ENTRY: **Socio-cultural perspectives on learning science**[1]

Synonyms: culture; history; society; activity theory; contradiction; dialectics; Vygotsky; Bakhtin

Introduction

Socio-cultural is an adjective that tends to be used in the Anglo-Saxon scholarly literature when research refers to and employs a range of concepts that have emerged in the particular domain of social psychology developed in the former USSR. Most fundamentally, the adjective is used to denote an epistemology that—in its original conception—uses society, culture, and history as the defining characteristics of human beings. It also is used to refer to a broad, internally highly differentiated movement with very different interests and approaches. The founder of this social psychology was Lev S. Vygotsky (1896–1934), sometimes referred to as the Mozart of psychology. After his premature death, Vygotsky's collaborators and students continued to elaborate and develop this form of psychology. Recent theoretical approaches in this perspective also include in their intellectual heritage the literary theorist and philosopher Mikhail M. Bakhtin (1895–1975) and his circle (V. N. Vološinov, Medvedev)[1]. The Anglo-Saxon use of the adjective "socio-cultural" actually is the result of an unfortunate, and likely politically motivated, choice to substitute the original Russian (from Vygotsky) and German (from Karl Marx) equivalents of *societal* with the linguistically associated but conceptually different adjective *social*. Together with society, Vygotsky, and his students and followers, emphasized *history* so that a more appropriate rendering adjective, as this occurs in some other languages, would be *societal-historical* (or cultural-historical).

Society as the Determinant Factor of Specifically Human Characteristics

The *societal-historical* perspective is fundamentally grounded in Marx's insight that what is specifically human is based on the societal relations in which an individual has participated. Thus, Vygotsky chose to explicitly refer to Marx when suggesting that all higher psychological functions first are *societal relations* before being *psychological functions* that can be attributed to an individual. More recent analyses show that these functions operate, for the first time, in a societal relation between people. Thus, the ways in which scientists orient each other to, and come to understand, images at work are the same ways in which infants and toddlers and their mothers employ when they begin to read books. From this perspective, personality is the totality of the societal relations that a person participates in, and is subject and subjected to, at any one point in time. From this perspective, therefore, inequities in science achievements between students from the working and under-

[1] Roth, W.-M. (in press). Socio-cultural perspectives on learning science. In R. Gunstone (Ed.), *Encyclopedia of science education.* Berlin Heidelberg: Springer-Verlag.

classes—including those living in poverty or the homeless—and those growing up in the middle and upper classes become understandable in terms of societal issues. In the latter classes, parents tend to spend more time with their infants, toddlers, and children—reading with them about animals or taking them to zoos and science museums—than those from the former classes, where families often struggle simply to make ends meet and to satisfy their basic needs. Thus, despite the rhetoric that comes with such agendas as *No Child Left Behind* (USA), the existing inequities in a society with respect to scientific understandings reproduce themselves with the different kinds of societal relations that children and youth come to participate in. In the Russian source language of the theory, therefore, as well as in the languages that retain the adjective, the *societal*-historical approach lends itself to critique—highlighted especially by those continuing Vygotsky's tradition, including A. N. Leont'ev, S. L. Rubinstein, and, subsequently, K. Holzkamp and the Berlin Critical Psychology group. The originators of the societal-historical perspectives recognized that psychology fulfills an ideological function and, in so doing, serves interests that tend to be those of the middle (bourgeois) class. The adjective *societal* explicitly makes this critical dimension possible, whereas the adjective *social* does not imply inequalities that derive from societal structure. The alternative adjective works against the ideology of an egalitarian society in which every individual is said to have the same potential and opportunities. This critical dimension of the societal-historical approach continues to be of importance in German-speaking countries and Scandinavia; but it is lost when the adjective is substituted by "social."

Marx's insight that *society* is what determines specifically human characteristics is saliently exemplified in the work with deaf and blind children conducted by Meshcheryakov. This work shows that without interactions with others, these children existed in a vegetative state, without any "innate" intention to explore, as Piaget proposed would be the case, and who did not stand upright let alone walk. These children were not incapable (e.g., genetically/intellectually). They subsequently developed specifically human capacities, including not simply learning to use material tools (like a spoon to feed themselves) but being guided to reflect on (by means of their developing intellectual tools) the material tools as objects in their own right. Some of these children, initially found in a vegetative state, subsequently developed to the point that they became university professors. That is, their explorative intentions were not "natural" and innate but rather developed while participating in intentional activities with others and reflecting on the objects involved in the activity and on the activities as a whole.

