Vygotsky in a TeamRoom:

An exploratory study on collective concept formation in electronic environments

Ilkka Tuomi
Nokia Research Center
P. O. Box 407, FIN-00045 Nokia Group, Finland

Abstract

Effective use of distributed collaboration environments requires shared mental models that guide users in sensemaking and categorization. In Lotus Notes -based collaboration systems, such shared models are usually implemented as views and document types. TeamRoom, developed at Lotus Institute, implements in its design a theory of effective social process that creates a set of team-specific categories, which can then be used as a basis for knowledge sharing, collaboration, and team memory.

This paper reports an exploratory study in collective concept formation in the TeamRoom environment. The study was run in an ecological setting, while the team members used the system for their everyday work. We apply theory developed by Lev Vygotsky, and use a modified version of an experiment on concept formation, devised by Lev Sakharov, and discussed in Vygotsky (1986).

Vygotsky emphasized the role of language, cognitive artifacts, and historical and social sources in the development of thought processes. Within the Vygotskian framework it becomes clear that development of thinking does not end in adolescence. In teams of adult people, learning and knowledge creation are continuous processes. New concepts are created, shared, and developed into systems. The question, then, becomes how spontaneous concepts are collectively generated in teams, how they become integrated as systems, and how computer mediated collaboration environments affect these processes.

Introduction: Vygotsky and mediated cognition

Wertsch (1985:14) summarized Vygotsky's theoretical framework as three core themes: "(1) a reliance on a genetic or developmental method; (2) the claim that higher mental processes in the individual have their origin in social processes; and (3) the claim that mental processes can be understood only if we understand the tools and signs that mediate them." According to Vygotsky, we use cognitive tools to control our thinking. Many of these tools are products of social, cultural and historical processes. Cognition, therefore, can not be understood as something that happens within an individual head. Instead, we should view cognition in an ecological setting, where humans borrow cognitive tools produced by earlier generations, as well as cognitive processes available in their social environment.

More recently, researchers on social construction (e.g., Berger and Luckmann, 1966), ecological and extended cognition (Wertsch, 1991; Norman, 1993a; Norman, 1993b; Bruner, 1986; Gibson, 1979), distributed cognition (Weick and Roberts, 1993; Hutchins, 1995) and situated learning and action (Leont'ev, 1978; Scribner, 1997; Engeström, 1996; Cole, 1996; Suchman, 1987; Engeström and Middleton, 1996; Lave and Wenger, 1991) have emphasized the role of cultural artifacts in cognition. As Gregory (1981:76) puts it: "We live off intelligence stored in artefacts designed by our ancestors." Social, historical and cultural dimensions of cognition are receiving increasing attention, and their relevance in developing collaboration technologies is widely recognized. Many of the studies in this area, however, have been conducted in laboratory settings, and there has been relatively little work done that would integrate theoretical considerations

Proceedings of the 31st Hawaii International Conference on System Sciences, IEEE Computer Society Press, Los Alamitos, CA, January 1998, Vol. 1, pp. 68-75.

with practical collaboration tools in actual working situations.

In this exploratory study, we observe the use of a state-of-the-art collaboration environment in an experiment that combines theory and practice. The focus of the experiment is on a team of people working to develop a framework for knowledge management in a large multinational corporation, using TeamRoom for their joint creation of the framework. Grounding our observations on the Vygotskian theory on concept formation, we follow the genesis of collective concepts in a distributed team collaboration environment, and try to develop insights and theory on team collaboration, and collaboration support systems.

Spontaneous and theoretical concepts

Based on his experimental studies with children of different ages, Vygotsky argued that concept formation consists of two parallel processes: organizing discrete elements into groups, and abstraction of some aspects of the attended phenomenon. (Vygotsky, 1986)

Grouping of objects or things develops through three major phases, each in turn comprising several stages. According to Vygotsky, a young child takes the first step toward concept formation when he or she puts together a number of objects in an unorganized congeries, or "heap," in order to solve a problem that adults would normally solve by forming a new concept. In the first phase, for example, the child sorts objects into heaps, based on syncretic organization of the child's visual field.

