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A Tutorial on Situated Learning

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Abstract: The theory of situated learning claims that every idea and human action is a generalization, adapted to the ongoing environment, because what people see and what they do arise together. From this perspective, thinking is a physical skill. As we create names for things, shuffle around sentences in a paragraph, and interpret what our statements mean, every step is controlled not by reinstantiated grammars and previously constructed plans, but adaptively recoordinated from previous ways of seeing, talking, and moving. Situated learning is the study of how human knowledge develops in the course of activity, and especially how people create and interpret descriptions (representations) of what they are doing. This introduction provides a historical perspective of situated learning, including the work of Dewey, Bartlett, Vygotsky, and Ryle. I provide examples of how situated learning is being applied today in business process redesign.

Concerns of Situated Learning

Situated learning is concerned with how learning occurs everyday. It is not a recommendation that teaching be "situated" or "relevant." It is a theory about the nature of human knowledge, claiming that knowledge is dynamically constructed as we conceive of what is happening to us, talk and move. Especially, our *conception of our activity* within a social matrix shapes and constrains what we think, do, and say. That is, our action is *situated in our role* as a member of a community. The common idea in the AI literature that "situated" means "in a physical setting" or "interactive" grossly distorts the psychological nature of the theory.

The theory of situated learning claims that knowledge is not a thing or set of descriptions or collection of facts and rules. We model knowledge by such descriptions. But the map is not the territory: Human knowledge is not like procedures and semantic networks in a computer program. Human knowledge should be viewed as a capacity to coordinate and sequence behavior, to adapt dynamically to changing circumstances.

If the above description of situated learning still seems confusing, it is probably because of how the AI literature has equated the following terms:

"knowledge"
"knowledge representations"
"representations"
"mental models"
"knowledge base"

Identifying knowledge with descriptions often leads to interpreting situated cognition to mean that there are "no internal representations" or "no concepts in the mind." Rather, the claim is that "knowledge" is an analytic abstraction, like energy, not a substance that can be in hand. You cannot inventory what someone knows. Knowledge representations (e.g., textbooks, expert systems) are descriptions, which are tools, not knowledge itself. "The map is not the territory."

Because knowledge is not a thing or set of descriptions, we do not learn by transferring facts and rules from one head to another. Understanding how *learning is a process of conceiving an activity*, and activities are inherently social, puts emphasis on improving learning addressing issues of membership, participation in a community, and identity.

Notice that we are referring to the conception of activity, not tasks. Activities embrace the norms of social groups. Examples are: working home alone, phone conversations, attending a lecture, gardening, weekend relaxing, being a researcher, being a business trip, etc. Saying that activities are social means that norms constrain how we dress and talk, what constitutes being "on task," what constitutes an interruption, etc. This knowledge of *social choreography* orients how we communicate information, what constitutes an interesting theoretical inquiry, how we justify design judgments, and how we interpret policies. This is the social dimension of all knowledge.

Saying that activities are social has nothing to do per se with whether the activity is done alone or with other people present. Again, the superficial view that social means "in the presence of other people" (compare to the superficial view that situated means "in some location"), fully distorts the psychological claim. Action is situated because it is constrained by a person's *understanding* of his or her "place" in a social process.

Because knowledge is not merely indexed, retrieved, and applied, but problem solving involves reconceptualization, current models of problem solving are impoverished. Controlled experiments may reveal interesting patterns in how concepts are related, but they tell us little of how people come to conceive of a situation as being a problem. Because knowledge has been wrongly viewed as descriptions, problems have been viewed as descriptions—reducing the everyday sense of trouble, discomfort, and difficulty to mathematical puzzles, neatly expressed on paper and neatly solved by logic.

Because knowledge has been equated with scientific theories, the expertise of applying theories to develop a good design and the everyday problems of interpreting policies and rules have been ignored. The process of articulating theories about the world, expressing values, and arguing about conflicts has been relegated to simply knowing what the facts are and making logical inferences. In practice, the problem is that people disagree about the facts and how to make tradeoffs. Expertise is not merely knowing the rules, but knowing how to make good interpretations.

Practice, what people say and do is not the same as theory, descriptions of what people say and do. Therefore we cannot write down once and for all what people know. Learning to become a member of a community of professionals is not accomplished by transferring the rules and handing over the tools. Knowledge of the professional is conceptual, embodied in ways of seeing, roles, ways of interacting. And because concepts are not words, learning cannot be accomplished by describing or telling alone.

Again, saying that learning is situated is explaining *the nature of human concepts*. We are not saying that people learn best by "trying something out" (even that is a common oversimplification of the idea). We are saying that *learning occurs in all human activity*, all the time. The recommendations are to examine the nature of how problems arise, how people use theories in practice, how interpretations are biased by a person's conceptualization of his or her role. In effect, situated learning calls us to see how rules make ongoing learning necessary in the workplace, and how the development of knowledge is constrained by every individual's conception of what he or she is supposed to be doing.

Related Historical Trends

Situated learning has recently been discussed by cognitive anthropologists, (Lave, Scribner, Cole, Hutchins); but it is an old idea, with many origins in diverse fields, including:

- Sociology of knowledge (Marx, Durkheim, Mannheim)
- Functionalism (anti-associationism) (Dewey, Bartlett)
- Activity theory (Vygotsky, Leontiev, Luria; Cole, Wertsch)
- Cybernetics and systems theory (Bateson, von Foerster)
- Ethnomethodology (Garfinkel)
- Ecological psychology (Gibson, Jenkins, Bransford, Neisser, Barker)

Probably the best single reference is Gardner's (1985) history of cognitive science. Lakoff (1987) lays out many of the philosophical arguments. The work of Bateson (1972, 1979) is generally accessible.

A Primer on Activity Theory

To illustrate how situated learning is related and partially derives from other theories of knowledge, consider the following summary of Vygotsky's (1978) activity theory, followed by my interpretations:[1]

> Definition: Activities of the mind cannot be separated from overt behavior, or from the social context in which they occur. Social and mental structures interpenetrate.

Conceptions of social relations and roles ("social structures") are integrated with perceptual and physical coordinating processes in the brain.

> Knowledge is socially embedded, and learning occurs from socially-mediated collaborative processes.

Producing and evaluating designs and policies is conceptually integrated with the person's identity as a member of a group. For example, a researcher's knowledge of what constitutes "an intelligent tutoring system" and whether a design is novel is integrated with the researcher's conception of the ITS community and its norms.

> In the process of 'other-to-self regulation' within the zone of proximal development, the use of tools, activity (labor), and signs (language) inform and give access to representations that are socially constructed and socially shared. The zone of proximal development is the difference between what an individual can accomplish alone and the potential development through problem solving in collaboration with more capable peers.