Unit Analysis Replaces Element Analysis

Theoretical Foundation

In the societal-historical approach, the unit of analysis shifts from the individual to the collective. Underlying the approach is the attempt to work against the reductionism of cognitivist and biological approaches to exploring learning. Vygotsky suggested that there are two types of analysis used in psychological

research: analysis by means of decomposition of a whole into elements, comparable to the analysis of water in terms of the elements oxygen and hydrogen, and holistic analysis, equivalent to the analysis of water as hydrogen oxide. According to Vygotsky, the former is to blame for "all" the failures to understand psychological forms, whereas only the latter is the "correct" starting point for doing a first step in the direction of understanding the human psyche. Vygotsky metaphorically elaborated this contention by saying that to understand why water extinguishes fire, we need to look at the properties of water rather than at the properties of oxygen and hydrogen. When science educators research learning in terms of emotions, or beliefs, or mental frameworks, or conceptions, they reduce the complex human being to elements. This contrasts with the alternative approach that seeks to understand learning in the sciences from the fullness of (everyday) life. In the latter approach, learning in/of science is understood in terms of all the activities in which a person lives in the course of a day, week, month, or year rather than within a particular activity, such as the science classroom. *Perežívanie*—which translates broadly as experience and feeling—is one such encompassing all-encompassing, irreducible unit that comprises the characteristics of the person, characteristics of the environment, and the temporal unfolding of both.

The following analogy is useful for distinguishing these two approaches, these two forms of analysis (Fig. 1). In this analogy, we model the shearing process that turns a rectangle into a parallelogram. In the common (reductionist) approach, complex phenomena are reduced to elements that are thought to be composing the phenomenon, and these elements are individually considered. Thus, in the example, the element is a square (e.g. representing prior science knowledge). A shearing force external to the square (a cause, e.g. representing an experience) acts upon the shape, changing it into a parallelogram (e.g. post-experience knowledge) (Fig. 1a). That is, there is an observable effect. The parallelogram is another element or, rather, the new shape (form) of a given material entity.

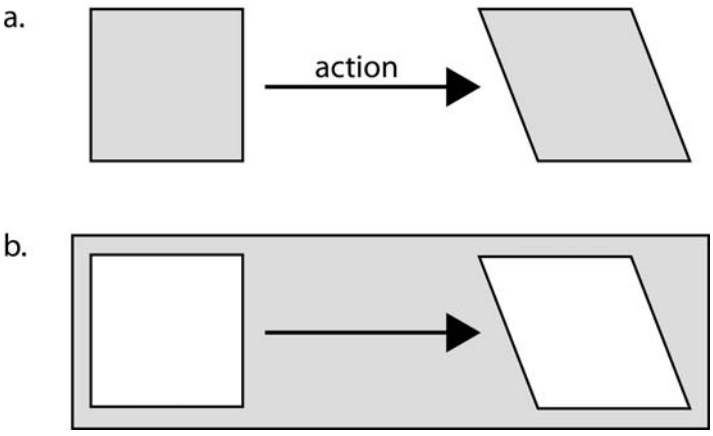

Fig. 1. Element analysis versus unit analysis.
a. In element analysis the square is the unit, which, subjected to a shearing action (cause) is turned into a parallelogram (effect).
b. In unit analysis, the entire process of change is included in the minimal unit; beginning, end, and everything in between, are constitutive parts of the whole.

Unit analysis is different; because it is intended to capture change itself, unit analysis requires a minimum unit of *change*. This situation is represented in Fig. 1b. The entire situation including square, parallelogram, change, and time all are part of the minimum unit. In contradistinction to the preceding analysis in terms of elements, all of the square, the dynamic of change, and the parallelogram no longer can be conceived independently. These are taken as different ways in which the unit *manifests* itself. This unit would therefore focus on learning rather than on prior and post-unit knowledge. This also leads to the fact that there are no longer independent causes and effects, a characteristic of all process philosophies from Heraclitus to the present day: A cause is a cause because there is an effect; and there is an effect, because there is a cause. This actually captures the observation that in the consideration of processes, we can attribute causes only after having observed something denoted as the effect. In science education research, a teaching method such as the use of analogies might be said to cause higher achievement or conceptual change. Yet in any particular case, a student from an experimental group (using analogies) might achieve less than a student from a control group (not using analogies). That is, whether a science curriculum is a causal force bringing about learning or conceptual change can be decided only after the fact, only after making the observation in any particular case.