The second major phase comprises variations of "thinking in complexes." A complex is a concrete grouping of objects connected by factual bonds. Whereas in the first phase a child mistakes connections between his or her own impressions for connections between things, in the second phase the child groups objects based on their actual relations. In the second phase, categorizing objects into groups is based on the properties of the objects, although the groups don't reflect the relations between things in the same way as adult conceptual thinking. At the second phase the child thinks in family names, as it were:

> "In a complex, the bonds between its components are concrete and factual rather than abstract and logical, just as we do not classify a person as belonging to the Petrov family because of any logical relation between him and other bearers of that name. The question is settled for us by facts." (Vygotsky, 1986:113)

Vygotsky's research revealed five basic types of complexes during the child's development. First, complexes formed as *associations* between a sample object and other objects. Second, complexes formed as *collections* based on some trait in which they differ. Third, a dynamic process of grouping of objects emerges, where the child forms groups by linking one object to another as *chain complexes*. In a complex, all the traits of the objects seem to be equally important for the child. In a chain complex, therefore, each grouped object relates to the next object in chain, but there is no common abstract feature shared with them all. In the fourth stage of development a new form of complex emerges. This Vygotsky calls *diffuse complex*. Diffuse complexes are groups of things that are similar, not because a genuine likeness as judged by an adult, but because the child thinks the objects have something in common. For example, the child could group first triangles, then add trapezoids, as they made him think of triangles with their tops cut off; then trapezoids could lead to squares, squares to hexagons, hexagons to circles, and so forth.

According to Vygotsky, the development of concept formation proceeds from complexes to fully formed concepts through *pseudoconcepts*. To an adult observer, concepts and pseudoconcepts look similar, but their psychological history is very different. At this stage, the child correctly uses abstract concepts, but as a result of word meanings acquired from adults, not because the child's thinking would use spontaneously generated abstract concepts.

> "Adults, through their verbal communication with the child, are able to predetermine the path of the development of generalizations and its final point—a fully formed concept. But the adult cannot pass on to the child his mode of thinking. He merely supplies the ready-made meanings of the words, around which the child builds complexes. Such complexes are nothing but pseudoconcepts. They are similar to concepts in their appearance, but differ substantially in their essence." (Vygotsky, 1986:120)

Pseudoconcepts are generated as complexes in child's thinking, but their word meaning coincides with concepts used by adults. Therefore they act as a bridge between thinking in complexes and thinking in concepts. Using pseudoconcepts, the child begins to operate with concepts, to practice conceptual thinking, before he is clearly aware of the nature of these operations. The child can engage in adult forms of thinking, as in a "cognitive" play, where these forms can acquire meaning. As the child proceeds in this "zone of proximal development," his though processes change, and advanced cognitive processes emerge. (Vygotsky, 1978)

Proceedings of the 31st Hawaii International Conference on System Sciences, IEEE Computer Society Press, Los Alamitos, CA, January 1998, Vol. 1, pp. 68-75.

By organizing discrete elements of experience into groups, complex thinking creates a basis for later generalizations. But conceptual thinking requires more than unification of things. Some elements of the concrete experience need to be singled out, *abstracted*, from the totality of experience where they are embedded. In genuine concept formation, it is equally important to unite and to separate. According to Vygotsky, these two processes of generalization and abstraction undergo simultaneous development in child's thinking, eventually leading to advanced conceptual thinking.

In the first stage of abstraction, the child pays attention to some aspects of the objects, and groups together *maximally similar* objects based on the attended traits. In the second stage of the development of abstraction, the grouping of objects on the basis of maximum similarity is superseded by grouping on the basis of a single attribute. For example, an object can be categorized based on its shape or color. Vygotsky calls such formations *potential concepts*. Potential concepts may be formed either in the sphere of perceptual thinking or in that of practical, action-bound thinking—on the basis of similar impressions in the first case (e.g. "a pyramid"), and on the basis of the similar functional roles in the second (e.g., "a hammer").

According to Vygotsky, pure forms of thinking rarely exist, even in adults. More advanced cognitive processes are built on earlier ones, and fully formed conceptual thinking is only the most advanced form of thinking. Potential concepts play a role in associative complexes, for instance, as association presuppose the abstraction of one trait common to different units. As long as complex thinking predominates, however, the abstracted trait is unstable, and it has no privileged position. In proper potential concepts, a trait once abstracted is not easily lost again among the other traits. The totality of traits has been destroyed through its abstraction, and the possibility of unifying the traits on a different basis opens up.

