DOCUMENT RESUME

ED 436 153 IR 019 778

AUTHOR	Gilbert, Linda S.
TITLE	Where Is My Brain? Distributed Cognition, Activity Theory, and Cognitive Tools.
PUB DATE	1999-02-00
NOTE	12p.; In: Proceedings of Selected Research and Development Papers Presented at the National Convention of the Association for Educational Communications and Technology [AECT] (21st, Houston, TX, February 10-14, 1999); see IR 019 753.
PUB TYPE	Reports - Evaluative (142) -- Speeches/Meeting Papers (150)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Cognitive Processes; *Computer Uses in Education; Educational Technology; *Educational Theories; Literature Reviews; Role
IDENTIFIERS	*Activity Theory; Computer Use; Conceptual Frameworks; *Distributed Cognition; Technology Role; Technology Utilization

ABSTRACT

This paper provides a general overview of distributed cognition and activity theory in order to provide perspective for a discussion of the computer as a cognitive tool. Both distributed cognition and activity theory enlarge the scope of cognition to include the individual's interactions with the environment. Activity theory offers a framework congruent with distributed cognition that addresses some of its concerns. Despite the complexity of its vocabulary and concepts, it offers the potential for increased interdisciplinary exploration of issues related to cognitive tools. A table presents the division of labor between computers and single users as evidenced in computer roles, including computer roles ranging from servant to expert, goals (desirable outcomes), concerns (undesirable outcomes), and questions (contradictions). (Contains 48 references.) (Author/MES)

Where Is My Brain?: Distributed Cognition, Activity Theory, and Cognitive Tools

By:

Linda S. Gilbert

WHERE *IS* MY BRAIN?: DISTRIBUTED COGNITION, ACTIVITY THEORY, AND COGNITIVE TOOLS

Linda S. Gilbert
The University of Georgia

Abstract

This paper provides a general overview of distributed cognition and activity theory in order to provide perspective for a discussion of the computer as a cognitive tool. Both distributed cognition and activity theory enlarge the scope of "cognition" to include the individual's interactions with the environment. Activity theory offers a framework congruent with distributed cognition that addresses some of its concerns. Despite the complexity of its vocabulary and concepts, it offers the potential for increased interdisciplinary exploration of issues related to cognitive tools.

Introduction

Though not in total alignment, a number of current learning theories focus on the interaction of the individual with the environment in gaining and using knowledge, drawing on concepts related to those of Vygostsky, Dewey, and the Gestalt psychologists. Examples include activity theory, situated cognition, and distributed cognition (Carroll, 1997; Cole & Engeström, 1993; Hutchins, 1995; Nardi, 1996; Prawat, 1996). These theories are of increasing interest as computers become an integral part of the environment in which knowledge is gained and used. This paper will provide a general overview of distributed cognition and activity theory in order to provide perspective for a discussion of the computer as a cognitive tool.

Situated cognition, distributed cognition, and activity theory

The terms "situated cognition," "distributed cognition," and "activity theory" share similar concepts, and sometimes overlap in use. Distinctions are not always clear. All move from studying the individual in relative isolation, to studying the larger systems, in which people live and work. In addition to their focus on interactions between the individual and the community, a distinguishing characteristic that these theoretical perspectives have in common is their acknowledgement that a portion of the cognitive power used by an individual resides in artifacts or tools created by the larger society. These tools may be physical, or they may be technologies or concepts, or a combination.

Situated cognition theories (and related concepts such as cognitive apprenticeships) stress that individual development occurs in a realistic environment, and is highly contextual (Brown, Collins, & Duguid, 1989; Collins, 1988; Lave & Wegner, 1991; Wilson, 1993). Criticisms of this theory focus on charges of over-estimating the specificity of knowledge, failing to account for the individual's ability to transfer from context to context, and failing to consider the effects of "persistent structures" and their design (Anderson, Lynn, & Simon, 1996; Nardi, 1996b).

In distributed cognition, the unit of analysis extends beyond the individual to include the context within which the individual operates. Further, cognition is seen as less a function of the individual as much as a function of an overall system that includes groups of individuals and their tools (Hutchins, 1995). Cognition may distributed socially, across groups of people, or may be distributed across artifacts and tools, or both. Thus, proponents of distributed cognition acknowledge that situational factors such as social processes not only affect individual cognition, but can be treated as integral to the cognitive process (Hutchins, 1995; Lajoie & Derry, 1993; Salomon, 1993a).