A Practical Example: Classifying

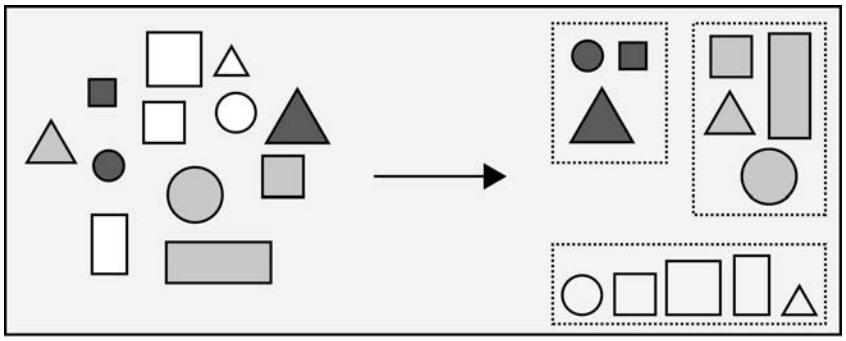

Fig. 2. Fundamental to the conceptualization of the socio-cultural approach is that it attempts to grasp change. The minimum unit of analysis therefore has to be one of change rather than one in which elements are subject to external forces.

Classifying is one of the core scientific skills. The research literature shows that from as early as 2 years to being a mature scientist, doing science involves classifying objects and events. In the example of the classification of objects typical for a second-grade classroom shown in Fig. 2, the entire activity beginning with the pile of objects until the point of three ordered groups would constitute the minimum unit for a unit analysis approach. This inherently implies all the interactions between students, between students and their teachers, the particular division of labor that was enacted, the forms of participation and the particular rules

that were practiced, and the means of production in use. Thus, for example, in the case of leaf classifications, we might consider making available field guides. The societal-historical perspectives then would lead us to anticipate that classifying leaves with and without field guides will change the outcomes. There are studies that exhibit the considerable differences in classification if the field guides employ photographs or drawings, the latter, against expectations, making classification easier than the former. Also, students might create resources for classification, such as a plastic bag with core examples of different categories of leaves. In this case, the activity transforms itself, as new tools are produced and, therefore, change the nature of the activity. As a result, we should expect very different outcomes with the use of technologies. Moreover, from these societal-historical perspectives, we should expect the observed outcomes of activities to change if students are tested in the absence of such tools.

Classification also will be different as a function of culture. This was quite explicit in research that Luria—a founder and leader of what sometimes is referred to as the *Vygotsky circle*—conducted with Kazakh peasants. Asked to sort skeins of wool by color, they refused and suggested this was an impossible task as all the colors differed. According to a Piagetian perspective on human development, these peasants were of lower cognitive capacity than most Western children. However, it turns out that the experience of attending school changed the ways in which these peasants would classify. That is, the cultural and historical (presence or absence of institutional forms of learning) mediates classification and, therefore, the outcomes of the testing activity. We should therefore not be surprised if children growing up in an aboriginal setting with strong focus on cultural heritage—e.g., in Australia, New Zealand, Hawai'i, or on the Canadian and U.S. Northwest coast—should engage in leaf classification and other science activities related to nature very differently than students in more urban areas and surrounded by more typical Western culture. We should expect that the schooling of science, as well as the schooling of traditional ecological knowledge, would change the ways in which students understand and, therefore how they would learn and develop with respect to scientific knowledge.

Implications of Unit Analysis

Choosing a minimum unit (category) that is change itself leads to the position that change is the norm (e.g., learning, development) and stasis (knowledge, conceptual framework/structure) is the exception. Whereas in the classical case, change (learning, development) is problematic, in the societal-historical approach, stasis is problematic (knowledge, conceptual framework/structure). Every time students engage in and with science, they change—though the nature of the change is not predetermined. For some students, a given science curriculum leads to learning and conceptual change; for others, however, even the best-designed curriculum might turn them away from pursuing a career related to science.

Within this perspective, society—its material and cultural aspects—is understood as a self-moving system. There are no outside (divine or other) forces that bring about the change. In the same way, there are no outside forces that change knowing and understanding. Participation in the activity of schooling,

concretely realized in the science classroom, *is* change. There is no being outside of consciousness (knowledge) that makes consciousness develop, in the way that it might appear in constructivist approaches (i.e., a subject constructs its knowledge as if the subject could exist outside of its knowledge). Vygotsky explicitly critiques this latter approach that makes thoughts appear to think themselves.

