, Trueit, & St. Julien, 2005; Fleener & Merritt, 2007). Yet these elements alone seem to lack the psychological dimension that would make them immediately applicable to problems of pedagogical practice.

What stands out in Jörg’s current effort is the reliance on Vygotsky’s sociogenetic theories of learning and development as an interpretive lens for complexity theory applied to education. Our responsive paper analyzes and evaluates Jörg’s recruitment of Vygotsky, but more than critique, our aim is to join Jörg in his consideration of Vygotsky’s relevance to a complex educational project, even as we explore the very limits of that possibility. Our reluctant conclusion points to the possible incompatibility of complexity framed by its mathematics and hard sciences roots to basic requirements of a social science.

Vygotsky has inspired generations of psychologists and educationists to reconceive learning and teaching. Yet existing sociocultural and activity theory, extensions of Vygotsky’s work, have not tended to frame learning as complex in the ways that Jörg has. Still, Vygotsky did share Jörg’s concern for the vast inefficiencies of traditional pedagogy, as well as his passionate belief that radically more effective instruction was possible: “We have given the child a penny’s worth of instruction and the consequence has been a dollar’s worth of development. A single step in instruction can represent a hundred steps in development” (Vygotsky, 1987, p. 198). Enlisting Vygotsky to aid in the framing of a complex pedagogy seems eminently reasonable.

Vygotsky’s unique place in psychology owes to his “genetic law of cultural development”:

Any function in the child's cultural development appears on stage twice, on two planes. First it appears on the social plane, then on the psychological, first among people as an intersychical category and then within the child as an intrapsychical category. (Vygotsky, 1978, p. 57).

Jörg looks to Vygotsky to help focus complexity in education on the effectivity of social interaction. But Vygotsky offered far more than a position on the social foundations of development; he offered a full-bodied theorization of the process.

One of the challenges of making use of Vygotsky's theories is the diversity of interpretations to be found in current scholarship, both Vygotskian and neo-Vygotskian. The problem stems in part from dealing with the discontinuities in Vygotsky's own thinking as his ideas matured and evolved, in part from translation issues arising for English speaking readers of Vygotsky's work, and in part from ideological preconceptions and biases that scholars, East and West, have brought with them to the interpretive task.

In the next section, we review some of the major interpretations of Vygotsky's work that have motivated pedagogical applications, noting aspects of dissonance with central tenets of Vygotsky's own thinking. Then we turn our attention in the final section to considering possible interpretations of dyadic interaction that might advance Jörg's complexivist perspective, at the same time doing better justice to Vygotsky's own views.

Interpreting Vygotsky on Learning, Teaching, and Development

We enter the thicket of pedagogical interpretations with Vygotsky's distinction between learning, understood at a microgenetic level as the moment-by-moment process of change in mental structures and in concept, and development, understood at the ontogenetic level as the unfolding of speech and thinking over the life span of the individual (1987, p. 212). These two levels are deeply intertwined. The child's current state of development constitutes the environment in which learning may unfold. More importantly for Vygotsky, learning/teaching can awaken the functions which lead to the next stage of the child's mental growth. For Vygotsky's pedagogical agenda was fashioned primarily in support of students' developmental progress. It is in this connection that Vygotsky's insights into the child's internalization of sociocultural processes come into play (p. 114).

The focus on the support of development gives Vygotsky's pedagogical emphasis a unique twist that has been difficult for many readers of his work to come to terms with. For Vygotsky (1987), the daily focus on skills and concepts in schools isn't of primary importance in and of itself (p. 200). Beyond whether students learned a particular concept or skill, his attention was on the ways in which concepts or skills might transform the very mental apparatus of the developing child. His sustaining interest was on the students' development of consciousness/volition, self-regulation, and abstract thought (p. 222).

In this respect, the instrumentalist approach of most schooling in which the dependent variable, learning, is conceptually distinct from the independent variable,

teaching, is problematic. For Vygotsky's pedagogical agenda involved co-facilitation of the dynamics of external and internal transitions within the classroom social process. Indeed, the conjoined Russian term "obuchenie" that Vygotsky used means either learning or teaching depending on the arguments attached to the verb (van der Veer & Valsiner, 1994, p. 114). But even beyond the linguistic difficulties associated with interpreting what Vygotsky meant by learning/teaching, the commodification of knowledge characteristic of Western capitalist societies makes it difficult to apprehend the dynamics of learning/teaching implicit in Vygotsky's famous notion of the Zone of Proximal Development (ZPD) (compare, for example, his 1978 comments, pp. 86-89 with an emphasis on learning and testing with his 1987 comments, pp. 209-214, where the emphasis is on instructed learning in a public school setting).