For example, programming languages, research activities, and research papers belong to the community of practice of ITS research. When a new researcher gains access to existing ITS programs, development environments, and published reports, he or she becomes a participant in the community. The individual's capabilities are stressed by the activities of the community, such as when a paper is rejected by a conference committee. The individual comes to understand the norms of the community through "collaboration with more capable peers." That is, the person comes to properly conceive of the activity of paper writing in terms of this group's values, methods, and distinctions.

> The "expert-novice dyad" is a metaphor for any pair of individuals in a guided learning process.

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[1]Based on "A Summary of Activity Theory" (July 1993) by Trudy Williams, Work Systems Design Group, Nynex Science and Technology, White Plains, NY.

> Scaffolding[2] is a dynamic process by which an expert deliberately expands a novice's skills, based on feedback from the novice in practice. Expert and novice progress together through the ZPD, reciprocally building shared experience and representations.
>
> Both expert and novice are relating their own task actions (self-regulation) to the speech and actions of the other (other-regulation), by which they adjust their perception and make new choices of language and activity.
>
> Put another way, the ZPD is mutually constructed to maintain a correspondence between other- and self-regulated behavior achieved through scaffolding.

These concepts—dyad, scaffolding, ZPD, expert/novice—describe how learning occurs by recoordinating perception, talk and other actions. The constraints are mutual (bi-directional) and the result is co-determined by each person's conceptions and actions.

> Tools are the basis for carrying out the socially organized activity which, is, in turn, the basis for the development of new mental functioning and activity in the world.
>
> Signs (language and other representations) are representations of external activity that become reconstructed and internalized. In this way, speech, which organizes meaning encountered in the social world, is internalized to become thought, allows for speech production (necessary to take part in the social community), and becomes the basis for activity.
>
> Tools and signs are acquired by participation in the social environment.

Programming languages, electronic mail, graphic programs, etc. are some of the tools of the ITS community. They are acquired (as possessions and as skills) when an individual begins participating in a research environment of a university or corporation. The way people in the community talk and how they write becomes internalized, as ways of coordinating the new researcher's actions. That is, conceptions of activity become shared through the exchange of tools and representations in conversation.

This short tour through activity theory helps explain why and in what sense learning is situated. It helps to remember that the learner's *conception* of the situation is what frames and orients his or her experience, that is, what is learned. Activity theory partially explains how individual conceptions are brought into alignment with a community of practice through tools, signs, and activities.

Origin of Situated Learning in Anthropology

According to Gardner (1985, p. 256), situated learning is an "Attempt to infuse careful case studies with concepts of cognitive science, while contrasting learning in the field with thought processes taught and measured in Western schools." Different studies have illustrated the theory:

- Lave: studied apprenticeship in Liberian tailors
- Scribner: studied mathematics used by New York dairymen
- Cole: studied character and function of Liberian literacy
- Hutchins: logical reasoning about land rights in the Tiobriand Islands

But returning to cognitive science, anthropologists sometimes antagonistically placed social perspectives first:

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[2]The term "scaffolding" is attributed to later interpreters of Vygotsky's theory.

> Lave and Wenger...give us the opportunity to escape from the tyranny of the assumption that learning is the reception of factual knowledge or information. (Book jacket of *Situated Learning*)

> It is the community rather than the individual, that defines what a given domain of work is and what it means to accomplish it successfully. (Suchman and Trigg, "Understanding Practice," *Design at Work*, p. 73)

> Learning is a process that takes place in a participation framework, not in an individual mind. (Hanks, *Situated Learning*, p. 15)

> The point is not so much that arrangements of knowledge in the head correspond in a complicated way to the social world outside the head, but that they are socially organized in such a way as to be indivisible. (Lave, *Cognition in Practice*, p. 1)

This presentation, suggesting that social views and the group are more fundamental than cognitive, individual views, confused cognitive scientists and often led to an outright rejection of the situated learning theory (Sandberg and Wielinga, 1991).

What Situated Learning Emphasizes

The theory of situated cognition views learning as:

—always integrated with the individual's identity and participation, the "production of persons-in-activity."
—constituting an evolving membership and capability to participate in different forms.
—the means of reproduction and development of communities of practice.

"Participating" means knowing ways of talking, authoritative views, kinds of stories people tell. Also, participating means grappling with the inherent social conflict between continuity and displacement of ideas, practice, and people, over time and *between communities of practice*.

To understand *and change* the result of cognitive-social activity—what people believe and do—we must take into account their social-material interactions. Viewing context as merely the data for information processing leads to an over-malleable view of behavioral change, as if it is merely shaped by internal contents. Rather, we need to understand the duality of structuring inside and out, and how these transform each other.

The strongest effect is not in "how to teach," but in ***"how to change" a social system.*** Formal education alone—teaching theory more effectively—is not sufficient. Rather, we must understand change within the trends and resources available for activity. For example, we can't simply teach ITS researchers a new view of cognition and expect a change to occur in the practice of instructional design. We must work within the constraints of funding, computational methods, and forms of practical involvement already underway. Researchers must "get on board" the trends of the instructional design community and reshape practice as a participant (as opposed to lecturing or just delivering tools).

According to Lave, ethnographic studies emphasize apprenticeship in order to reveal the indivisible character of learning and work practice. This in turn helps to make obvious the social nature of learning and knowing:

> As these studies partially illustrate, any complex system of work and learning has roots in and interdependencies across its history, technology, developing work activity, careers, and the relations between newcomers and old-timers and among workers and practitioners. (Lave, Cognition in Practice, p. 61)

The Community of Practice Analytic Framework

Situated learning discussions often refer to the idea of a community of practice. This is a way of describing any group of people who work together to accomplish some activity (their *practice*), usually involving collaboration between individuals with different roles and experience. One cannot count the communities of practice in the world. Rather, one starts by assuming that a person being studied is part of one or more communities of practice and uses this framework as way of explaining what the person knows and why he or she behaves in a certain way. To summarize:

- *Knowledge* is ability to participate in a community of practice.
- *Learning* is becoming a member of a community of practice.
- *Tools* facilitate interaction in a community of practice.

Reconsider Relation of Social, Psychological, and Neural Views of Learning

To understand situated learning and work through its implications for instructional design, we must understand the situated view of knowledge:

- Descriptions of behaviors—procedures, grammars, or schemas—are always impoverished relative to the complexity of conceptualization. People create information and construct novel, personal representations in the course of everyday activity.

- When people act, they are not executing schemas, rules, or procedures that they retrieve from memory, but are always constructing something new.

- What we see and do arise together—during interaction—producing new, coordinated compositions of perception and action, which bias future behavior.