Vygotsky's coworkers, students, and followers point out that society and its history constitute the relevant unit for thinking about knowing, learning, subjectivity, and personality. The smallest unit, therefore, has to be one that has all the characteristics of society as a whole. This unit, emphasized especially in that perspective referred to as cultural-historical *activity theory*, is an *activity*. Examples of activities include farming, manufacturing, and, pertinent to the present context, *schooling*. To understand what happens in science classrooms, therefore, the smallest unit would be that of schooling (rather than the student, or a group of students, or a teacher, or classroom, or school, and so on). There then exists a whole–part relation between this smallest unit and those aspects in which it manifests itself: school, classroom, teacher, students, curriculum materials, and so forth. Thus, we cannot understand the science student independent of the schooling the student is experiencing: the whole (i.e., schooling) requires students; and to be a student in the way this term is commonly understood requires the societal activity of schooling. Taking only one identifiable part changes the whole and, because of the change in the totality of relations existing within the whole, each part also changes. Drawing on Vygotsky's water analogy, if we take away the hydrogen from water, what remains is a different whole: oxygen. Its behavior and characteristics are very different from the preceding whole, which while it included hydrogen had no behavioral or characteristic similarities with either hydrogen or oxygen. Similarly, if we were to remove all students from schooling, what remains would not be schooling in the way we know it.

In the perspective presented here, material and intellectual tools play an important role. Most tools are used to change the material world. Intellectual tools come in the form of signs, including the various forms of inscription scientists use and language. These allow humans, as Vygotsky explicitly noted, to control their brains from without. To understand language as a *living* phenomenon, we need precisely such a unit. Thus, language is alive when it changes every time it is used, every time someone articulates a word. A language is dead (classical Latin being one example), no longer changes, when it is not used.

Inner Contradiction

Contradiction is one of the most important categories in the formulation of the societal-cultural perspective on learning. This is immediately apparent when we consider the case depicted in Fig. 2 (and Fig. 1b). We can look at the unit and make one of two observations. These observations differ: the unit manifests itself in one or the other observation. That is, precisely because the minimum unit covers an activity from beginning to its end, we will make differing observations depending on the instant of time when we observe. There is a second way in which observations

will differ: these depend also on where we look in the activity. We will make different observations when looking at one (e.g., a child) rather than another individual (another child, the teacher), at the materials (e.g., the after the first few objects being moved), at division of labor (which may change), and so on, even though all of these are part of the same unit (e.g., pereživanie). Classical logic suggests that these differences are the result of looking at different times or at different aspects (people) or the result of different people looking ("interpreting") a situation. But Vygotsky's dialectical logic, which is based on taking a holistic perspective, suggests that the different manifestations are due to the *inner* difference *within* the unit considered—e.g., in Fig 1b, the *unit* is a square and a parallelogram simultaneously—rather than *between* elements. Vygotsky explicitly rejects analysis by elements and suggests that only thinking in units will give proper theories of human learning and development.

A second form of *inner* contradiction exists in the fact that in societal-historical approaches, the material (physical) and ideal (mental) are theorized as two sides of the same phenomenon. What happens materially during a science laboratory experiment and the ways in which the events appear in consciousness are two manifestations of the same unit: the activity *as a whole*. Thus, children who classify the shapes in Fig. 2 not only do something materially but also find the material reality reflected in their consciousness and in affect. Consciousness and affect are understood to be in a dialectical relationship, because each aspect is a manifestation of the current activity. These manifestations are not identical, though they are manifestations of the same (unit). Activities are characterized by their outcomes. Initially, these outcomes exist only on the ideal plane simultaneously with the reflection of the current material state. The participants in the activity orient to these anticipated outcomes. There is then an inner contradiction between the co-present reflection of the present state and the anticipated future state of the activity, the production process.