As Chaiklin (2003) astutely observed, most of the work on the Zone of Proximal *Development* actually describes what Vygotsky would have disowned as a Zone of Proximal *Learning*, incorporating key Non-Vygotskian principles: (a) The "generality" assumption that all skills are developmental; (b) The "assistance" assumption that interaction with a teacher or more capable peer is what creates a zone of proximal development; (c) The "potential" assumption that the developing functions is somehow inherent in the learner.

Based on this interpretive frame, Western educators have settled on a notion of Vygotskian pedagogy that tends to be individualistic, with the teacher providing scaffolding for the student's acquisition of skills and concepts. Compare, for example, Larsen-Freeman and Cameron's reductionist definition of a ZPD in their book on complexity theory in language teaching (2008, p. 23), with the perceptive criticisms of the way the ZPD has been used to spread "accountability without responsibility" to small groupwork in language teaching under "fast capitalism" detailed in Kinginger (2002). Here we find precisely the kind of pedagogical duet between teacher and student that Vygotsky rejected as a goal for instructional practice (1997a, p. 150). Missing is an understanding of the creative potential of the community, so important to Vygotsky, as well as to Jörg's sense of a complex pedagogy.

On the other hand, Eastern European interpreters have struggled with Vygotsky's sense of the problematic character of development as spurred by crises: "Education and creativity are always tragic processes, inasmuch as they always arise out of discontent, out of troubles, from discord" (1997b, p. 349). For Vygotsky, crises reflecting the contradictions between the child's immature appropriation of cultural resources within her or his current frame of reference, and the mature usage of those resources within a more adult sociality are a necessary process of development. However, interpretations of Vygotsky in Eastern European nations initially were shaped by the exigencies of Stalinism that regarded developmental crises with suspicion. Accepting that psychological relationships are always, at bottom, reflections and refractions of real relationships between real people, Stalinists could ill afford a version of child development in which crises are inevitable. If psychological crises imply social crises, then one of two things must be true: either socialism has not been achieved, or socialism

is not the final stage of history. We can see rejection and revision of Vygotsky's basic ideas in Leontiev (1981):

The existence of development of crises has long been known and their classic interpretation is that they are caused by the child's maturing inner characteristics and the contradictions that arise on that soil between it and the environment. From the standpoint of that interpretation the crises are of course inevitable because these contradictions are inevitable in any conditions. There is nothing more false however, in the theory of development of a child's psyche than this idea. ... There need be no crises at all if the child's psychic development does not take shape spontaneously but is a rationally controlled process, controlled upbringing. (pp. 398-399)

An interesting transposition of this crisis-free view of development can be found in Karpov's account of "The Neo-Vygotskian Approach to Child Development" (2005, p. 212), in which he claims that the crisis of adolescence is only brought about by the intransigence of parents.

In summary, neither the highly individualistic "scaffolding" interpretation of the zone of proximal development, nor the Soviet version, which theorizes away the "crises" which Vygotsky considered to be the very hallmarks of development (Leontiev, 1981, p. 398-399), has theorized the possibility of completely unpredictable outcomes; neither, therefore, can provide the unpredictable "conversation with the future" of which Mike Cole has spoken (2007). Jörg's paper does appear to offer a possible way out of this impasse by choosing a focus on local interaction. This dyad-based view appears to resist the downward reductionism of a purely learner-based view as well as the upward reductionism of one dominated by the curriculum implemented by the teacher. Further, it appears susceptible to treatment as a complex dynamic system, since dyadic interaction is hardly ever describable as a linear function of two verbal contributions by two individual consciousnesses. This possibility will be explored in the next part of this paper.