Situated learning relates to the theory situated action, which claims that the foundation of behavior isn't a bedrock of schema descriptions (see Arbib, 1992, Iran-Nejad, 1987, and Edelman, 1992 for related neurobiology arguments). As Mead explains, plans are *descriptions* of activity, resources that we refer to for guidance or perhaps rules that cause a problem:

> One kind of activity is an essentially situated and *ad hoc* improvisation—the part of us, so to speak, that actually acts. The other kind of activity is derived from the first, and includes our representations of action in the form of future plans and retrospective accounts. Plans and accounts are distinguished from action as such by the fact that, to represent our actions, we must in some way make an object of them. Consequently, our descriptions of our actions come always before or after the fact, in the form of imagined projections and recollected reconstructions.(Mead, 1934)

The same ideas were argued by Ryle:

> To put it quite generally, the absurd assumption made by the intellectualist legend is this, that a performance of any sort inherits all its title to intelligence from some anterior internal operation of planning what to do.
>
> 'Intelligent' cannot be defined in terms of 'intellectual' or 'knowing how' in terms of 'knowing that'; 'Thinking what I am doing' does not connote 'both thinking what to do and doing it.' My performance has a special procedure or manner, not special antecedents.
>
> Efficient practice precedes the theory of it; methodologies presuppose the application of the methods, of the critical investigation of which they are the products.
>
> It was because Aristotle found himself and others reasoning now intelligently and now stupidly and it was because Izaak Walton found himself and others angling sometimes effectively and sometimes ineffectively that both were able to give their pupils the maxims and prescriptions of their acts.
>
> It is therefore possible for people intelligently to perform some sorts of operations when they are not yet able to consider any propositions enjoining how they should be performed. (Ryle, 1949)

The traditional symbolic view of knowledge is that action is created by applying rules, conditional on information in the environment or working memory. Mead and Ryle are saying that to articulate a rule, you must already know how to act. The rule description "makes an object" of an interaction.

Instead of deriving from stored structures, interaction creates structure, which is always adapted in constructing future behavior. W.F. Hanks explains this in the preface to *Situated Learning* (Lave and Wenger, 1991):

> In the classical structural analysis, aspects of behavior are explained by, and serve as empirical evidence for, preexisting, "underlying" systems. It is these systems that provide the object of which an analysis is a model. To the extent that actual processes are analyzed, they are "structuralized"—made to follow from, or instantiate, structures. The activity of understanding, in such a view, comes down to recognizing and implementing instances of structure, filling them in with an overlay of situational particulars, and relating them to a "context" (which is in turn structured)....
>
> [In the work of Lave and Wenger] it is not merely that the structure issue is transposed from the level of mental representations to that of participation frames. Rather this transposition is compounded by a more subtle and potentially radical shift from invariant structures to ones that are less rigid and more deeply adaptive. One way of phrasing this is to say that *structure is more the variable outcome of action than its invariant precondition.... (*p. 16)
>
> It involves a *prereflective grasp of complex situations*, which might be reported as a propositional disposition, but is not one itself. (p. 20)

In terms of the symbolic view, this claims that the conditions, the associations, and the actions are dynamically constructed from previous coordinations at the time of behaving. Structure in the brain results from each new coordination.

Facets of "Transfer Research"

Situated learning has been associated with criticisms of the "transfer" model of learning. Lave examines the work of Hayes and Simon, which failed to demonstrate that problem isomorphs (missionaries & cannibals vs. monsters & globes) would be recognized by subjects. Hayes and

Simon concluded that knowledge of how to reason analogically must be taught. According to Lave (1988, p. 38), "They agree that where there is no analogic transfer, subjects must be unaware of powerful general processes of problem solving and should be taught them."

Contrasting different activities (not two puzzles), Lave found that transfer didn't occur between "best-buy calculations in supermarkets where the problem solver is agent and on paper where the problem solver is the object of the exercise." That is, experience in real-life didn't transfer to school work.

On the one hand, we could criticize Lave's work because the essence of the transfer claim is that *theoretical generalizations,* that is, descriptions, would be useful in multiple settings. Lave has implicitly identified knowledge with descriptions once again. In saying that knowledge doesn't transfer, Lave hasn't addressed the issue of whether *descriptions* are useful guides in multiple settings.

Knowledge engineering is a prime example of the power of descriptive generalization (Clancey, 1988). Domain-general representations are applied to build new expert systems. The idea that descriptive theory is "decontextualized" is a superficial rendering of what a theory is and how it is made useful in a new setting. The point is that a theory, like any map, must be interpreted for the problems at hand.

On the other hand, Lave is correct that in AI studies context is treated equivalently within a problem, across problems, across domains, and across ways of life (home, school, and experimental lab). *Claims about transfer must be relative to the grainsize of the change in situation.* In claiming that a descriptive theory "transfers" we must always say "more or less, depending on the perceptual similarity and social-interactional activity of the new setting." Lave summarizes the "decontextualized" position she is criticizing:

> Since situations are not assumed to impinge on the tool itself, a theory of learning transfer does not require a theory of an account of situations, much less of relations among them. Knowledge acquisition may be considered (and organized in schools and experiments on cognition) as if the social context of activity had no critical effects on knowledge-in-use. (p. 40)

Lave's analysis suffers by not making clear that "social context of activity" is *conceptual*, not a place or a description of a place. Furthermore, from the neuropsychological perspective, the context is never the same (Edelman, 1992). Some adaptation and generalization at the conceptual level is required for *every* human action; that is, conceptions of situations and knowledge ("the tool") are coupled. Again, remember that concepts are not words. When we say "generalization of a concept" we don't mean creating a description; we mean adjusting a physical coordination in the brain.

We will examine Lave's weight-watcher story in more detail later. The example, appropriately interpreted, suggests that a mathematical conceptualization more general than the situation at hand is orienting the person's behavior. Greeno has been aware of this idea, in his consideration of the conceptual invariants of mathematical reasoning across situations (Greeno, 1988), and not just their manifestation in situated activity. Because Lave and others have avoiding talking about the brain, they have poorly articulated the psychological implications of their claim: Conceptual organizers do get reused, but they are always adapted.

To be clear, Lave's analysis makes major, important claims for learning research. She shows in her studies that cognitive studies of learning based on descriptive mechanisms alone have several deficiencies:

- Devalue knowledge of "just plain folk, misconstruing relation of practice and theory.

- Reduce the complex non-linear, emergent processes of culture, meaning, knowledge, and context to descriptions of these.
- Restrict reasoning to symbol manipulation in a given, fixed language ("characterize on *a priori* grounds the structure of 'correct knowledge'" (Lave, p. 70))
- Reduce "using a theory" to instantiation and mapping of descriptions vs. non-descriptive processes of interpretation, reconceptualization, reperception & interactivity.

We will examine these claims in the example of the cottage cheese story, but first it is worth examining more carefully what the symbolic approach claims.