Moving the unit of analysis from the individual to the larger system raises uncomfortable questions about the role of the individual relative to the system, particularly when talking about computers (Pea, 1993; Perkins, 1993; Salomon, 1993b). Distributed cognition has been criticized for emphasizing system goals at the expense of individual goals, or, in Nardi's terms, assuming a "conceptually equivalent" relationship between people and artifacts (Nardi, 1996b). However, many proponents of distributed cognition go to great lengths to avoid such an equivalence. For example, Salomon uses the terms "analytic" and "systemic" to draw distinctions between the abilities of the individual and the system, and Pea eschews the term "distributed cognition" in favor of "distributed intelligence" because, in his words, "*people*... 'do' cognition." (Pea, 1993; Salomon, 1990; Salomon, 1993b; Salomon, Perkins, & Globerson, 1991).

Activity theory, a development of sociocultural theory, offers a flexible framework that addresses many of these concerns, one that some authors already see as merging with or even subsuming the concept of distributed cognition (Carroll, 1997; Nardi, 1996b). Activity theory specifically states that relations between individuals and artifacts are not symmetrical; artifacts may be mediators of human thought and behavior, but human motive and consciousness belong to people, not things (Kaptelinin, 1996b). Conceptually, distributed cognition and activity theory are very closely related; the same collection of articles will often include both perspectives (see, for example, Salomon, 1993a). In many cases, ideas from distributed cognition and from activity theory seem indistinguishable: Pea (1993), writing under the banner of distributed cognition, addresses important themes that are conceptually equivalent to those in activity theory. Such contributions are of great value, and should not be overlooked. However, activity theory offers a broader and more developed theoretical framework in which to examine questions related to the distribution of cognition.

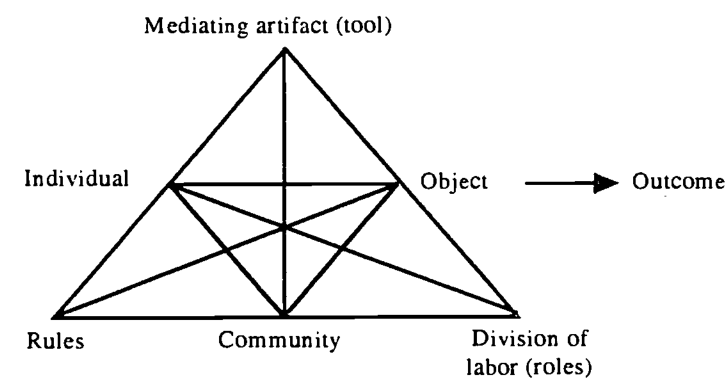
Activity theory

The underlying concepts of activity theory originate in the work of Leont'ev, a follower of Vygotsky (Leont'ev, 1978). Confusingly, "activity theory" now refers to both the original Soviet psychology tradition and to more recently developed theories that extend and develop the original concepts (Cole & Engeström, 1993; Kuutti, 1996). Current contributors are international and interdisciplinary, including representatives from psychology, anthropology, human-computer interaction (HCI), cultural research, and other social sciences. The history and development of activity theory is beyond the scope of this paper, which will sketch only a few key concepts, but numerous references offer more comprehensive discussions (for example, Cole, 1995; Cole, Engeström, & Vasquez, 1997; Nardi, 1996a).

The activity system

Activity theory provides a powerful descriptive framework focused around a "mediated activity system," which "comprises the individual practitioner, the colleagues and co-workers of the workplace community, the conceptual and practical tools, and the shared objects as a unified dynamic whole" (Engeström, 1992). Figure 1 depicts a general activity system as described by Engeström.

Figure 1. Model of an activity system, adapted from Engeström (1992).



Carroll (1997) describes activity theory as follows:

> The object of description in this approach is an "activity system," the ensemble of technological factors with social factors, and of individual attitudes, experiences and actions with community practices, traditions, and values. Activity theory emphasizes that these ensembles are inherently contingent and changing, that human activities are mediated and transformed by human creations, such as technologies, and that people make themselves through their use of tools.... Activity theory shifts attention from characterizing static and individual competencies toward characterizing how people can negotiate with the social and technological environment to solve problems and learn, which subsumes many of the issues of situated and distributed cognition. (p. 512)

In Engeström's model of an activity system, the components of the system continually influence and transform one another; the lines in the figure are sometimes even drawn as double-headed arrows, to reflect such mutual influences. At the same time, each system is a node in a network of related activity systems; for example, tools in an activity systems are products of previous activity systems for tool production (Engeström, 1992). Thus, current activity systems are influenced by layers of historical development.

The vocabulary related to activity theory is complex, and requires some patience during initial contact. A few key concepts relating to activity theory are needed for further discussion; however, this overview should be considered as only a preliminary introduction to the topic.