Before we do so, however, we conclude this section with an illustration of Vygotsky's central focus on consciousness and volition from a Hegelian perspective, a dimension of development that may be difficult to capture within a complexivist frame. In his discussion of creativity, Vygotsky (2004) addressed himself to the problem of why children characteristically draw enthusiastically in a schematic manner until they begin to develop a modicum of realistic skill and then suddenly lose all interest in drawing. Through a painstaking analysis of their drawings Vygotsky shows that children initially, attempting to copy their memories, merely succeed in entirely reconstructing the object they wish to draw. Even in attempting to copy exactly, the best older children can achieve is an imperfect imitation. We might, in a Hegelian vein, call this variation-in-itself, and compare it to the random gestures of the infant or, better, the random scribbling of the pre-schooler. In an objective sense, then, variation actually precedes exact imitation, for it is always easier to vary an action (even your own action) than to repeat it precisely. When this kind of initially involuntary variation itself is recognized as a variation on a theme, we may call it variation-for-others and compare it to the interpretation of a grasping gesture as a pointing gesture by a mother or the moment

where a child who scribbles and then decides that the scribble is a plume of smoke (1978, pp. 56, 113). Finally, this variation-for-others moves from the output of the action to its input, from being a result to being a motive. At this point, we may call it variation-for-itself, that is, true, will-governed creativity. Ironically, as Vygotsky noted, it is precisely this greater self-consciousness, characteristic of adolescence, which stymies the young creative artist.

What this example illustrates is Vygotsky's enduring interest in the development of sociocultural capabilities and sensibilities. What seems problematic with respect to the current project is the tendency for complexity theory oriented around its scientific and mathematical foundations to atomize the inputs into the model and simply wait for complexity to emerge. As we discuss below, this leveling of inputs means the loss of the volitional aspects of cognition; learning becomes a recapitulation of the original relatively unplanned construction of knowledge. In the next section, we consider various alternative framings of dyadic interaction that may inspire a complexivist pedagogy.

Dyadic Interaction and Complexity Theory

In this section, we consider 3 alternative ways of construing dyadic interaction with respect to the goal of founding a complexivist science of learning and teaching:

From "Beneath and Below": an "integrationist" linguistics that considers dyadic interaction not as the instantiation of a language system but as a complex, locally organized means of integrating otherwise chaotic human activities.

From "Around and About": an approach based on ethnomethodology and conversation analysis that looks at how participants in a dyadic interaction themselves construe the complexity they are creating.

From "Above and Beyond": returning to the original Vygotskian idea that dyadic interaction is always inscribed in a larger whole from which it draws both social sense and ideological meaning. As we shall see, this does not imply that it can never be described in terms of chaos-complexity theory; but it does suggest that it has not yet been so described, and it may even, as Prigogine and Stengers write, bring us to the limits of what chaos-complexity theory can usefully describe.

To guide us through this set of opportunities, we make reference to a brief dyadic classroom interaction. In the following transcript, Jimin and Anna are fifth graders sitting in an English classroom in a suburb of Seoul, South Korea. The lesson they are studying is called "She's Tall," and they have been given a magazine photograph to discuss:

Jimin: She has small face. She's face is white.

Anna: '마크다'가 뭐야? ("How do you say 'mareuda'?")

Jimin: Thin.

Anna: She's thin.

(Data collected by Ms. Guk Iju.)

On the face of it, we have an almost perfect example of what Jörg calls “mutual bootstrapping.” Jimin provides vocabulary (“thin”) to Anna. But it is Anna who provides the correct way to use “She’s...” to Jimin. In this way, each child provides something to the other, and the result is greater than just the sum of what the two children know about English as a system.

The problem with this bare level of analysis, as we see it, and as Jörg might well concur, is that it treats the language as a system that the children are trying to internalize. It does not address the orientation to the task and appears to assume there is really no contradiction between teacher goals and learner goals. Finally, by focusing on the division of labor in the dyad, it obscures the imitation and variation (that is, the complex interaction) between the two speakers. As promised, we shall examine this problem in three ways that may show these missing elements better.