Philosophical and Psychological Assumptions of the Rationalist Approach

How could so many confusions have developed in the scientific study of cognition? As I indicated in the introduction, the fundamental problems originate in identifying knowledge with descriptions of knowledge (exemplified by Vera and Simon, 1993). Figure 1 summarizes how various ideas relate in this confusion.

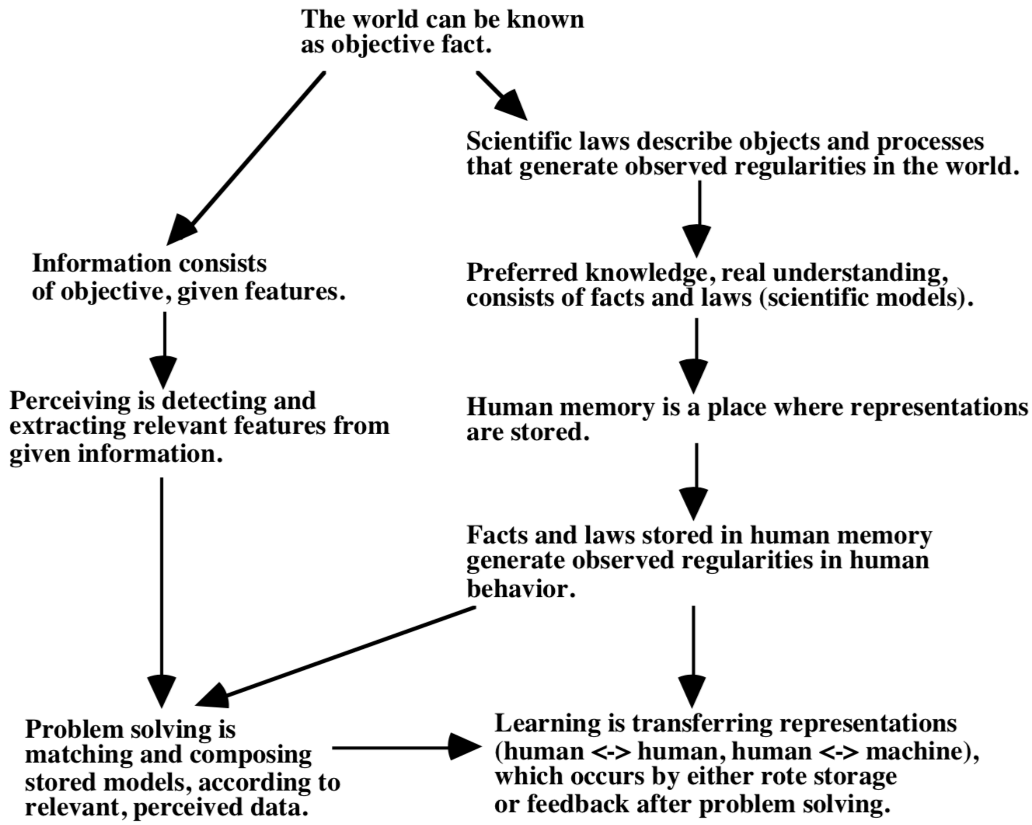

Figure 1. Rationalist view of knowledge and representations: Culture can be inventoried by facts and rules, based on the flawed philosophical assumption that all objects and events in the world can be objectively described.

The statements in Figure 1 indicate how the idea that knowledge consists of stored facts and laws derives from the philosophical assumption that the world consists of segmented objects with defined properties, which are selected and filtered by perception. Furthermore, the rationalist view holds that the laws we observe are somehow embedded in the world, rather than being *descriptions* of patterns we observe. An alternative view is that there are many ways to describe the world (Lakoff, 1987; Edelman, 1992; Gregory, 1988). The direction of science is culturally influenced by language and tools. But the important impact of this observation is in everyday design and decision making when tradeoffs are required.

The relevant facts when designing something or interpreting a policy are culturally determined. The force of the social construction of knowledge is not to say that science is impossible and anything can be believed. Rather, the force is on the production of designs and the learning about how to act within a social matrix of policies and values. By reducing knowledge to scientific facts and laws, the *cultural expertise* of a practitioner in creating and evaluating good designs is inadequately understood (Schön, 1987). In effect, knowledge has been equated with theories, designs, and policies; such *descriptions* must be properly understood in relation to each other, and not equated with *concepts*.

Figure 2 presents the common view that equates descriptions in the world with concepts in the mind. The term "representation" is used equivalently to refer to external representations such as programs, text files, and diagrams, and internal acts of representing such as visualizing something, talking to oneself; and these experiences are equated with conceiving, a subconscious process. Instead of distinguishing between descriptions, experiences, and concepts, the exclusively symbolic view insists that these are all isomorphic, all the same thing, just symbols (Vera and Simon, 1993).

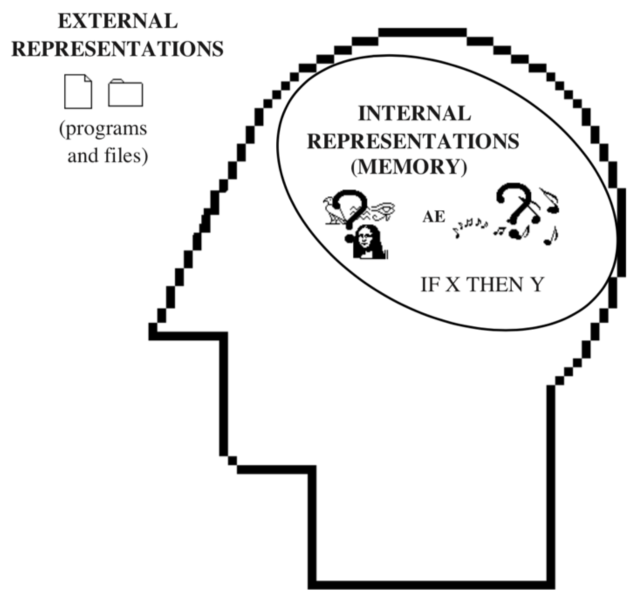

Figure 2. Symbolic view that descriptions, experiences, and concepts are all the same kind of thing.

The field of ITS was founded on this idea:

> Much of what constitutes domain-specific problem-solving expertise has never been articulated. It resides in the heads of tutors, getting there through experience, abstracted but not necessarily accessible in an articulatable form. (Sleeman and Brown, 1982, p. 9)

In ITS research through the 1970s until the late 1980s, "expertise" is equated with something that "resides" in the brain (a stored substance), which like descriptions is "abstracted" but not accessible. This claims that words and statements are in the brain: The reason we sometimes have difficulty expressing ourselves in words is because we can't get "access" to what has already be described and stored inside. This is like saying that we are all great sports stars, we just can't get access to the strength stored in our muscles.