Dialogue and the Development of Speech and Language

To understand the dynamic nature of language, one has to theorize it as a moving phenomenon. Bakhtin and Vološinov therefore insisted that language changes every time that it is *used,* which always transforms the thing (e.g., Fig. 1b); moreover, they suggest for this reason that the word constitutes the same kind of dialectical unit. With every word or sentence usage, scientific language changes. This then explains how words, such as *atom*, come to be the same and different simultaneously not only from a historical perspective but also from the perspectives of individual development or that of language in a concretely unfolding situation. We can also understand the historically changing ways in the discursive organization of fields, for example, the changes from structure to function in the teaching of biology, or the changing ways in which an individual physics or chemistry teacher might talk about a certain topic from the beginning to the end of her career. The changes are not just changes in individual speech ability but changes in the language at large. Thus, Bakhtin provided a concrete analysis of the changing

nature of the novel genre. He suggested that this change could not be understood if we aligned on some trajectory all the forms that the novel has taken historically. To achieve a coherent account, each novel had to be understood instead as a manifestation of current *general* culture and language. The changing nature of language, which occurs because mundane language is changing, leads to the different forms the novel takes. Every change of scientific language is a change in general language, which is the ground upon which any and all scientific languages are built.

Following Vygotsky and Bakhtin, who shared the conviction that dialogue is the origin of language, scholars working from this perspective tend to be very interested in the role of language in science learning. Pertaining to language, its use, comprehension, and development, everything is happening in real, affective-emotive societal relations where concrete speech activity takes place (Fig. 3). Speech activity is subordinated to and constitutive of activity. Activity generates and drives speech activity, which, in turn, generates and drives societally motivated activity: There is a mutually constitutive relation. It is precisely here that we find the word, a phenomenon that integrates interlocutors: speakers and listeners.

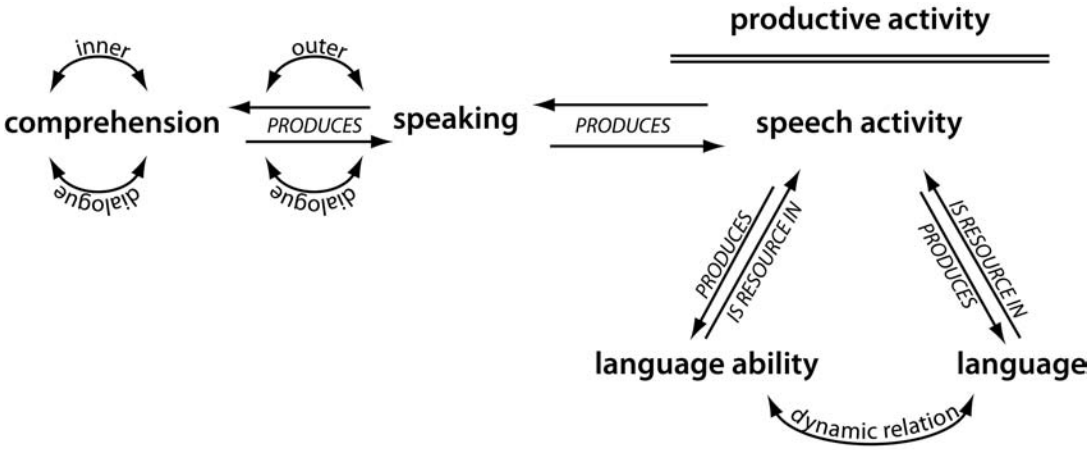

Fig. 3. Model of the relation between the different components in speaking and language.

Speech activity is concretely realized through speaking and replying, which is based on comprehension, including that of the speaker who comes to know his/her thought (after the fact) in the expressions used. Again, there is a mutually constitutive relation, as speaking concretely realizes speech activity but is produced in the service of the latter. In a conversation, there are interlocutors, who not merely externalize what is their own but who speak *for* the others using language that is not their own but has come to them from the other. Some science educators, therefore, suggest that "misconception" talk is inherently intelligible and shared: science educators understand this talk all the while knowing that it is different from the talk they intend students to use. To properly understand the phenomenon of speaking, it needs to be analyzed from the perspective of hearing, which implies comprehension. Comprehension itself is a dialogical process on the internal plane, and, in fact, all speaking has its genetic origin in *dialogical* speech. Thus, inner dialogue is the

psychological reflection of outer dialogue, where it has its origin both at the cultural-historical (phylogenetic) and individual developmental (ontogenetic) levels (Fig. 3). The subjective reality of an *inner voice* is born in its *externalization* for the other. It therefore becomes what it is simultaneously for the other and the individual.