Activities, actions, and operations

Kuuti (1996) provides an excellent description of the hierarchical levels of an activity. At the highest level is an *activity*, which is essentially defined at the level of motives or goals. "An activity is a form of doing directed to an object, and activities are distinguished from one another according to their objects. Transforming the object into an outcome motivates the existence of an activity" (Kuutti, 1996, p. 27). *Objects* are an important and difficult construct in activity theory, since the term is used both in the sense of "objective," as in purpose or intention, and in the sense of the "thing" to be transformed (Kuutti, 1996; Nardi, 1996b). Kuutti (1996) observes that the original Russian term for activity carries the connotation of 'doing in order to transform something,' which he considers essential (p.41). Thus, while "objective" or goal is probably the easiest English translation for beginners, it is not complete.

Objects can and do evolve and change during an activity system, but are relatively slow to change. *Actions* are shorter-term processes underlying activities, which accomplish goals related to the activity. Actions require the context of an activity to be understood. An activity can be achieved through a variety of actions, and a single action can belong to multiple activities. The example Kuutti offers is the action of making a workplace project report, which might belong to a "project management" activity or to a "competing for promotion" activity.

Below the level of actions are *operations*, "well-defined habitual routines used as answers to conditions faced during the performance of an action." (Kuutti, 1996, p. 31). Kaptelinin offers this distinction between the three levels:

> The criteria for separating these processes are whether the object to which the given process is oriented is impelling in itself or is auxiliary (this criterion differentiates between activities and actions), and whether the given process is automatized (this criterion differentiates between actions and operations). (Kaptelinin, 1996a, p. 108-109).

However, actions can be folded into operations as they become more familiar, and operations can return to the level of actions in response to changing conditions that demand greater attention. The boundaries between actions and activities are equally fluid, and movement is possible in both directions.

Functional organs

Another key concept concerns *functional organs*, or goal-directed combinations of human abilities with tools that improve existing capabilities, or even allow new functions (Kaptelinin, 1996a; Kaptelinin, 1996b; Zinchenko, 1996). These combinations can be seen as belonging to the individual, much as the stick of Bateson's blind man can be considered as an extension of his senses, and can be quite temporary in nature (Cole & Engeström, 1993; Kaptelinin, 1996b).

Some functional organs extend the *internal plane of action* (IPA), or the capability for mentally representing and transforming external objects (Zinchenko, 1996). This is an important and complex concept: activity theory explicitly attempts to describe interactions between internal consciousness and the external world in a non-dualistic manner. "Context is both internal to people – involving specific objects and goals – and, at the same time, external to people, involving artifacts, other people, specific settings. The crucial point is that in activity theory, external and internal are fused, unified..." (Nardi, 1996b, p.76).

Contradictions

Because activities are affected by related activities, tensions are inevitable. The terms *contradiction* and *breakdown* refer to misfits between different activities, or even among elements in an activity system. Such contradictions are sources of tension, but can also be sources of development (Cole & Engeström, 1993; Kaptelinin, 1996b). According to Cole (1993) "Activity systems are best viewed as complex formations in which equilibrium is an exception and tensions, disturbances, and local innovations are the rule and the engine of change." (p. 8). Explicitly identifying contradictions within a system can lead to positive changes (for case studies, see Cole & Engeström, 1993; Engeström, 1992; Favorin & Kuutti, 1996).

Artifacts as mediators of human action

Artifacts – tools, symbols, and signs – are the result of previous activity systems. They incorporate "crystallized" knowledge and implicit goals, which can shape the goals of their users (Kaptelinin, 1996b). At the same time, users actively create the meaning of a tool as they interact with it and the environment, and do not merely react to "affordances" (Kaptelinin, 1996b).

An interesting perspective is that artifacts are created by people to provide external support and control. "Artifacts, broadly defined to include instruments, signs, languages and machines, mediate activity and are *created by people to control their own behavior.* Artifacts carry with them a particular culture and history (Kuuti 1991) and are persistent structures that stretch across activities through time and space." (Nardi, 1996b, p. 75. Emphasis added.) Carroll's (1996) description of activity theory includes the phrase "people make themselves through their use of tools" (p. 512).

These perspectives on artifacts will contribute to the following discussion of the computer as a cognitive tool.

Current areas of development

Activity theory combines a number of the elements of concern to educational technologists into a powerful descriptive framework. In the United States, two groups have been especially influential in extending and refining activity theory. At the Laboratory of Comparative Human Cognition in San Diego, Cole and Engeström form the center of a group who concentrate on the cultural contexts of learning and work, juxtaposing activity theory with the work of Jean Lave, James Wertsch, Dewey, and various sociocultural anthropologists (Cole et al., 1997). Another core has developed within the field of human-computer interaction (HCI). This group, which includes Nardi, Kuutti, and Kaptelinin, sees activity theory as providing a contextual framework for the consideration of artifacts (especially computers) that connects to previous HCI research directions (Carroll, 1997; Nardi, 1996a). In their explorations of activity theory, these groups draw on overlapping research traditions and integrate previous research with this developing descriptive framework.