The epistemology of knowledge driving the early design of ITS programs was of course the epistemology of expert systems and symbolic learning programs. Figure 3 illustrates how learning was conceived as a separate module and hence a process independent from acting. Learning was viewed as something that only occurs on reflection, in which the problem solver generates descriptions criticizing the performance and finding ways to improve the models and inference procedures: "A learning systems responds acceptably with respect to some performance element within some time interval following a change in its environment" (Smith, et al. 1977).

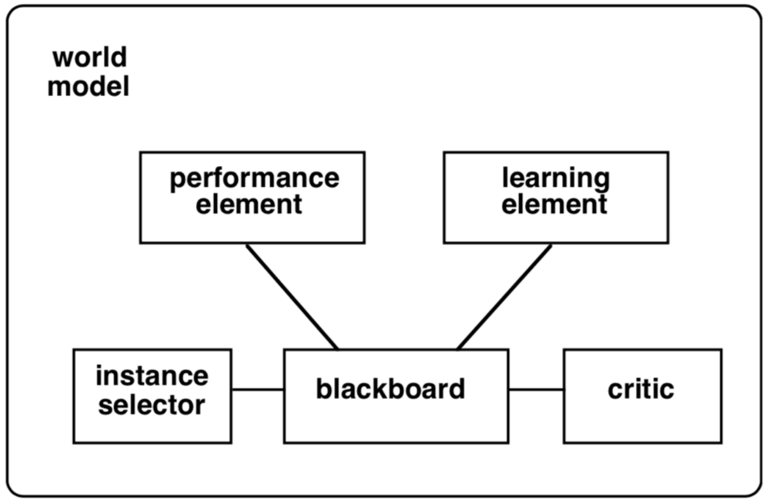

Figure 3. The components of a learning systems (from Smith, et al.., 1977)

This is a reasonable description of how people modify descriptive models, but it doesn't allow for recoordination to occur during problem solving itself. It suggests that all learning involves manipulating descriptions and fundamentally ignores perceptual recoordination. This model fundamentally distinguishes between physical skills and intellectual skills, suggesting that there is no important physical aspect to conceptualization. Newell made these assumptions explicit in describing "the total cognitive system," a generalization of Soar (Figure 4).

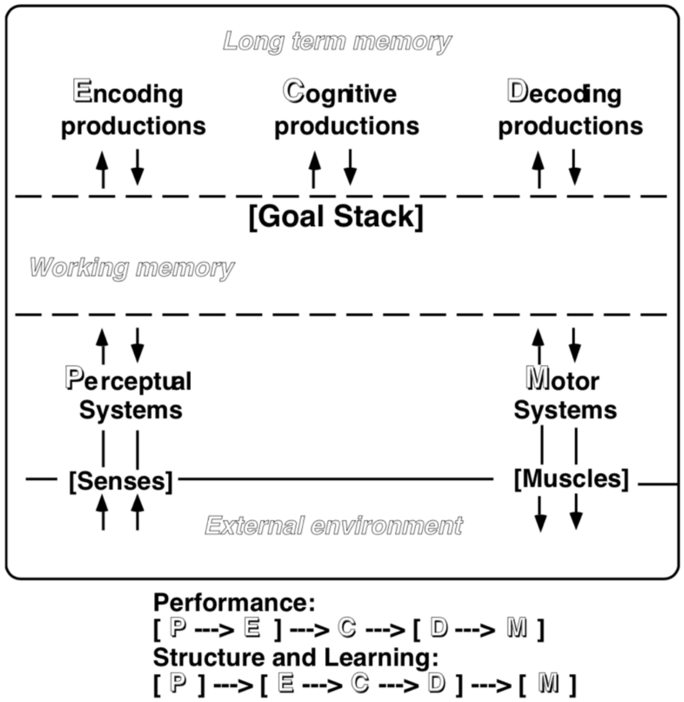

Figure 4. Total Cognitive System (from Newell, 1990, p. 195)

In Figure 4 see that perceptual and motor systems are independent from the deliberation process (P->E, C, and D->M are disjoint during performance). Features for segmenting the world are learned independently from productions (P, E->C-D, and M are disjoint). And once again, performance is distinguished from learning: Doing and learning are viewed as separate kinds of action.

Finally, because the assumptions of the symbolic approach identifying situations with descriptions are not called into question in the design of laboratory experiments or the creation of symbolic models, this approach cannot be falsified on its own terms. On the one hand, researchers claim that philosophy is irrelevant (Vera and Simon, 1993). The philosophy of science might appear irrelevant to someone (following Figure 1) who believes that science is objective, without cultural underpinning. Lave argues that *the manner of carrying out an experimental investigation of cognition* is cultural because it makes assumptions about the nature of knowledge, situations, and problems (e.g., that problems in everyday life are experienced as descriptions like puzzles). Unfortunately, this suggests a symbolic theorist that situated learning is unscientific, because it is attempting to eliminate experimentation. But the issue is understanding the starting point for the experimental subject and how experiments are related to everyday life:

> Problems of the closed, 'truth or consequences' variety are a specialized cultural product, and indeed, a distorted representation of activity in everyday life, in both senses of the term—they are neither common nor do they capture a good likeness of the dilemmas addressed in everyday activity. (Lave, p. 43)
>
> The research genre...relies on normative models of good thinking as justification, source, and standard for experimental tasks and performances. (Lave, p. 39)

Lave emphasizes that problems like cryptarithmetic and missionaries and cannibals and the Tower of Hanoi, which Simon has emphasized in his work, are not representative of how trouble arises and is resolved in everyday life. Especially, these mathematical puzzles, by the manner in which they are delivered to a subject and the manner in which they can be solved by applying a symbolic calculus, capture little of the nature and origin of tradeoffs in design and policy interpretation in everyday life. Lave tells us that these are "normative models,"—they equate good thinking with mathematical and scientific facts and laws, ignoring the problematic nature of evaluating and justifying design decisions in real life. Schön (1987) makes a related critique of "professional knowledge."

If we criticize a symbolic model, such as a model of medical diagnostic problem solving, the symbolic theorist can always make *post hoc* repairs. Examining protocols, the symbolic theorist will claim that the subject's vocabulary and beliefs that don't fit the initial cognitive model were in their heads before the experiment began. Of course, this is the very assumption which must be experimentally demonstrated. Schön (1979) calls this "historical revisionism."

Situated learning research amply demonstrates how "normative" models don't fit human behavior when we give people a chance to show us what kinds of descriptions they prefer for modeling their own experience. Bamberger shows this clearly in her studies of children creating their own music notation (Bamberger, 1991). In related work (Clancey, 1994), I showed how two children learning basic geometry are unable to identify the straight lines on a screen because they are unsure what grainsize is appropriate for segmenting the markings on the screen. Confused by the pixels which are visible, and the artifacts of a low-resolution screen, they describe the lines in terms of "the little dots," "these little lines," "bigger" and "thicker." Claims that the world consists of symbols that are objectively available and matched against production rules in long-term memory ignore how perception is a process of *segmenting* and *grouping*, not selecting or filtering from given objects. Furthermore, a close study of such problematic situations shows that what learners see or hear is coupled to the kinds of interpretations they are capable of making. In a complicated, *conceptual* process, perceiving and activities are learned together as a unit.