Beneath and Below

Suppose instead, as integrationists claim, the reality of language is not so much that of a system (even a complex system) but rather a form of animal communication which is only locally and then imperfectly exapted¹ in order to integrate human activities (Harris, 1980; 1990a; 1990b). Suppose, in other words, we treat the language in this interaction not as a kind of traffic signal (where “thin” unambiguously means “mareuda” just as red means “stop”) but more like a car horn, where the attribution of meaning must necessarily depend on noting who is honking at what and only then interpreting why. A different picture arises: Anna and Jimin are not chiefly concerned with exchanging messages in English but mainly preoccupied with a material object in their immediate physical environment, viz. the magazine picture. Their attitude towards the linguistic material reflects their handling of the object; there is a tendency to create new linguistic material by repeating and varying. Thus “She has small face” becomes “She’s face is white.” The Korean subject matter and their Korean experience invariably impose Korean word-meanings which are simply relabeled in English. “Small face,” for example, is the name of a firm in Seoul providing plastic surgery to young women, and “white” is a highly prized skin color (Korean society is racially quite homogenous and generally unaware of the racist overtones of such preferences). The local sense of “She’s thin” then emerges quite naturally from the alignment of the interactants to the photograph, and the alignment of “She’s thin” with the language system of English and the abstract meaning highlighted in this lesson (“She’s tall”) is probably a temporary coincidence: Anna is actually trying to imitate an incorrect sentence from Jimin (“She’s face is white”) when she produces this correct utterance.

¹ **Exaptation** is a term introduced by Steven J. Gould and E.S. Vrba, 1982, pp: 4-5, to describe how a complex organ can evolve when only the finished organ is really useful, and its evolution requires many apparently dedicated adaptations. Their explanation is that what eventually will become the major function of the organ initially is a side-effect, unforeseen and unexpected, of an unrelated adaptation. Analogously, we understand Vygotsky’s theory of development to explain how social processes that eventually form the basis for important intrapsychological functions initially are appropriated by the child for quite different purposes.

Around and About

Conversation analysts (Sacks, 1994; Seedhouse 2004) base their work on ethnomethodology, and therefore orient their analysis to inter-alignment of the interactants themselves, as expressed in “adjacency pairs.” The first part of an adjacency pair is a verbal initiation which normatively requires some form of response in the next turn, but this is a norm rather than a rule. Unlike a natural law, it admits exceptions, and unlike a legal code, violations are not punished but are instead occasions for the renegotiation of the norm. In this case, Jimin’s initiating remark should be seen as the first move in an adjacency pair, to which Anna is required to follow suit. Lacking the vocabulary to do so, Anna instead offers another adjacency first pair part in Korean, asking for the wherewithal to construct a reply. Jimin obliges, completing the Korean adjacency pair, and Anna is accordingly able to complete the English adjacency pair and respond to “She has small face” with “She’s thin.” The “adjacency pair” structure faithfully reflects the dyadic nature of the interaction, and the “adjacency pair within an adjacency pair” reflects its orientation towards labeling Korean senses with English word meanings. Both structures, however, are explicit and even explicated in the sequence of statement-query-response-counter-statement. In this ethnomethodological view of the data, the tools for analyzing pragmatic purposes are exactly the same as those available to the participants themselves; the analysis is, therefore, emic rather than etic.

Above and Beyond

Jörg remarks, almost in passing, that sharing meaning like this involves both “meaning-making” and “personal sense making” (p. 12). This parallels Vygotsky’s distinction, in Chapter Seven of *Thinking and Speech* (1987, p. 276), between “znachenie” (semantic meaning) and “smysl” (sense, or what Widdowson, 2004, would call pragmatic meaning). “Znachenie” is what Anna asks Jimin to supply, the “dictionary definition” of “mareuda”. But only “smysl” gives the pronoun “she” its concrete, shareable content, and of course this conversation is really, when viewed thematically, about “she” rather than about “mareuda.”

For Vygotsky, learning a foreign language is an example of development and not simply learning, precisely because access to a foreign language, like algebra, reveals that the everyday material of expression (the native language or arithmetic) is simply one instantiation of a much more powerful human capability, the human, rather than specifically Korean, faculty for language. Vygotsky ridicules Stern for “getting it ass backwards” when he imagines that children of two are capable of asking about meaning (1998, p. 247); children do not go around asking “Mommy, what does the word ‘mean’ mean?” Yet this is exactly what we see in Anna’s question about “mareuda;” one child building foreign language word meanings on the foundations of the most abstract, most decontextualized forms of native language word meaning understood by the other (“mareuda” is in the uninflected, neutral form Koreans use when they are discussing a verb as a linguistic object).

It's for precisely this reason that in Chapter Six Vygotsky uses foreign language learning (and algebra) as the very archetype of the zone of proximal development, the kind of instruction which restructures the very means through which learning takes place. But it takes place precisely because it is not a repetition of the original learning process, but instead a conscious reformulation thereof. With this apparently chance remark about "meaning" and "personal sense", we come back once again to Vygotsky, but this time with omissions omitted and the distortions put right: "obuchenie" is indissolubly linked to development, and what develops is not complexity per se but rather volitional analysis and deliberate control.