Applying activity theory to educational technology

Many current concerns of educational theory, particularly as related to computers, can be discussed using activity theory, which offers a flexible framework that addresses the dynamic and complex nature of educational interactions. For example, the description of activities, actions, and operations can clearly be related both to motivational theories and to cognitive theories about "chunking." The active role of the individual corresponds to a constructivist viewpoint, while the inclusion of both individual and community goals incorporates the social dimension of knowledge and culture. The conceptualization of artifacts encompasses theories about "affordances," while acknowledging both the situated nature of artifacts-in-use and the learned responses of the individual user. Though researchers may be interested in exploring specific relationships within an activity system, describing these interactions as part of an overall system maintains an awareness of contextual factors – the "forest" within which the "trees" are rooted.

While the descriptive power of activity theory can most easily be brought to bear on specific cases and situations, applying the framework to describe larger issues can also be profitable. Here is an example of how the vocabulary of activity theory can enrich understanding some of the issues surrounding computers as cognitive tools.

Using activity theory to describe the computer as a cognitive tool

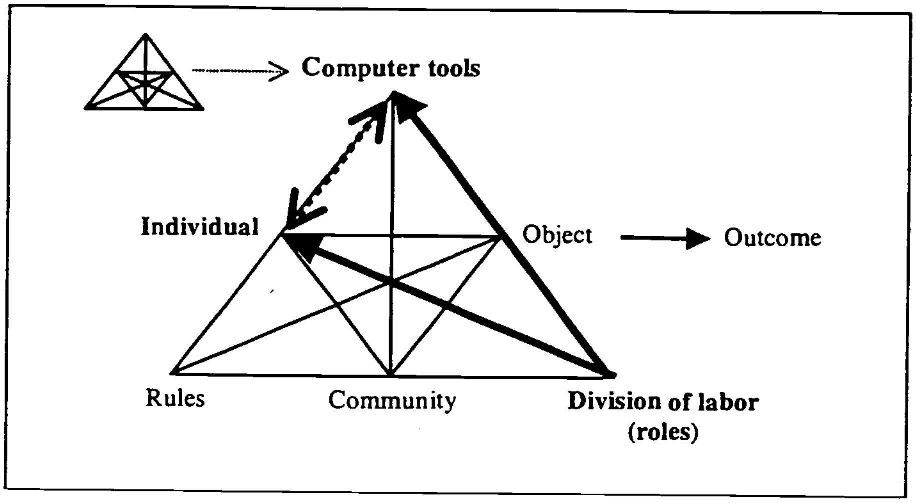
Jonassen and Reeves (1993) offer the following definition of cognitive tools: "Cognitive tools refer to technologies, tangible or intangible, that enhance the cognitive powers of human beings during thinking, problem solving, and learning. Written language, mathematical notation, and most recently, the universal computer are examples of cognitive tools." (p. 693).

Many authors distinguish using the computer as a cognitive tool from using it as a medium for the delivery of instruction, often linking to constructivist learning principles in which the learner designs with the tool. (Cole & Engeström, 1993; Jonassen & Reeves, 1996; Lajoie, 1993; Pea, 1993; Pea, 1985; Perkins, 1993; Salomon, 1993a; Salomon, 1993b; Salomon, 1993c; Salomon et al., 1991). However, "enhancing cognitive powers" can be interpreted in multiple ways, and affect what one considers a cognitive tool. At one extreme, some limit the term to tools that intentionally develop human capability, however that development is accomplished. At the other extreme, tools that augment human performance (and perhaps make some learning unnecessary) are included. In between are a range of programs such as microworlds, intelligent tutoring systems, expert systems, and the now-commonplace computer applications usually shelved under "productivity programs" – for example, spreadsheets, databases, and word-processing programs.

One of the discussions associated with cognitive tools is their effects on the person using the tool; a particular concern is the inadvertent "de-skilling" of the user. In the context of distributed cognition, Salomon has provided a critical distinction between effects *with* and effects *of* the computer (Salomon, 1990). Effects *with* the computer refer to the efficacy of the total system (the person-plus-computer). In contrast, effects *of* the computer refer to the "cognitive residue" left upon the person, changes evident when operating as a solo performer. Salomon also proposes evaluating human-computer partnerships according to *systemic* and *analytic* criteria. The former looks at the total performance (effects with), while the latter specifies the specific contributions of user and system. Pea (1993) acknowledges the distinction between analytic and systemic criteria, but takes issue with the assumption that a low proportion of user contribution is cause for alarm. He persuasively argues Salomon's approach is overly simplistic, and fails to consider the evolving relationships between the users and tools.