As Dewey pointed out, the terms we use for describing a situation are grounded in our physical method of *looking*: orienting the paper, gesturing, and aligning reference objects such as rulers. Dewey emphasized that the context, the world, is not a given entity, but consists of *conceptual situations*. Again, a situation is not the observer's *description*, but the person's *experience*:

> The statement that individuals live in a world means, in the concrete, that they live in a series of situations. The meaning of the word 'in' is different from its meaning when it is said that pennies are 'in' a pocket or paint is 'in' a can. It means...that interaction is going on between individuals and objects and other persons. The conceptions of *situation* and of *interaction* are inseparable from each other." (Dewey, 1902)

Fully refuting the modular view of serial or parallel independence (Figure 4) Dewey criticized the early stimulus-response theories of his day (called the "reflex arc"). He insists that conceiving what the situation is, is inseparable from conceiving the nature of the interaction. In other words, conception is a form of *physical coordination*:

> The older dualism between sensation and idea is repeated in the current dualism of peripheral and central structures and functions; the older dualism of body and soul finds a distinct echo in the current dualism of stimulus and response.
>
> Instead of interpreting the character of sensation, idea, and action from their place and function in the sensorimotor circuit, we still incline to interpret the latter from our preconceived and preformulated ideas of rigid distinctions between sensations, thoughts,

> and acts. The sensory stimulus is one thing, the central activity, standing for the idea, is another thing, and the motor discharge, standing for the act proper, is a third.
>
> As a result, the reflex arc is not a comprehensive, or organic, unity, but a patchwork of disjointed parts, a mechanical conjunction of unallied processes...
>
> What is wanted is that sensory stimulus, central connections and motor responses shall be viewed, not as separate and complete entities in themselves, but as divisions of labor, functioning factors, within the single concrete whole, now designated the reflex arc.... What shall we term that which is not sensation-followed-by-idea-followed-by-movement...? Stated on the physiological side, this reality may most conveniently be termed co-ordination. (Dewey, 1896, p. 137)

Dewey would argue that Figure 4 is a "patchwork of disjointed parts, a mechanical conjunction of unallied processes." Although a symbolic theorist would argue that surely the production rules are "allied" in their operation, Dewey wanted a more integral architecture, one based on the idea of a physical *circuit*. He would claim the descriptions in symbolic models, like Soar, are "preconceived and preformulated"; these are the observer's distinctions between sensation, thought and act, which we do not find physically existing independently in biological systems. Dewey's analysis points to an architecture in which different functions develop as "divisions of labor" in relation to one another. These ideas are developed especially by Bickhard (in preparation), who has explored how functional differentiation may develop within a representing system, without requiring encodings (descriptions of the world or behavior). Similar ideas are explored in Edelman's theory of neuronal group selection (Edelman, 1992; plus see book reviews in (Clancey, Smoliar, and Stefik, 1994)).

The Cottage Cheese Example

As I have explained, the social theorists' claims about knowledge and learning are poorly understood by many cognitive scientists because these claims have not been adequately expressed in psychological terms. Here I will examine one of the most famous examples presented by proponents of situated learning and consider how it has been misconstrued by each side of the argument.

The "cottage cheese story" demonstrates that inquiry is a complex coupling of physical materials, sensorimotor coordinations (including non-descriptive ways of seeing), plus the articulation and manipulation of constraints, in the manner described by Dewey. Pedagogically, the cottage cheese story celebrates inventiveness and the importance of teaching representational conventions without destroying creativity, without leading children to believe there is only one way to think, only one "correct" way of describing facts and working problems (Brown, et al., 1988).

Lave's analysis of the cottage cheese story is inherently focused on understanding the "multiple and mutually constitutive character of problem-solving processes" (p. 165). Her analysis is concerned not only with social processes, but also perception, hand-eye coordination, conceptualization, and talk. In studying how a shopper judges which items to buy, she observes the precise ordering of attention and motion:

> Information and procedural knowledge accessed by eye, hand, or transformed in activity, make possible a move toward the solution or suggest a change in the solution shape that draws it closer to the information at hand... "Problem solving" is part of an articulatory phenomenon constituted between persons-acting and the settings of activity. (p. 159)

In contrast with viewing problem solving as manipulating mathematical notation on paper, Lave finds that reasoning in the store is best characterized in terms of qualitative comparisons, articulating purposes and alternatives, and the arrangement of materials in the visible, reachable field.

Lave explains that the aspects of problem-solving activity, such as calculating which item in a store is a better buy, are often assigned in our analysis to different times and locations. But the process of knowing similarities and differences and articulating them is not easily located within the activity:

> Dialectically ordered problem-solving processes are difficult to analyze, since one characteristic of gap-closing arithmetic is that individual moves serve multiple functions. The dilemma may be resolved by giving up the goal of assigning arithmetic problems to unique locations—in the head or on the shelf—or labeling one element of a problem-solving process as a "calculation procedure," another as a "checking procedure." It may be difficult, even, to distinguish the problem from its resolution...(Lave, p. 164)

This idea of "dialectic ordering" and "mutually constitutive character" claims that perception and action arise together in human behavior. Again, the argument is not whether or when symbolic representations are used, but fundamentally how attention, categorization, and motion are physically coordinated including when we speak and comprehend.

With this introduction, we consider now Lave's presentation of the cottage cheese story:

> Another problem posed to new members of the Weight Watchers in their kitchens provides a further illustration. As in the exercise concerning peanut butter sandwiches, the dieters were asked to prepare their lunch to meet specifications laid out by the observer. In this case they were to fix a serving of cottage cheese, supposing that the amount allotted for the meal was three-quarters of the two-thirds cup the program allowed. The problem solver in this example began the task muttering that he had taken a calculus course in college (an acknowledgment of the discrepancy between school math prescriptions for practice and his present circumstances). Then after a pause he suddenly announced that he had "got it!" From then on he appeared certain he was correct, even before carrying out the procedure. He filled a measuring cup two-thirds full of cottage cheese, dumped it on a cutting board, patted it into a circle, marked a cross on it, scooped away one quadrant, and served the rest. Thus, "take three-quarters of two-thirds of a cup of cottage cheese" was not just the problem statement but also the solution to the problem and the procedure for solving it. The setting was part of the calculation process and the solution was simply the problem statement, enacted with the setting. At no time did the Weight Watcher check his procedure against a paper and pencil algorithm, which would have produced 3/4 cup x 2/3 cup = 1/2 cup. Instead, the coincidence of problem, setting, and enactment was the means by which checking took place." (p. 165)

Lave emphasizes that although this is an experimental situation, the Weight Watchers are preparing an actual lunch in their kitchens. That is, they are solving a problem that is part of their everyday lives, which requires measuring food according to a dietary plan. Two of Lave's statements are problematic:

> 1. "[He] appeared certain he was correct, even before carrying out the procedure" suggests an internal experience of conceptualizing. This process is not explained or even mentioned by Lave. Recall the statement by Suchman and Trigg: "It is the community rather than the individual, that defines what a given domain of work is and what it means to accomplish it successfully." And also the statement by Hanks, "Learning is a process that takes place in a participation framework, not in an individual mind." Just as "calculating" and "checking" are mutually constitutive, the internal and social-interactive

aspects of the Weight Watcher's behavior are mutually constitutive. We cannot explain the social-interactive process without referring to internal, conceptual processes. The statements by Suchman, Trigg, and Hanks ignore the conceptual aspect of cognition.