The generative role of speech activity *in societal relations* is shown in the model in Fig. 3 as the arrow from speech activity to language ability, whereby participation in the former is the origin of the latter. At the same time, language ability is a requisite in speech activity: the relation between the two is mutually constitutive. The same mutually constitutive relation exists between everyday speech activity and scientific language. Any change in everyday, scholarly, and aesthetic language emerges in and arises from common speech activity in societal relations, becoming a feature of language as a structured system. Simultaneously, there is always already language that serves as a resource in scientific speech activity. As a result, we obtain a relation between individual language ability and the language of society. The relation between language as a societal phenomenon and language as a psychological phenomenon is a dynamic relation—and so is that of language as a system and language as a capacity. In terms of the perspective outlined here, speech activity is the category that sublates (overcomes and preserves) and therefore mediates between language as a system and language as a capacity, each of which is a (one-sided) manifestation of the overarching whole.

Thinking and Speaking

In the classical theoretical approaches from Aristotle to Augustine to present-day psychology, speech expresses on the outside what has been thought on the inside, and, therefore what is already represented in the structures of the mind (e.g., conceptions). In the societal cultural approach, the relationship between speaking (the material dimension of an activity) and thinking (the ideal dimension of an activity) is much more complex. If we consider the situation of an individual student or teacher spontaneously speaking during a science class, then speaking and thinking are taken to be two related *processes*, each contributing to shaping the other, but neither taking precedence. In fact, the two processes are manifestations of one higher order process: *word-signification* [Rus. *značenie slovo*] (Vygotsky) or theme [Rus. *tema*] (Vološinov). This overarching process makes it that the same word, even if spoken multiple times in the same unfolding situation, is never the same (never has the same function). Recent studies in science education—as those by Vygotsky and Bakhtin before—show that although there is a stable sound formation, intonation especially, in the articulation of a specific word, the placement of the same sound-word changes how it is heard (semantics) and what it achieves (pragmatics). But what a science word achieves in any situation can be known only subsequently. Thus, individual speakers in spontaneous (science lecture) talk will find their thought in what they have actually said rather than expressing what has been thought out in all its details before speaking. Moreover, science education research has shown that language itself is a resource for articulating thoughts even

when we have never had these thoughts before. Thus, when asked about some scientific phenomenon—e.g., distance, relative movement, and relative orientation of sun and earth—people respond even if they have never thought about it before. In fact, they may even say they have not thought of this before and still respond to the question. Thus, being familiar with sunrises and sunsets easily allows someone, a child or a Harvard graduate, with rudimentary language competencies to say that the sun moves—it rises in the morning and sets in the evening—rather than that the earth spins around its axis. Because of the everyday experience that the warmth experienced near a heat source changes with the distance to it, it is reasonable for someone to suggest that the earth is closer to sun in summer, especially if one has had no information to the contrary.

From this perspective, the word is not a property of the individual. Any word specifically, and language more generally, is a feature of culture and, by definition, impossible for one person. When a child talks about a phenomenon in a way that some science educators assert constitutes a "misconception," this misconception is enabled by and exists in language. Even if a sound or other sign was to be created and used by a single individual—e.g., Einstein's publication of the special theory of relativity—this would be based on the general practice of communicating by means of signs. Moreover, even when a sound-word (science concept) is used for the first time, it implies the understanding of another. This is why other scientists could, for example, understand Priestley when he presented his ideas about "*dephlogisticated* air" (oxygen), even though the adjective had not existed before. Thus, with every sign initially used by one person also comes the possibility of general, shared use. Every idealization inherently implies reproducibility, both by the individual and other persons, and, therefore, intersubjectivity.

Intellect and Affect

In the works of Vygotsky, Bakhtin, their students, and their followers, intellect and affect are theorized as two sides of the same coin. They are not independent, somehow *inter*acting elements that determine human behavior, as is conceptualized in most psychological theories. Piaget, for example, described affect as a sort of energy source (gasoline) to a motor (intellect) that does not change the structure of the motor. In the present perspective, on the other hand, intellect and affect are two sides of the same coin: different reflections of the same activity. This holistic conception of activity obviously also leads to the position that affect is not something that can be thought independent of intellect. According to Vygotsky, the separation of affect and intellect is the essential reason why traditional psychological theories fall short of understanding human behavior. This is so because there appears to be an autonomous stream of thoughts thinking ("constructing") themselves irrespective of the interests, motives, and impulses of the *whole* person. As recent research suggests, this means that to understand learning in the science classroom we need to look at the whole person, in the course of leading a life that includes but does not reduce itself to the science classroom. What we observe in the science classroom is a function of its place in a hierarchy of

all the daily activities in which the person participates. This, as some studies in this field show, changes what we observe. If teaching physics is fourth in a list of importance for the teacher—following religion, family, and missionary activities—then what happens in and around the physics lessons will differ from observations we might make when teaching physics is the primary activity of the teacher.