Looking at this discussion through the filter of activity theory clarifies the two separate kinds of interaction under consideration. One involves the role of the computer. There are goals inherent in the design of the computer program in question, which is the outcome of a previous activity system. One way these goals are evidenced is in the division of labor between the individual and the computer in the current activity system, or the role that the computer plays in the system (See Figure 2). The dark solid line indicates that interaction.

Figure 2. Describing computers as cognitive tools within an activity system.



The dotted line indicates the second area of consideration, which are the interactions and transformations between the individual and the program. These include both the "cognitive residue" upon the person and the individual's adaptation of the tool to his or her own goals (possibly in ways unforeseen by the developers). Like all interactions in an activity system, these two interactions are mutually influenced by one another, and by the other interactions within the system, but focusing on them separately for the moment allows goals and concerns to be more clearly identified for discussion.

Distinguishing between these two types of interactions helps to clarify the issues surrounding cognitive tools, and identify some of the points of tension (contradictions or breakdowns) within the discussion.

The following synthesis draws on the literature specifically discussing cognitive tools (for example, Jonassen & Reeves, 1996; Pea, 1985; Perkins, 1993; Salomon, 1990; Salomon, 1993a; Salomon, 1993b; Salomon, 1993c), from the literature on electronic performance support systems (EPSS's), a type of cognitive tool most commonly used in business (for discussion, see Collis & Verwijs, 1995; Dorsey, Goodrum, & Schwen, 1993; Gery, 1995; Laffey, 1995; Raybould, 1995; Rosenberg, 1995; Scales & Yang, 1993), and from considerations of computer-based learning environments (Cognition and Technology Group at Vanderbilt University, 1991; Hannafin, 1992; Lajoie, 1993; Land & Hannafin, 1996).

In Table 1, the first column addresses the division of labor commonly discussed in relation to computers as cognitive tools. Of course, this division could be conceptualized in multiple ways. In this analysis, the division is considered not in terms of specific tasks, but in terms of the role that the computer plays in respect to the user: expert, intellectual partner, or servant. Such roles are of course fluid, and may be operative at different points during the use of the same program.

Table 1. Considering the "division of labor" between computers and single users as evidenced in computer roles.

	POTENTIAL INFLUENCES UPON THE INDIVIDUAL		
COMPUTER ROLES	goals (desirable outcomes)	Concerns (undesirable outcomes)	questions (contradictions)
Expert Partner Servant	• teaches user, improving solo performance • creates "zone of proximal development" • scaffolds (as in cognitive apprenticeships) • identifies processes and strategies • provides tools for knowledge representation • provides feedback on decisions • provides situated learning experiences in the context of performance • extends capabilities in a synergistic relationship • allows focus on strengths • allows off-loading of onerous mental tasks • reduces need to learn unnecessary information	• allows successful outcomes without learning • encourages over-reliance on "authority" of the computer. • fails to develop necessary skills • develops "useless" skills • encourages emphasis of form over content • fails to develop reflective skills • extends capabilities for error • obscures critical decision points • reduces human abilities • reduces "executive control" of tasks • reduces command of necessary information	• What are the competencies and skills needed in today's society? • What balance should exist between process and product? How do we evaluate the two? • How should skills for monitoring, assessment, and reflection be developed? • What information, knowledge, or skills ought people have "in their heads," as solo performers? Why? • Can software design ensure that users perceive critical information and decision points?

In the "servant" role, the computer primarily supports lower-level cognitive processes in order to free the user to engage in higher level activities, or augments memory. Users may off-load tedious or repetitive tasks, or refer to stored information. They may also create reminders or similar low-level procedural supports.

As the computer offers increased informational access, procedural support, and representational capabilities, its role is more comparable to a partner or expert. The distinction between these roles can be subtle, and may have less to do with the capabilities of the tool than with the nature of the interactions between the user and the computer – specifically, how much of the "goal direction" is assumed by the computer, and how much is consciously retained by the user. In an expert system, the intelligence built into the computer program is responsible for decisions, and the user relies upon it for guidance. Expert systems can encourage learning by modeling problem-solving strategies or working methods, or they may operate in a "black box" fashion.

As a partner, the user and the computer work in an interactive partnership, directed by the user's intent. The computer not only amplifies but re-organizes mental functioning (Pea, 1985; Perkins, 1985; Perkins, 1993). In this role, the computer most approaches being a *functional organ,* increasing the ability to represent problems and to envision the results of potential decisions.