Is this emphasis on teaching/learning, and on development as self-planning and self-regulation compatible with chaos-complexity theory? If we stick narrowly to the models provided by mathematics (Mandelbrot, 1965), chemistry (Prigogine and Stengers, 1985) and meteorology (Lorenz, 1995), the answer is undoubtedly no; we may take the word of Mandelbrot, Prigogine and Stengers, and Lorenz themselves for this, for each of these has separately concluded that with our current models of complexity, any attempt to reduce dyadic interaction to a "complex system" must tend to destroy its volitional nature and its link to conscious development (e.g., Mandelbrot, 1965, p. 554; Prigogine & Stengers, 1985, pp. 204-205). The complex dynamic modeling that has been found so useful for describing self-organization in the evolutionary origins of speech (Oudeyer, 2006; Ke & Holland, 2006) is much less useful for describing how speech is learnt and how it changes: ontogeny is no blind recapitulation of phylogeny. This does not, of course, rule out the possibility that in the future complexity theory may yet be able to deal with what Locke called "the guided re-invention of language." But in order to do so, it needs to find a social science model (e.g. Byrne 1998) rather than one based on the natural sciences, and that social science model cannot be based on the relatively nonvolitional "market" models currently in use (Waldrop, 1992).

With respect to complexity, the physical sciences may indeed come to envy the social sciences and humanities rather than (as is now traditional) vice versa. As Vico also remarked, insofar as man is made by God, he is a difficult thing to fully explain. But insofar as man is made by man, the task is rather easier. Prigogine and Stengers point out that in many ways complex systems that incorporate rational human consciousness (such as the way people behave when a bridge is overused and traffic jams occur) is rather easier for humans to understand than those that do not (1985, p. 191). In addition, the element of communication, which is right now at the very frontier of chaos-complexity thinking, has always been at the heart of the human sciences, and most particularly those concerned with human teaching and learning. This element is essential for the preservation of any large-scale chaotic system. As Prigogine and Stengers put it:

The question of the limits of complexity has often been raised. Indeed the more complex a system is the more numerous are the types of fluctuations that threaten its stability. How then it has been asked can systems as complex as ecological or human organizations possibly exist? How do they manage to avoid permanent chaos? The stabilizing effect of communication of diffusion processes, could be a partial answer to

these questions. In complex systems where species and individuals interact in many different ways, diffusion and communication among various parts of the system are likely to be efficient. There is competition between stabilization through communication and instability through fluctuation. The outcome of that competition determines the threshold of stability. (1985, p. 188)

An analogous competition, between explanatory force and extension, obtains within any academic discipline. In 1926-1927, as he lay gravely ill, Vygotsky (1997a) hastily sketched out a long essay on "The Historical Meaning of the Crisis in Psychology." In it, he traced five stages in the development of a given explanatory idea. In the first stage, a quite specific explanation is discovered for a specific set of facts (e.g. the Pavlovian reflex, the Freudian libido, the Gestalt, and Stern's concept of personality). This explanation is then generalized to similar problems within the domain, weakening its specificity but greatly increasing its explanatory power. The explanatory power is not only decontextualized but transformed, "stretched thin" as it covers greater and greater area. At length the idea comes to cover virtually the whole of the scientific domain in which it arose, at which point it no longer really explains anything. At this point the fate of the idea inevitably becomes intertwined with the basic concept of its own domain (in psychology, the mind). Like a country whose internal market is saturated, the discipline must now, with obligatory references to the need to be inter-disciplinary and even transdisciplinary, turn to other disciplines and offer the idea as an explanation for phenomena beyond its own domain. Vygotsky reminds the reader of a Russian parable about a bull frog tricked into blowing itself up the size of an ox, whereupon it exploded. Perhaps there is no need for educational psychology to be the size of a complexity theory ox; we may well understand ourselves better if we remain what we are, an intimate science intimately concerned with the "meaning to" in meaning