From the perspective articulated here, affect and intellect are manifestations of the same activity. Affect is an indication of the difference between the current state of activity and its intended outcome. Being unable to progress through a science activity may be marked by both frustration (affect) and by the understanding that one is stuck (intellect). However, continuing with attempting to progress through the activity may lead to becoming "unstuck," which would be accompanied by more positive affect; on the other hand, not continuing is very unlikely to change the negative affective tone. Thus, even though both teacher and student might be frustrated about how far they are from understanding the task and each other, the only hope for getting closer to achieving their goals is to go on and to engage despite the frustration. Studies show that without this attempt to engage, there is no movement and students and teacher remain frustrated. With engagement, they can hope to get closer to the goal, which in turn tends to be reflected by more positive affect. Of course there is no guarantee that engagement leads to learning and more positive affect; quite the contrary, the parties involved might increase the distance to the intended goals of the science activities or come to understand that there are insurmountable barriers. In both situations, the tonality of affect will tend to be more negative.

Considering affect together with the expansion of action possibilities that emerge from cooperation with others leads us to understand two forms of learning: *expansive* and *defensive*. Expansive learning arises from the fact that in and through our participation, all of our action possibilities, our room to maneuver, and our control over conditions expand. Such expansion is inherently related to more positive affect. This might well explain why students often prefer working in groups. We engage in certain actions even though they may involve hardship when doing so increases our possibilities (e.g., success on an exam) once we are through the hard part (e.g., studying for an exam). Defensive learning denotes the situation where we engage in learning only to avoid sanctions (e.g., receiving a low grade, school suspension). It then becomes completely understandable that some students become perfect cheaters: To avoid low or failing grades, one can become good at a practice that avoids the real goal of the activity, knowing and understanding science, but still achieve the desired outcome (e.g., passing or high grade). When students do not accept the motive of activity, passing or high grade in science, then there is nothing teachers can do to motivate them: the students "don't care any more." It is quite apparent that this societal-cultural perspective no longer requires us to operate with such concepts as individual motivation.

Learning and Development

One important aspect of the societal-historical approach that is often not well understood pertains to the distinction between learning and development. For Piaget, there existed two different processes, *assimilation*, in which new experience is associated to and understood in terms of existing mental schemas, and *accommodation*, a restructuring of mental schemas to make them appropriate for thinking about experiences that previously could not be understood. The two are very different, independent processes. For Vygotsky, on the other hand, learning and development are related; but learning, he insists, always precedes development. The two are related even though learning refers to a (quantitative) accretion of understanding and development to a qualitative change of understanding that is followed by a fundamental change in the forms of experiences that the person has. To understand this relation requires dialectical thinking, where, as developed by Marx, quantitative change leads to qualitative change. This change from quantitative to qualitative can be observed involving: (a) a particular form of initial understanding (conception); (b) objective changes in the environmental conditions that lead to a contradiction within the person; (c) the emergence of a new form of understanding (conception) existing *side-by-side with* the older type/s of experience; (d) change in dominance from the prior to the new form of understanding (conception); and (e) experiences in terms of the qualitatively new form of understanding (conception). Here, there are two qualitative changes: first, the emergence of a new form of understanding; and, second, the change in the nature of the dominant form of understanding. In this model, the older form of understanding (conception) is not eradicated, as some science educators have previously suggested has to occur in the case of misconceptions, but exists side by side with the older form of understanding (conception). This actually models quite well our everyday understanding that an astronomer can marvel at the beauty of a sun*rise* or sun*set*, a Ptolemean perspective, all the while using a Copernican perspective at work or while teaching astronomy. It has been shown that this societal-historical perspective can be modeled using catastrophe theory, a form of mathematics that combines quantitative and qualitative dimensions to explain the emergence of new forms (e.g., conceptions, talk), that is, morphogenesis.