In the second column of Table 1, the goals and concerns of developers and researchers concerning potential influences on the individual, or "cognitive residues," are grouped, roughly corresponding to the role of the computer. The division into desirable and undesirable categories reflects the general discussion in the literature, though many items could be debated. These goals and concerns are obviously shaped by historical influences, including the values of the educational community.

From this simple organizational strategy, some interesting questions can be developed, which are presented in the final column of the table. These questions are complex, but by no means exhaustive. They merely illustrate the kinds of underlying tensions that shape the development and assessment of cognitive tools – potential contradictions, in activity theory terminology.

Looking at this portion of this particular type of activity system is only the beginning. A more comprehensive examination of this same interaction would consider not only the computer's impact on the user, but the *user's* impact on the *computer*, which might include creating a knowledge base or constructing specialized tools (Laffey, 1995; Lesgold, 1993). Other aspects of the activity system should also be considered, and patterns identified: for example, in discussions of EPSS's and other workplace computer systems, contradictions between community objectives (the goals of the organization implementing the system) and individual objectives (the goals of a typical end-user) are gaining increasing attention (Carroll, 1997; Kling & Jewett, 1994; Scales & Yang, 1993). Alan Cooper, speaking from decades of experience as a software developer and interface designer, offers a trenchant description of a typical contrast:

The user's goals are often very different from what we might guess them to be. For example, we might think that an accounting clerk's goal is to process invoices efficiently. This is probably not true. Efficient invoice processing is more likely the goal of the company or the clerk's boss. The clerk is more likely concentrating on goals like:

- Not looking stupid
- Not making any big mistakes
- Getting an adequate amount of work done
- Having fun (or at least not being too bored).

If you think about it, those are pretty common goals. (Cooper, 1995, p. 12).

They are pretty common goals, and seem to be as prevalent in education as in business. Perkins (1985) points out that an individual goal of many student users of computers seems to be "avoiding cognitive load," citing programming examples involving Logo. Obviously, there is a contradiction between this goal and the objectives of the educational community!

Areas for additional research

Writing about cognitive tools for pedagogy, Salomon points out that

> No tool is good or bad in and of itself; its effectiveness results from and contributes to the whole configuration of events, activities, contexts, interpersonal processes taking place in the context of which is used....If nothing significant changes in the classroom save the introduction of a tool, few if any important changes can be expected. (Salomon, 1993c, p. 189)

Research confirms that tools like Logo can have widely different effects when used in varying contexts. (Jonassen & Reeves, 1996; Pea, Kurland, & Hawkins, 1987). Salomon (1994) points out in regard to media and cognition studies that there is often a great difference between what *can* be affected and what is *typically* affected; the same is true for any technology, whether the potential is for good or ill (Salomon, 1994). Using perspectives from activity theory to revisit the use of such tools may help to identify contextual factors that influence the widely varying results that have been reported.

The previous example used concepts from activity theory at a fairly abstract level, adopting the framework to summarize an ongoing discussion; a more common and practical approach is to use activity theory to analyze specific systems. While activity theory is descriptive, not prescriptive, it has been used for both analysis and diagnosis (Bødker, 1996; Cole & Engeström, 1993; Engeström, 1992; Engeström & Escalante, 1996; Favorin & Kuutti, 1996). The results of such an analysis can even be used to consciously re-design the activity system, as Cole and Engeström (1993) demonstrate in two different examples (though neither specifically focused on computers).

However, what constitutes a "better" activity system is always open to debate: the answers involve individual and societal goals as much as they involve capabilities of people and tools. Considering the activity system as a whole – and acknowledging the value-laden questions that arise in considering "objects" – is one way to address concerns about the potential consequences for individuals and society as computers become more commonly used as cognitive tools.

Summary

Theoretical perspectives provide both organizing structures and a set of filters. Both distributed cognition and activity theory enlarge the scope of "cognition" to include the individual's interactions with the environment. Activity theory offers a framework congruent with distributed cognition that addresses some of its concerns. This framework has a rich history, and is being extensively developed by disciplines related to educational technology, such as psychology and human-computer interaction. Despite the complexity of its vocabulary and concepts, it offers the potential for increased interdisciplinary exploration of issues related to cognitive tools.

References

Anderson, J. R., Lynn, R., & Simon, H. A. (1996). Situated learning and education. Educational Researcher, 25(4), 5-11.

Bødker, S. (1996). Applying activity theory to video analysis: How to make sense of video data in HCI. In B. A. Nardi (Ed.), Context and consciousness: Activity theory and human-computer interaction (pp. 147-174). Cambridge, MA: MIT Press.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. Educational Researcher, 18(1), 32-42.