References

- Byrne, D. 1998. *Complexity theory and the social sciences*. London and New York: Routledge.
- Chaiklin, S. 2003. "The ZPD in Vygotsky's analysis of learning and instruction." In *Vygotsky's educational theory in cultural context*, edited by A. Kozulin, B. Gindis, V. S. Ageyev, and S. M. Miller, 39-64. Cambridge: Cambridge University Press.
- Cole, M. 2007. http://lhc.ucsd.edu/mca/Mail/xmcamail.2007_11.dir/0257.html.
- Davis, B., & Simmt, E. 2003. Understanding learning systems: Mathematics education and complexity science. *Journal for Research in Mathematics Education*, 34(2), 137-167.
- Doll, W. E. 1993. *A postmodern perspective on curriculum*. New York: Teachers College Press.
- Doll, W., Fleener, M. J., Trueit, D., St. Julien, J. (Eds.) 2005. *Chaos, complexity, curriculum and culture: A conversation*. New York: Peter Lang (Translated into Chinese, 2009).
- Fleener, M. J. & Merritt, M. 2007. Paradigms lost? *Nonlinear Dynamics, Psychology and the Life Sciences*, 11(1), 118.
- Gaddis, W. 1975. *JR*. New York: Alfred A. Knopf.
- Gould, S-J. and Vrba, E.S. 1982. Exaptation; a missing term in the science of form. *Paleobiology*, 8(1) 4-15.
- Harris, R. 1980. *The language makers*. Oxford: Oxford University Press.
- Harris, R. 1990a. "Making sense of communicative competence." In *The foundations of linguistic theory*, edited by N. Love, 112-135. London and New York: Routledge.

- Harris, R. 1990b. "Must monkeys mean?" In *The foundations of linguistic theory*, edited by N. Love, 158-179). London and New York: Routledge.
- Karpov, Y. 2005. *The neo-Vygotskian approach to child development*. Oxford: Oxford University Press.
- Ke, J.-Y., & Holland, J. H. 2006. Language origin from an emergentist perspective. *Applied Linguistics*, 27(4), 691-716.
- Kinginger, C. 2002. Defining the zone of proximal development in US foreign language education. *Applied Linguistics*, 23(2), 240-261.
- Larsen-Freeman, D. & Cameron, L. 2008. *Complex systems and applied linguistics*. Oxford: Oxford University Press.
- Leontiev, A. N. 1981. *Problems of the development of the mind*. Moscow: Progress.
- Lorenz, E. N. 1995. *The essence of chaos*. Seattle: University of Washington Press.
- Mandelbrot, B. 1965. "Information theory and psycholinguistics." In *Scientific psychology* edited by B. B. Wolmann & E. Nagel, New York: Basic Books.
- Oudeyer, P.-Y. 2006. *Self-organization in the evolution of speech*. Oxford: Oxford University Press.
- Prigogine, I., & Stengers, I. (1985). *Order out of chaos: Man's new dialogue with nature*. London: Fontana.
- Sacks, H. 1994/ 1997. *Lectures on conversation*. Malden MA and Oxford: Blackwell.
- Seedhouse, P. 2004. *The interactional architecture of the language classroom: A conversation analysis perspective*. Malden, MA and Oxford: Blackwell.
- Van der Veer, R., & Valsiner, J. (1994). *The Vygotsky reader*. Oxford UK and Cambridge USA: Blackwell.
- Vygotsky, L. S. 1978. *Mind in society*. Cambridge MA: Harvard University Press.
- Vygotsky, L. S. 1987. *The collected works of L.S. Vygotsky: Vol.1, Problems of general psychology. Including the volume Thinking and Speech*. (N. Minick, Trans.). New York: Plenum.
- Vygotsky, L. S. 1997a. *The collected works of L. S. Vygotsky: Vol. 3. Problems of the theory and history of psychology*. (W. Rieber & J. Wollock, Vol. Eds.; R. van der Veer, Trans.). New York: Plenum. (Original work 1924-1934).
- Vygotsky, L. S. 1997b. *Educational psychology* (R. Silverman, Trans.). Boca Raton, FL: St. Lucie Press.
- Vygotsky, L. S. 2004. Imagination and Creativity in Childhood. *Journal of Russian and East European Psychology*, 42(1), 7-97.
- Waldrop, M. 1992. *Complexity: The emerging science on the edge of order and chaos*. New York: Simon and Schuster.
- Widdowson, H. G. 2004. *Text, context, pretext*. Malden, MA: Blackwell.

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