An important concept that Vygotsky initially introduced to show how learning leads to development is that of the *zone of proximal development*. It was initially defined as the difference between a child's current cultural practices and those that it could enact in collaboration with a teacher or a more competent peer. The latter are said to *scaffold* the individual who is less competent at the task. For example, children in an early childhood science lesson may not arrive at the desired categorization of objects depicted in Fig. 2; they would be considered to be operating at one developmental level. But in the interaction with their teacher, they do achieve the categorization; in this societal context, they are operating at another developmental level. This change then precipitates operating at this more advanced level on their own because with the teacher they already operate at the higher level until they are in a situation to operate at this level on their own (similar to children learning to ride a bicycle by having adults first stabilize the bicycle until they can stabilize it themselves). In contrast to the nature-driven cognitive development in

(Piagetian) constructivism, in the societal-historical approach development is mediated by culture.

In this example, the idea of the zone of proximal development is employed asymmetrically: metaphorically the teacher pulls the child to a higher level. However, new research in this perspective has shown that groups of equally capable students achieve *beyond* the developmental levels of any individual in the group. When children engage in the classification of objects such as depicted in Fig. 2, not only the product of activity but also the learning opportunities change if they work alone or in groupings with others, if they interact or not with the teacher. Moreover, recent STEM studies show that in groups with asymmetric experiences, even those to whom more initial knowledge is attributed learn from the group experience. Thus, for example, there are studies in science education showing that not only do science teachers continue to learn to teach while teaching (i.e., pedagogical content knowledge), also they learn and come to better understand the science content. That is, any time people work together in collectivities, that is, when they engage in societal relations with others, we can observe learning and development. Working in and as constitutive parts of collectivities leads to learning by expansion. It is likely for this reason that some scholars, such as Engeström and Holzkamp, have suggested alternative ways of understanding learning that occurs in relations with others. Thus, the zone of proximal development should be thought of in terms of the whole unit of analysis, which changes when a new form of activity is created in the collaboration of two or more individuals (cf. studies on coteaching science or studies on collaborative learning in the science classroom). As a result, there is a distance between current everyday actions and those possible in cooperation with others. In other words, the range of possibilities for individuals and their control over existing conditions increases in the cooperation with others for the purpose of achieving common, general goals; in this cooperation, any individual also increases control over individual conditions. Working with peers and teachers on the classification task (Fig. 2) in the societal activity of schooling not only expands what is collectively achieved but also what the individual can achieve, for example, the affective experiences that come from and with achievement.

Opportunities and Continuing Problems

The societal-historical perspective has proven to be of tremendous use for understanding and planning what happens in science classrooms. Most fundamentally, it shifts our attention from the individual to the collective (the group, class). With this shift, relations to others, language, and the all the material, cultural, and historical dimensions of the setting in which change and learning occur, all come to be made thematic. Despite the tremendous positive impact this perspective has had, there continue to be a range of problems. As science educators reading the works of Vygotsky, Leont'ev, Bakhtin, and other Russian scholars may note, there are sometimes tremendous differences in content and quality between the texts rendered in Russian and their native tongues and the English versions. This will not come as a surprise, as specialist scholars recognize the highly variable quality of

translations into some Western languages. Some translations are more exact than others, that is, more in the spirit of the original Russian works. For example, the German and Italian versions of Vygotsky's *Thought and Language* are recognized to better represent what Vygotsky was writing and the spirit underlying his approach. The first English translation of this text omitted many crucial passages, and even the second, somewhat better translation has been criticized for leaving out materials or for incorrectly translating individual words and passages. It has almost completely changed the sense of what Vygotsky has written. The same is the case for the translations of Bakhtin and the members of his circle. Again, the English translations have been labeled as inferior to those that have been produced for other languages. One of the requirements for the continued evolving fruitfulness of the approach therefore would be better translations and a greater attention to the role of society, unit analysis, and the nature of a category (i.e., unit).

Note

[1] Depending on the language into which the works of these scholars are translated, alternative spellings of Vygotsky's Russian name (Rus. Выготский) include Vygotski (Fr., Sp.), Vygotskij (ling., Ital.) and Wygotski (Ger., Pol.); the name Bakhtin (Rus. Бахтин), depending on language, also is spelled Bachtin (Ger., Pol., Ital.), Bakhtine (Fr.), and Bajtín (Sp).

Cross-references

Activity theory; science skills; schooling of science; technology-enhanced learning; Bakhtin; cognitive abilities; discourse in science learning; emotion and the teaching of science; language and learning; talk and science learning; Vygotsky; zone of proximal development; scaffolded learning; team teaching; acculturation; culture and science learning; indigenous students; socio-cultural perspectives and gender; traditional knowledge; science education in / out of school contexts;

Suggested Readings

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