Carroll, J. M. (1997). Human-computer interaction: Psychology as a science of design. International Journal of Human-Computer Studies, 46, 501-522.

Cognition and Technology Group at Vanderbilt University. (1991). Technology and the design of generative learning environments. Educational Technology, 31(5), 34-40.

Cole, M. (1995). The supra-individual envelope of development: Activity and practice, situation and context. In J. J. Goodnow, P. J. Miller, & F. Kessel (Eds.), Cultural Practices as Contexts for Development (Vol. 67, pp. 105-118). San Francisco: Jossey-Bass Publishers.

Cole, M., & Engeström, Y. (1993). A cultural-historical approach to distributed cognition. In G. Salomon (Ed.), Distributed cognition: Psychological and educational considerations (pp. 1-46). New York, NY: Cambridge University Press.

Cole, M., Engeström, Y., & Vasquez, O. (Eds.). (1997). Mind, culture, and activity: Seminal papers from the Laboratory of Comparative Human Cognition. Cambridge: Cambridge University Press.

Collins, A. (1988). Cognitive apprenticeship and instructional technology. (Technical Report). Cambridge MA: Bbn Labs, Inc.

Collis, B. A., & Verwijs, C. (1995). A human approach to electronic performance and learning support systems: Hybrid EPSSs. Educational Technology, 35(1), 5-21.

Cooper, A. (1995). About face: The essentials of user interface design. Foster City, CA: IDG Books Worldwide, Inc.

Dorsey, L. T., Goodrum, D. A., & Schwen, T. M. (1993). Just-in-time knowledge performance support: A test of concept. Educational Technology(November 1993), 21-29.

Engeström, Y. (1992). Interactive expertise: Studies in distributed working intelligence. (Research Bulletin No. 83). Helsinki, Finland: Helsinki University Dept. of Education. (ERIC Document Reproduction Service No. ED 349 956)

Engeström, Y., & Escalante, V. (1996). Mundane tool or object of affection: The rise and fall of the Postal Buddy. In B. A. Nardi (Ed.), Context and consciousness: Activity theory and human-computer interaction (pp. 325-373). Cambridge, MA: MIT Press.

Favorin, M., & Kuutti, K. (1996). Supporting learning at work by making work activities visible through information technology. Machine-Mediated Learning, 5(2), 109-118.

Gery, G. (1995). Attributes and behavior of performance-centered systems. Performance Improvement Quarterly, 8(1), 47-93.

Hannafin, M. (1992). Emerging technologies, ISD and learning environments: Critical perspectives. Educational Technology Research and Development, 40(1), 49-63.

Hutchins, E. (1995). Cognition in the wild. Cambridge, MA: MIT Press.

Jonassen, D., & Reeves, T. C. (1996). Learning with technology: Using computers as cognitive tools. In D. H. Jonassen (Ed.), Handbook of research for educational communications and technology (pp. 693-719). New York: Simon & Schuster Macmillan.

Kaptelinin, V. (1996a). Activity theory: Implications for human-computer interaction. In B. A. Nardi (Ed.), Context and consciousness: Activity theory and human-computer interaction (pp. 103-116). Cambridge, MA: MIT Press.

Kaptelinin, V. (1996b). Computer mediated activity: Functional organs in social and developmental contexts. In B. A. Nardi (Ed.), Context and consciousness: Activity theory and human-computer interaction (pp. 45-68). Cambridge, MA: MIT Press.

Kling, R., & Jewett, T. (1994). The social design of worklife with computers and networks: A natural systems perspective. In M. Yovitz (Ed.), Advances in computers (Vol. 39, pp. 239-293). Orlando, FL: Academic Press.

Kuutti, K. (1996). Activity theory as a potential framework for human-computer interaction research. In B. A. Nardi (Ed.), Context and consciousness: Activity theory and human-computer interaction (pp. 17-44). Cambridge, MA: MIT Press.

Laffey, J. (1995). Dynamism in electronic performance support systems. Performance Improvement Quarterly, 8(1), 31-46.

Lajoie, S. P. (1993). Computer environments as cognitive tools for enhancing learning. In S. P. Lajoie & S. J. Derry (Eds.), Computers as cognitive tools (pp. 261-287). Hillsdale, N.J.: Lawrence Erlbaum Associates.

Lajoie, S. P., & Derry, S. J. (1993). Computers as cognitive tools. Hillsdale, N.J.: Lawrence Erlbaum Associates.