According to Vygotsky, only the mastery of abstraction, combined with advanced complex thinking, enables the child to progress to the formation of genuine concepts. A concept emerges when the abstracted traits are synthesized anew and the resulting abstract synthesis becomes the main instrument of thought. (Vygotsky, 1986:139)

Central to Vygotsky was the idea that complex thinking is based on socially shared and culturally inherited language. Words fulfill different roles in the various stages of thinking in complexes. Complexes, as well as fully formed concepts, can be understood as stages in verbal thinking, and therefore in Vygotsky's point of view there is an essential difference between natural biologically grounded intelligence, and historically developed human intelligence. (Vygotsky, 1978) Abstraction, on the level of potential concepts, emerges early in development, and it is possible for animals as well as humans. For example, hens can be trained to respond to one distinct attribute in different objects, such as color or shape. But the other development path, that of thinking in complexes, is possible only because of language.

> "From our point of view, the processes leading to concept formation develop along two main lines. The first is complex formation: The child unites diverse objects in groups under a common 'family name'; this process passes through various stages. The second line of development is the formation of 'potential concepts', based on singling out certain common attributes. In both, the use of the word is an integral part of the developing processes, and the word maintains its guiding function in the formation of genuine concept, to which these processes lead." (Vygotsky, 1986:145)

In the development of thought, awareness and deliberate mastery of concepts eventually leads to fully formed conceptual thinking. Empirical and spontaneous concepts are re-organized within systems of concepts, where two dimensions of generalization define their relations: first, they have a degree of abstractness, i.e., distance from concrete empirical grasp of an object; second, they have a more or less broad ontological scope. The first of these dimensions is a characteristic of thought processes, the second a characteristic of their objective reference. For example, two concepts that are of the same degree of abstractness, e.g., plants and animals, may differ in their referents, as well as the number of objects within their scope. (c.f. Vygotsky, 1986:199)

Thinking in concepts can be understood only when concepts are seen as a part of the "fabric" made of concepts. Then, Vygotsky points out, we will discover that connections between concepts are neither associative nor structural, but are based on the principle of the relations in generality. Most fully developed, such systems of concepts consist of scientific concepts. Whereas spontaneous concepts are created by the child based on empirical interactions with the object world, scientific concepts are acquired through a social process of instruction. Development and learning, however, are tightly intertwined, new scientific concepts opening new possibilities for conceptual structuring, and building on available spontaneous concepts.

Vygotsky's posthumously published writings represent the development of his own thinking, and may sometimes be confusing and contradictory (Wertsch, 1985; Minick,

Proceedings of the 31st Hawaii International Conference on System Sciences, IEEE Computer Society Press, Los Alamitos, CA, January 1998, Vol. 1, pp. 68-75.

1996). One could argue that there is no fully formed Vygotskian model of the development of conceptual thought. At best, there are hermeneutic reconstructions of Vygotsky's model that correct some of the contradictions found in his writings.

One "reconstruction" of his theory of development of conceptual thinking may be built by focusing on the process of abstraction, viewing generalization and systematization as processes enabled by the development of abstraction. Such a model is depicted in Figure 1.

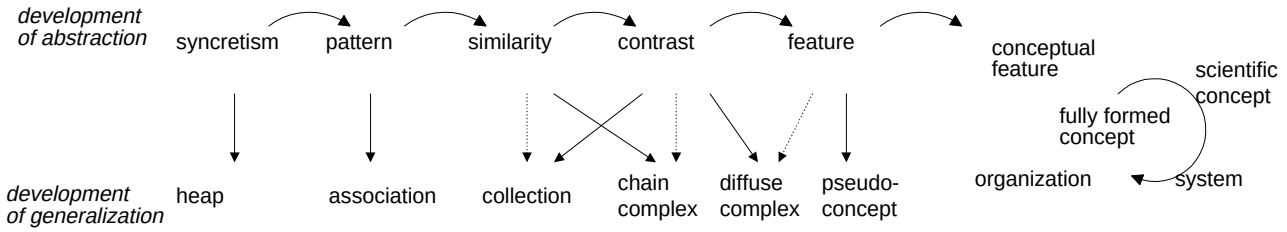

Figure 1. A model of Vygotskian theory on development of conceptual thinking.