2. "...the solution was simply the problem statement, enacted with the setting" suggests that the setting is *given*, rather than being perceived in a certain way, as affording a certain kind of activity. The problem of how this person saw the cottage cheese in a way different from the typical reader of Lave's book requires psychological explanation. Nobody would say that the subject sees the softness of the cheese as affording a certain separation into sections *because* he is a member of the Weight Watchers social group.

The subject's *certainty* is evidence for conceptual understanding, which coordinated the activity as a procedure; this was not carried out in the manner of following an algorithm, but enacted with the materials. In Brooks's (1991) terms, the Weight Watcher "used the world as its own model." Rather than manipulating descriptions of the world, the subject manipulated the materials directly.

But besides contrasting this enactment with calculation on paper, we must also draw out the psychological aspects of perception and conceptualization, which themselves contrast with symbol manipulation on paper. That is, our analysis of the cottage cheese story needs to relate three phenomenon:

Conceptualizing <—> Interacting <—> Symbolically Manipulating

Unfortunately, the attempt to bridge social and cognitive views in examples like this has caused an number of misunderstandings. For example, Vera and Simon believe that the cottage cheese anecdote is meant to illustrate that "knowledge about interaction with real-world objects is not symbolically represented."(p. 18) We can't be sure what the subject muttered to himself, but he did say "got it!" and talked about calculus. This suggests that the subject was symbolically representing the situation in his imagination. That is, the subject was interpreting the meaning of his thoughts, moves, and experiences. "Symbolic" here refers to anything interpreted as meaningful, not to conventional marks or symbols in a symbol *structure* (Newell's (1990) definition).

Of course, the issue raised by Lave is whether *comprehending* the specification ("take three-quarters of two-thirds of a cup of cottage cheese") involved a description, which was then coded into movements (Figure 4). Or was the subject visualizing and projecting an ordering of movements that arose as an embodied physical coordination?

Lave argues for a dialectic process, but without a theory of perception and coordinated movement, her explanation fails to account for individual differences. This is ironic because the theory of situated learning "promotes a view of knowing as activity by specific people in specific circumstances."(Lave & Wenger, p. 52) We understand the circumstances better, but without a psychological foundation for knowledge-level descriptions, there can be no specific accounting for where ideas come from, how situations are *recognized* (even though they are always different in particulars), and how habits are developed and sustained over time. In this respect, situated learning theory requires psychology and perhaps neurobiology to be comprehensible to educators and cognitive scientists.

Implications of Situated Learning for Organizational Learning

Although the theory of situated learning is incomplete, we can apply the ideas to understanding successful learning and the origin of problematic situations in everyday life. For example, Table 1 summarizes two views about organizational learning. The exclusively symbolic, individual view is that knowledge centers on each individual. Following this epistemology, an organization would be conceived in terms of specialists and knowledge about specific facts, designs, and policies in separate domains.

Table 1

Epistemological shift implicit in an organizational redesign

	Knowledge is about	Knowledge resides in	Knowledge developed by
Individual View: *Reify individual employee, a constant player moving in the corporation*	Technical details of products and services (internal capacity)	Specialized employees (stored in individual heads)	Training given to individual
Interactional View: *Reify company-customer relations as stable & responsive*	Customer relations (interactive capacity)	Cross-functional team (manifest in activity)	Project activity of functional workgroup and teams

The interactional view conceives knowledge as a capacity to coordinate the competencies of the company with the customer's needs. Designs and policy interpretations are viewed as dynamically and interactively constructed across functions. Knowledge of how to satisfy the customer is viewed as developing within the activity of working with the customer as a team. Learning is viewed as occurring with every transaction; the focus is not on applying stable, fixed rules, but on adjusting business processes and flexibly interpreting policies for the overall advantage of the organization. We need both an individual and interactional view, especially to understand the origin of new ideas as well as conflicts. But we will view the development of individuals—including motivation and conception of quality—within the roles and identities conferred by project activities.

As a second example, consider the problem of exploiting computer technology in the workplace to facilitate learning. Typically, applying the symbolic, individual view, we would say that the problem to be solved is delivering the proper facts and policies to the desktop. Again, we would adopt a normative view and say that people fail because they don't know the rules.

But when we study what happens everyday in the workplace, we find that problematic situations arise not only because people don't know the rules, they don't know what to do about the rules when they *conflict* with the company's goals and values:

> Well, I guess the message here is we can't do anything about what headquarters won't give us. It's just like a lot of other things that we can't do anything about. So, the best thing we can do as a team is to work together to 'work around.' Cause that's what it is, it's a 'work around.' Just as if you were doing a DIJ-S package, that they've misloaded a table of whatever.
>
> There are issues out there that we have no control over. This is one of them. And I have begged for a year and a half to get this. And I haven't gotten it and I'm not going

> to. So then, we're going to have to be more flexible as a team and use our creativity to support what we have to do to get our jobs done....
>
> I'd just like to make you aware, this is not a new problem. It's a very, very old problem. I've worked with it. And, when you're told no, you just have to deal with the 'no.' And, get smart about how to work around that 'no.'

Here a manager is telling her team that because corporate headquarters has told them that something cannot be done, it is now necessary to engage in problem solving, to be creative. They must invent a workaround for the rules. How can they satisfy the customer, given that literally following the rules will make the customer unhappy?

In designing computer tools for learning on the job for situations like this, we will not help if we simply deliver the company's policies to the desktop. We must help people invent creative interpretations and develop good designs which resolve conflicts. We could start by understanding the context in which people are operating and focus down to develop a genuinely useful tool.

This team is not trying to rotely learn the company's methods and procedures, but to find creative interpretations of policies, creative adaptations of information systems, and new forms of collaboration that will enable them to get their job done, despite other people's obstructions. Learning is again occurring on several levels: The team leader is teaching her cohorts how to deal with difficult situations. She is conveying a constructive attitude and orientation for "dealing with the 'no.'" To understand what kinds of tools would be useful, we would want to follow such interactions in the workplace to see how the workers represent their situation and learn how to deal with it.