Land, S. M., & Hannafin, M. J. (1996). Student-centered learning environments: Foundations, assumptions, and implications, Proceedings of Selected Research and Development Presentations at the 1996 National Convention of the Association for Educational Communications and Technology (Vol. 18, pp. 395-400). Indianapolis, IN.

Lave, J., & Wegner, E. (1991). Situated learning. New York, NY: Cambridge University Press.

Leont'ev, A. N. (1978). Activity, consciousness, and personality (Hall, M.J., Trans.). Englewood Cliffs, N.J.: Prentice-Hall.

Lesgold, A. (1993). Information technology and the future of education. In S. P. Lajoie & S. J. Derry (Eds.), Computers as cognitive tools (pp. 369-383). Hillsdale, N.J.: Lawrence Erlbaum Associates.

Nardi, B. A. (Ed.). (1996a). Context and consciousness: Activity theory and human-computer interaction. Cambridge, MA: MIT Press.

Nardi, B. A. (1996b). Studying context: A comparison of activity theory, situated action models, and distributed cognition. In B. A. Nardi (Ed.), Context and consciousness: Activity theory and human-computer interaction (pp. 69-102). Cambridge, MA: MIT Press.

Pea, R. (1993). Practices of distributed intelligence and designs for education. In G. Salomon (Ed.), Distributed cognition: Psychological and educational considerations (pp. 47-87). New York, NY: Cambridge University Press.

Pea, R. D. (1985). Beyond amplification: Using the computer to reorganize mental functioning. Special Issue: Computers and education. Educational Psychologist, 20(4), 167-182.

Pea, R. D., Kurland, D. M., & Hawkins, J. (1987). Logo and the development of thinking skills. In R. D. Pea & K. Sheingold (Eds.), Mirrors of minds: Patterns of experience in educational computing (pp. 178-197). Norwood, N.J.: Ablex Publishing Corporation.

Perkins, D. N. (1985). The fingertip effect: How information-processing technology shapes thinking. Educational Researcher, 14(7), 11-17.

Perkins, D. N. (1993). Person-plus: A distributed view of thinking and learning. In G. Salomon (Ed.), Distributed cognition: Psychological and educational considerations (pp. 88-110). New York, NY: Cambridge University Press.

Raybould, B. (1995). Performance support engineering: An emerging development methodology for enabling organizational learning. Performance Improvement Quarterly, 8(1), 7-22.

Rosenberg, M. J. (1995). Performance technology, performance support, and the future of training: A commentary. Performance Improvement Quarterly, 8(1), 94-99.

Salomon, G. (1990). Cognitive effects with and of computer technology. Communication Research, 17(1), 26-44.

Salomon, G. (Ed.). (1993a). Distributed cognition: Psychological and educational considerations. New York, NY: Cambridge University Press.

Salomon, G. (1993b). No distribution without individual's cognition: A dynamic interactional view. In G. Salomon (Ed.), Distributed cognition: Psychological and educational considerations (pp. 111-138). New York, NY : Cambridge University Press: Cambridge University Press.

Salomon, G. (1993c). On the nature of pedagogic computer tools: The case of the *Writing Partner*. In S. P. Lajoie & S. J. Derry (Eds.), Computers as cognitive tools (pp. 179-196). Hillsdale, N.J.: Lawrence Erlbaum Associates.

Salomon, G. (1994). Interaction of media, cognition, and learning: An exploration of how symbolic forms cultivate mental skills and affect knowledge acquisition. Hillsdale, N.J.: L. Erlbaum Associates.

Salomon, G., Perkins, D. N., & Globerson, T. (1991). Partners in cognition: Extending human intelligence with intelligent technologies. Educational Researcher, 20(3), 2-9.

Scales, G., & Yang, C.-S. (1993). Perspectives on electronic performance support systems. Paper presented at the Eastern Educational Research Association Conference (ERIC # ED 354 883), Clearwater, FL.

Wilson, A. L. (1993). The promise of situated cognition. In S. B. Merriam (Ed.), An update on adult learning theory (pp. 71-79). San Francisco: Jossey-Bass.

Zinchenko, V. (1996). Developing activity theory: The zone of proximal development and beyond. In B. A. Nardi (Ed.), Context and consciousness: Activity theory and human-computer interaction (pp. 283-324). Cambridge, MA: MIT Press.

NOTICE

REPRODUCTION BASIS

☒ This document is covered by a signed "Reproduction Release (Blanket) form (on file within the ERIC system), encompassing all or classes of documents from its source organization and, therefore, does not require a "Specific Document" Release form.

☐ This document is Federally-funded, or carries its own permission to reproduce, or is otherwise in the public domain and, therefore, may be reproduced by ERIC without a signed Reproduction Release form (either "Specific Document" or "Blanket").

EFF-089 (9/97)