Abstraction leads from syncretism to perceived similarity, contrast, and eventually features that are singled out as representative and relevant. As spontaneous concepts become available, these features become increasingly conceptual and "theoretical". Abstraction continues as a process where new layers of concepts are built on top of earlier ones, and where earlier concepts are simultaneously re-organized as conceptual systems for communication, social interaction, and meaning processing.

As more developed possibilities for abstraction become possible, new ways to categorize a world become available. Generalization leads from unorganized congeries, or heaps, to complexes comprising associative complexes built around a nucleus, collections, chain complexes, diffuse complexes, and eventually pseudo-concepts. When stabile features and pseudoconcepts become available, fully formed concepts can be created by organizing them into structures of generalization. Systematization then opens the opportunity for empirical spontaneous concepts to be organized within systems of non-spontaneous culturally and historically developed concepts, in some cases forming "scientific" systems that can be learned through instruction. From Figure 1., it can also be seen that until fully formed concepts become available, thinking is essentially empirical. Therefore, although communicative interaction is possible already when complexes emerge, only after the conceptual level is established, systems of meaning can become inter-generational.

TeamRoom and social construction of team worlds

TeamRoom is a Lotus Notes -based collaboration environment, designed by Lotus Institute to support the work of teams (Cole and Johnson, 1995). The design implements several interesting ideas and best practices on effective collaboration environments. A number of pilot studies have been conducted by Lotus Institute and other organizations during the development of the tool.

TeamRoom provides a template for a Lotus Notes application that can be tailored by each user team. The tailorability of TeamRoom applications, however, is limited to a carefully selected set of application parameters, and the process of deployment is designed to create a shared mental model within the team. This mental model is created during the deployment process. In essence, the tailoring of a TeamRoom for a specific team during the deployment process sets up a collective conceptual world from pieces provided by individual team members. The created world can then be shared and used by team members. During the deployment process, also roles and expectations are clarified, for example, by assigning one of the team members to the role of facilitator.

TeamRoom is intended to be used by small teams of less than a couple of dozen members. A team is defined as a group of people, who share a common goal. The set-up of a TeamRoom happens through a process, where the mission of the team is discussed, defined and documented, the expectations about the tool use are made explicit, and the categories used in the TeamRoom contributions are defined.

Categorization of contributions in a TeamRoom is based on a two dimensional model. Each Notes document within the TeamRoom has a defined communication type, and a category that relates it to a pre-defined work area. During the setup process, members of the team discuss the work areas that are relevant for the goal of the team. Each such work area will be defined as a category keyword that,

Proceedings of the 31st Hawaii International Conference on System Sciences, IEEE Computer Society Press, Los Alamitos, CA, January 1998, Vol. 1, pp. 68-75.

after the setup, can be used to categorize created documents. During the setup process the team also negotiates the communication types that will be used within the TeamRoom. These two obligatory categories mean that each contribution within the TeamRoom will be related to one or more work areas and its content type is used as a label for the contribution.

The TeamRoom design addresses three major problems in collaboration environments. First, to support action and work, the focus of activity in a TeamRoom is based on natural activity areas, or work categories. Contributions are in a context where they can be easily understood and acted upon. Second, as work proceeds and the number of documents grows, it becomes increasingly important to label the content for easy retrieval and to indicate expected actions. For this, defined communication types provide structure. Third, in general, a team collaboration system needs to support various teams and the evolution of their conceptual worlds. TeamRoom design ensures that appropriate categories are negotiated and shared within the team before it starts to use the system. During the actual work, new categories can be formed and old ones deleted, but only through a controlled process that maintains these shared conceptual models. In this way, the TeamRoom design integrates the tool and social processes that underlie collaboration.

TeamRoom can be used in a number of ways. Simply using the work categories and communication types to label documents stored in a TeamRoom make it a document library, where documents can be found in context. Another way to use TeamRoom is to define communication types that enable threaded discussions. Full use of the capabilities of TeamRoom, however, make it a real collaboration environment, where documents are collectively created, shared, and stored for organizational memory; where distributed and asynchronous team discussions are supported; and where actual work gets done.