Broadly speaking, we find that learning on the job often arises when trying to manage activities. They are not solving puzzles but trying to *describe* the situation that appears problematic. Such on the job learning is fundamentally not rotely digesting somebody else's representations, but improving capability to create vocabularies and notations, in order to explain, document, and manage activities.

- *Creating* new vocabularies, meanings, priorities;
- *Interpreting* company policy or textbook theories;
- *Adapting* existing tools.

Success is facilitated by ready access to facts and representational tools, means for generating alternative conceptions and plans, helpful colleagues, and time to reflect. We find that people use word processors, voice mail, e-mail, spreadsheets, and sometimes simulation programs to represent their situation.

People are not just digesting and "implementing" pre-existing, written methods and procedures that formalize work processes. "Learning on demand," a catch-phrase we hear today, must be more than classroom learning at a different time and location, as if someone sitting at his or her desk finally decides to memorize someone else's theory. In the workplace, learning occurs within socially-coordinated inquiry, as a process of *creating new representations* to document, understand, or gain control of everyday work. Talk about a "curriculum" obscures the learner's perspective: 1) how to use existing tools and languages, 2) how to represent one's own activities within a new language or visualization, and 3) how to participate effectively in multiple communities of practice.

Learning on the job often is a process of finding words and frameworks for describing one's conceptualization. These descriptions, diagrams, and partial plans then become guides, as they are later interpreted for articulating the pros and cons of alternative designs and ways to work around policies.

That is, workers need tools for representing what is on their mind, as ways of:

- *Being persuasive:* A researcher uses a chart to explain to the lab director how project time is allocated, to justify hiring assistants.

- *Coordinating work:* An ethnographer uses a table format in a word processor to plan and record her field work, notify remote researchers of future events, and link documents to events.

- *Explaining policy:* A team leader collects in memo form a trainee's on-line transactions from an information system to show how to interpret company policy in dealing with customers.

People create representations in order to manage their participation within a community of practice. Learning on demand is occurring on several levels: Learning about a representation tool, learning about the expressiveness of languages and notations, and learning how to interact more effectively within a group.

Eleanor Wynn (1991) summarizes the limitations of the normative, business functional view of work:

> Information flow charts show 'information' moving in little blocks or triangles moving along arrows to encounter specific transformations and directions along the diagram. In reality, it seems, all along the arrows as well as at the nodes, that there are people helping this block to be what it needs to be—to name it, to put it under the heading where it will be seen as a recognizable variant, deciding whether to leave it in or take it out, whom to convey it to. A more traditional approach would treat both the information and the functions as if they were permanently defined, always recognizable entities. (pp. 56-7)

Here the circularity of the symbolic view is revealed: We start by attempting to inventory what people know in terms of facts, rules, and procedures. We then identify these descriptions with knowledge. We claim that the expert has such descriptions stored in his or her head. We reify these theories as a "curriculum" and develop instructional designs for transferring these models to the student.

The alternative view, which Wynn advocates, is to understanding what is problematic in everyday work. Rather than treating knowledge as static, we view categorizing, sorting, evaluating, and judging as dynamic processes. So how to interpret a policy means *adapting* a prior interpretation, not merely applying a rule. By definition, what constitutes information and appropriate criteria must be adjusted with every problematic situation—otherwise the situation would not be a problem, indeed, there would be no "situation" to speak of. In effect, situated learning calls for the kind of "metacognitive" approach that ITS has advocated. But the emphasis is again not on learning a fixed strategy or way of organizing the world, but learning how to learn. It's a cliché, but situated learning reveals the idea in a new way. The focus is not on "learning how to digest" or "learning how to access facts" but learning how to invent, to work around and through difficulties, and to interact productively.

Conclusions

Situated learning suggests a view of the nature of people, learning, and work different from the view that motivated the initial design of consultation programs and intelligent tutoring systems in the 1970s. This epistemological shift suggests a different view of how people use tools and what kinds of tools would be helpful. Rather than delivering to students what has already been preconceived and designed, we seek to develop tools for representing what's problematic about a situation, alternative designs, and interpretations of policy for each other (Wynn, 1991). Finally, such designs suggest a different view of the design process: Studying how problems arise in everyday experience and how learning successfully occurs; designing tools in the context of use, by a participatory, inclusive process. We might call this "activity-based design"—designing for the nonroutine, within a framework of a community of practice. Consequently, situated learning researchers often work with schools, universities, corporations, and government agencies to study and design for the actual settings in where knowledge is created and is useful.

Situated learning theory reveals the limitations of computer-human interaction analysis based on a descriptive, stored view of knowledge. Such assumptions led us to use computers for automation, to replace people and teachers by machines. We sought to store knowledge in computers and deliver expert systems to workers and intelligent tutoring systems to students. We didn't ask, "Why are representations (diagrams and descriptions) created? How are categories, priorities, and policies interpreted within the constraints of an activity?" We viewed people as information processors working alone at a workstation. We didn't understand the origin of problems in conflicting values and identities, different paradigms influencing decisions about roles, rights, and access to information (Zuboff, 1988).

In the idealistic, objectivist world of the symbolic approach, we ignored that the problems arise not only because people don't know scientific facts and laws, but they disagree *conceptually* about how to create and value alternative designs. For all the concern about knowledge, the symbolic view fundamentally misconstrued the psychological nature of how decisions get made. As we saw in the cottage cheese example, the same criticism can be made about the social-interactional view, which appropriately encourages us to look outside the web of information-processing computers and telecommunications links, but never explains why changing human behavior is so difficult.

Some of the implications for ITS research are:

- Understand better the student's point of view; focus on how people create representations, perceive symbols, and attribute meaning in physical manipulation of materials. Contrast: Teaching a pre-formalized, normative curriculum vs. studying how a new language develops in practice.

- Attempt to relate levels of analysis—perceptual, deliberative, and social—to reconceive the nature of misconceptions, as well as the notational resources facilitating learning.

- Stepping out of "representational flatland"—understanding learning as a process of multimodal recoordination and trouble as a problem of reconciling perception, conception of activity, and how to value designs and interpret policies may enable us to consolidate arguments about coaching, discovery, tutoring.

Finally, consider how common ways of talking about knowledge are obscuring the nature of knowledge and inhibiting our own research on learning. The following statements were heard at a recent workshop on organizational learning and technological change:

"They have knowledge but cannot act."
"Knowledge should be stored before it gets lost."
"Mental models are in the head of the user."
"Perception is controlled by theory."
"Learning is an individual, knowledge-based process and a social communication process."

How would we criticize or reinterpret these statements from the perspective of situated learning theory?

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