An experiment in concept formation

The original concept formation test that Vygotsky uses as the basis for his discussions on development of conceptual thinking, was conducted by Lev Sakharov in 1930 (see Vygotsky, 1986:103-4). The test uses 22 wooden blocks varying in color, shape, height, and size. On the underside of each figure, which is not seen by the subject, is written one of the four nonsense words: *lag*, *bik*, *mur*, *cev*. Regardless of color or shape, lag is written on all tall large figures, bik on all flat large figures, mur on the tall small ones, and cev on the flat small ones. The examiner turns up a sample, shows and reads its name to the subject, and asks the subject to pick out all the blocks which the subject thinks might belong to the same kind. After the subject has done so, the examiner turns up one of the "wrongly" selected blocks, shows that this block has a different word written at its bottom, and encourages the subject to make a new try. After some trial and error the subject learns to group all the blocks based on the name on their bottom. The types of conceptual thinking used by the subject can be inferred from the nature of the groups he or she builds, as nearly every step in the reasoning is reflected in the manipulation of the blocks. "The first attack on the problem; the handling of the sample; the response to correction; the finding of the solution—all these stages of the experiment provide data that can serve as indicators of the subject's level of thinking." (Hanfmann and Kasanin, 1942:42)

The Sakharov experiment was designed to create data on the development of conceptual thinking. In different ages, children grouped wooden blocks differently, and reacted differently to the errors. Small children created heaps of blocks, older children utilized various types of complex thinking, eventually becoming able to sort the blocks based on abstract categories, and to associate a nonsense "concept" word with the category.

Vygotsky's interpretation of the Sakharov's experiment assumed that fully formed conceptual thinking is based on synthesizing abstract features, like "height" and "smallness," into combinations that can then be applied to other objects. In Sakharov's experiment, the relevant features and their combinations were pre-defined, and the problem for the subject was to discover a given concept that was associated with a nonsense word.

In electronic collaboration environments and ecological settings the situation is different. A major problem is understanding the ways other people in the environment categorize the domain. The categories may be idiosyncratic, they are not predetermined, and there is typically no one "right" way to categorize the domain of discourse. Moreover, the interpretation of a concept evolves as the conceptual system develops. Distributed collaboration environments lack many commonly utilized means to build a shared conceptual world, and the social construction of reality is difficult as much of it relies on written interactions.

Although Vygotsky discussed mainly the development of child thinking, within the Vygotskian framework it becomes obvious that learning does not end in adolescence. In teams of adult people, learning is a continuous process. New concepts are created, shared, and developed into systems. The question, then, becomes how spontaneous categories are collectively generated in teams, how they become integrated as systems, and how computer mediated environments affect these processes.

Proceedings of the 31st Hawaii International Conference on System Sciences, IEEE Computer Society Press, Los Alamitos, CA, January 1998, Vol. 1, pp. 68-75.

To study these processes, and to evaluate the relevance of Vygotsky's model of concept formation, we modified the Sakharov experiment for distributed collaboration in a TeamRoom.

Concept generation in the TeamRoom

The exploratory experiment in TeamRoom was a simple modification of the Sakharov experiment: in an actively used TeamRoom we created four new categories: *lag*, *bik*, *mur*, *cev*. Breaking the assumptions on appropriate use of TeamRoom these categories were not negotiated with the team members, and the category definitions were not disclosed to them. New categories were created one by one and at the beginning the number of new categories was not revealed. Instead, a simple informational message was posted as the first document in the new *lag*-category, explaining that there will be a couple of new categories. In this message, team members were also asked to create a private document visible only to the experimenter, giving a definition of the nonsense category word as soon as it seemed to be clear. New documents were created in the experiment categories, approximately one document per day.

All members of the team were experienced TeamRoom users. The team was actively trying to develop a conceptual framework for knowledge management, reviewing promising ideas and best practices in the scientific, consulting, business, and information technology domains. The contributions in the nonsense categories were part of that work.

The exploratory study tried to find answers to the following questions:

- How long it takes to discover the meaning of the nonsense word?
- Are there group processes involved; for example, will the team members learn the concept definitions from each other?
- What happens when a category definition devised by a team member becomes too narrow?
- How long it takes before a category can be actively used?
- Can the Vygotskian theoretical framework be applied in distributed collaboration environments?

Results

During the first three weeks of the experiment several unexpected observations were made.

On the fifth day of the experiment—two days after the second category *bik* was created with a single document—one team member used the category in his own contribution. On the ninth day, category *mur* was created as the fourth nonsense category with one document. Three hours later one team member used it successfully. On the ninth day, the first private document with suggestions for category definitions was created by a team member.

These observations indicate that team members were willing and confident enough to use new nonsense categories even though there was clearly insufficient information available about their exact definitions. One could assume that this behavior resulted from two factors: small perceived risk associated with errors in guessing the appropriate use, and high perceived probability of guessing right. As a result of earlier socialization, some team members seemed to have high level of trust that errors will be seen as constructive attempts to learn, and not as opportunities for punishment. In such an environment, "educated guesses," open communication, and mistakes have low cost. A reasonable probability of getting the nonsense concept right is, in turn, guaranteed by the shared context that results from effective socialization.

One could also argue that the appropriate use of category labels does not require that their definitions are known. Indeed, such use would be similar to the use of pseudoconcepts, in this case putting a team of adults simultaneously into their collective zone of proximal development. Already before the concept is fully internalized, it is possible to engage in social collaboration using the nonsense word. The mode of internalization in this case contrasts with those forms of conceptual development where concepts are introduced through defining their meaning in relation to an already existing conceptual system. In the Vygotskian terminology, the latter alternative corresponds to learning "scientific" concepts, the former to learning "spontaneous" concepts.

This process of making educated guesses, however, is not without risk. On the fourteenth day, one team member created a document using category *bik*. The appropriate category would have been *mur*. Within two hours, another team member made the same mistake. In the following day, another team member made the same error again. The documents were re-categorized by the experimenter on the 18th day. On the 21st day, one team member created three new documents in *bik*. These were re-categorized by the experimenter so that each document was in two categories, *bik* and *lag*.

Around that time, one team member complained to other team members about the nonsense categories, and argued that they should immediately be replaced by meaningful category names. When creating a document on the 24th day, he put the document to all nonsense categories. The document was re-categorized by another team member, who was acting as the facilitator for the TeamRoom.

Proceedings of the 31st Hawaii International Conference on System Sciences, IEEE Computer Society Press, Los Alamitos, CA, January 1998, Vol. 1, pp. 68-75.

These preliminary observations need to be elaborated based on a more detailed survey that will analyze the degrees of generalization used by the members and explicate the group processes used during the test. It is, however, clear that in this experimental setup, a number of observations can be made:

Team members assumed that there is a reasonable—although hidden—set of categories which map to the problem domain. The problem was seen as a problem of discovering the experimenters mental model and making sense of his private language. In practice, the team members seemed to create alternative plausible models of the world, and guess which of these is the one used by the experimenter. In some cases, a minimal clue was sufficient to lock parts of the model. This obviously requires that the team members already have a model of the experimenter's thought processes. As the experimenter was one of the team members, the problem domain was shared. This made it easier for the subjects of the experiment to understand the various ways that could be used to categorize it. Learning was in some cases extremely fast, as most of the learning was about a meta-model of the domain, not the domain itself.

In actual collaboration situations, there is no "right guess" that would solve the problem of domain categorization. Instead, the language evolves as team members use it and create knowledge about the domain. The concepts acquire new meaning, sometimes requiring a complete revision of the conceptual structure.

In organizational memory and collaboration systems, the evolution of meanings often leads to erosion of the conceptual basis. The meanings of the conceptual categories change, eventually leading into problems as fully formed concepts become unstable diffuse complexes. The process of accumulating organizational memory in team environments looks similar to a formation of a chain complex, where each unit links with the following one, but where the beginning and end do not have anything in common.

Concluding remarks

In TeamRoom the development of team and domain specific private language is possible when the tool is used as a part of a social process that maintains the language. This is the fundamental reason for the requirement that teams are "small." Only if the team can effectively negotiate concepts and meanings throughout the team process, the conceptual structure can be maintained. In theory, such conceptual maintenance doesn't require face-to-face discussions, and could be supported by the TeamRoom itself. In practice, however, it seems that social construction of shared worlds and related languages is a process that requires physical presence. Moreover, it seems that traditional means of socialization are important in creating trust, which is required for team members to take risks associated with erroneous guesses.

Vygotsky argued that speech and written communication have very different cognitive processes involved, as writing requires awareness of concepts. This may mean that especially in teams that create new knowledge, writing can not replace speech. According to Vygotsky, performance always comes before awareness of it. Knowledge, when created, is always tacit.

Vygotsky's main thesis was that almost all conceptual knowledge is social, before it becomes internalized. Therefore, his theoretical framework is inherently able to address learning on both the social and individual levels of analysis, in contrast to most alternative descriptions of organizational learning and knowledge creation. Vygotsky's model of the development of thinking also easily accommodates situations where new conceptual structures are collectively built. Vygotsky's main contribution to developers of collaboration systems may be in his insightful analysis of the nature of linguistic forms of thought, and their relation to various forms of cognitive artifacts. Social history, culture, and its signs, practices, and artifacts are not only transferred from a generation to the next, but they are continuously in the making. The deployment of a collaboration system, therefore, not only changes the way things are done, but it also changes the way we think. Most important, qualitatively new collaboration tools imply qualitatively new forms of intelligence.

Proceedings of the 31st Hawaii International Conference on System Sciences, IEEE Computer Society Press, Los Alamitos, CA, January 1998, Vol. 1, pp. 68-75.

References

Berger, P.L. and T. Luckmann (1966). *The Social Construction of Reality: A Treatise in the Sociology of Knowledge.* Penguin Books, New York.

Bruner, J. (1986). *Actual Minds, Possible Worlds.* Harvard University Press, Cambridge, MA.

Cole, M. (1996). *Culture in Mind.* Harvard University Press, Cambridge, MA.

Cole, P. and E.C. Johnson (1995). Lotus deploys TeamRoom: A collaborative application for work teams.

Engeström, Y. (1996). *Non scolae sed vitae discimus*: toward overcoming the encapsulation of school learning. In H. Daniels (ed), *An Introduction to Vygotsky.* Routledge, London, pp. 151-170.

Engeström, Y. and D. Middleton (1996). *Cognition and Communication at Work.* Cambridge University Press, Cambridge.

Gibson, J.J. (1979). *The Ecological Approach to Visual Perception.* Houghton Mifflin, Boston.

Gregory, R.L. (1981). *Mind in Science: A History of Explanations in Psychology and Physics.* Penguin Books, London.

Hanfmann, E. and J. Kasanin (1942). *Conceptual Thinking in Schizophrenia.* NMDM, New York.

Hutchins, E. (1995). *Cognition in the Wild.* MIT Press, Cambridge, MA.

Lave, J. and E. Wenger (1991). *Situated Learning: Legitimate Peripheral Participation.* Cambridge University Press, Cambridge.

Leont'ev, A.N. (1978). *Activity, Consciousness, and Personality.* Prentice-Hall, Englewood Cliffs, NJ.

Minick, N. (1996). The development of Vygotsky's thought: an introduction to Thinking and Speech. In H. Daniels (ed), *An Introduction to Vygotsky.* Routledge, London, pp. 28-52.

Norman, D.A. (1993a). *Things That Make Us Smart.* Addison-Wesley, Reading, MA.

Norman, D.A. (1993b). "Cognition in the head and in the world: An introduction to the special issue on situated action," *Cognitive Science*, **17**, pp.1-6.

Scribner, S. (1997). *Mind and Social Practice: Selected Writings of Sylvia Scribner.* Cambridge University Press, Cambridge.

Suchman, L. (1987). *Plans and Situated Actions: The Problem of Human-Machine Communication.* Cambridge University Press, New York.

Vygotsky, L. (1978). *Mind in Society: The Development of Higher Psychological Processes.* Harvard University Press, Cambridge, MA.

Vygotsky, L. (1986). *Thought and Language.* The MIT Press, Cambridge, MA.

Weick, K.E. and K.H. Roberts (1993). "Collective mind in organizations: heedful interrelating on flight decks," *Administrative Science Quarterly*, **38**, pp.357-381.

Wertsch, J.V. (1991). *Voices of the Mind: A Sociocultural Approach to Mediated Action.* Harvard University Press, Cambridge, MA.

Wertsch, J.V. (1985). *Vygotsky and the Social Formation of Mind.* Harvard University Press, Cambridge, MA.

Proceedings of the 31st Hawaii International Conference on System Sciences, IEEE Computer Society Press, Los Alamitos, CA, January 1998, Vol. 1, pp. 68-75.