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Learning and Transfer in Everyday Cognition

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This theoretical article deals with the interrelations and sociocultural origins of everyday cognition, formal reasoning, and transfer in cognitive development. Sociocultural origins are analyzed in terms of modes of informal education and formal schooling. After reviewing studies carried out in a wide variety of cultures, we propose the development of a model that integrates structural accounts of individual development with cultural and situation-bound functionalism. The notion of representation provides a key theoretical link between sociocultural context and individual cognitive constructions. Representation of cultural instruments and cultural goals is presented as the theoretical link between individual cognition and sociocultural context, both in everyday cognition and formal reasoning. Abstract schema representations are seen as crucial to generalized transfer. The conditions that foster abstract schemas include (a) the use of a tool or procedure in a variety of problem-solving contexts, (b) reflection on the structural similarity of problems and their solutions from diverse domains, and (c) exploration of problems and their solutions under conditions of low goal specificity. When these conditions are not present, transfer is less likely to occur. This is the case for both school-based learning and everyday cognition.

Everyday cognition refers to how people use their knowledge and reasoning skills in informal settings. It is usually contrasted with the abstract reasoning people display in schools, psychological experiments, and intelligence tests. Investigations of everyday cognition have generally focused on how people solve the problems and tasks they encounter in their everyday lives. The distinction is not, however, hard and fast. To the extent that cognitive socialization takes place in school, the technologies and interactions of formal education also affect styles of communication and interaction outside of school (Duranti & Ochs, 1986; Greenfield, 1972; Ochs, Smith, Rudolph, & Smith, in press). Indeed, recent definitions of everyday cognition make the general point that cognition is always embedded in the context of sociocultural practices. Formal education then becomes the locus of a number of sociocultural contexts of its own. Just as reason-

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ing varies from one informal context to another, reasoning in school may vary from one formal context to another.

INFORMAL EDUCATION

Investigations of informal education, including studies of apprenticeship training and parent–child interaction, have focused on two related areas. First, researchers have compared informal education (usually in non-Western settings) with formal, Western-style schooling. Second, detailed analyses of tutor–tutee interactions have focused attention on how tutors naturally structure tasks and match their assistance to tutees' abilities. This has been termed *scaffolding* (Wood, Bruner, & Ross, 1976). Whereas the first group of studies concentrates on what is learned in informal contexts, the second group treats informal teaching as one example of everyday cognitive skill (e.g., Childs & Greenfield, 1980; Greenfield, Brazelton, & Childs, 1989; Rogoff & Gardner, 1984; Wertsch, Minick, & Arns, 1984).

Concerning the contrast between formal and informal education, investigators have gathered data indicating that participation in formal, Western-style schooling is a critical factor in the development of flexible categorization skills (Greenfield, Reich, & Olver, 1966), use of a style of pattern representation that combines abstraction and analysis (Childs & Greenfield, 1980; Greenfield & Childs, 1977), use of a general rule to solve multiple problems (Scribner & Cole, 1973), and less use of social authority in reasoning about the physical world (Greenfield, 1966).

On theoretical grounds, Scribner and Cole (1973) proposed that formal instruction often begins with a generalized verbal rule which is then applied to a variety of concrete instances. In formal schooling, according to their view, children are taught abstract symbol systems such as numeration and written language, independent of any specific practical activity. In contrast, rules or principles are rarely verbalized in informal education (e.g., Childs & Greenfield, 1980; Greenfield, 1984), nor are they generalized to related but different events.

Informal education entails practical activity, with the appropriate concrete and specific tools. Whereas the goal of formal schooling is learning, and trial-and-error exploration is valued, the goal of informal education is often efficiency, or "getting the job done" (Greenfield & Lave, 1982; Wertsch, Minick, & Arns, 1984). Wertsch et al. (1984), for instance, found that parents provided more structured assistance on a task than did teachers. Because the parents saw the goal as getting the task done as efficiently as possible, they often performed the task for the children and attempted to prevent circumstances that might lead the children to err; in contrast, the teachers imposed a pedagogical goal on the task and encouraged independent performance and the use of trial-and-error strategies.

However, these distinctions hold most strongly for informal education in

societies where schooling is not indigenous and where informal education is provided by relatively uneducated adults. The fact is that school-based instruction affects informal socialization practices and interaction. Education in school leads to particular patterns of communication outside of school: greater reliance on verbal communication (Richman et al., 1988), a corresponding lesser reliance on nonverbal cues in communication (Greenfield, 1972), and stimulation to provide causal explanations (Ochs, Smith, Rudolph, & Smith, in press). Another problem with such distinctions is cultural bias and contradictory results from comparative studies of formal and informal education. Thus, whereas Kpelle children failed to apply a discrimination rule learned in one problem to subsequent problems (Cole, Gay, Glick, & Sharp, 1971), unschooled Wolof children did apply a single categorization rule to multiple problems, but were unable to shift rules even when asked explicitly to do so (Greenfield, Reich, & Olver, 1966). The problem of a school-oriented bias in interpretation comes into play: Each research group interpreted the style associated with schooling as better than the unschooled style, thereby finding two diametrically opposed defects in the thinking of unschooled children! At the same time, it was also the case that, for each research group, the school children's strategies were better adapted to the task requirements of the experimenter. Anticipating our final analysis, the problem seemed to be located in understanding the goals of the experimenter rather than in cognitive competence.

EVERYDAY COGNITION

Although people clearly reason in situations other than schools or experimental laboratories, only in the last decade has the broader domain of everyday cognition become an important focus of psychological investigation. In their attempts to achieve objectivity and replicable results, psychologists traditionally have sought settings and tasks that were "context-free" (Laboratory of Comparative Human Cognition [LCHC], 1983). They chose abstract tasks that were unfamiliar to their subjects so that performance would be free of the "contaminating" effects of prior experience, leaving only "pure" cognitive processes.

The popularity of theories that propose reasoning develops through a sequence of broad stages (e.g., Piagetian theory) encouraged psychologists to search for an underlying or domain-general organization of cognition. Many believe that these "mental structures" should manifest themselves in uniform performance across a broad spectrum of tasks regardless of task content, social context, or subjects' prior experiences (LCHC, 1983). Context effects were considered mere noise, and performance was interesting only for what it revealed about underlying competence.

The current focus on everyday cognition stems from the challenges cross-cultural research has posed to Piagetian theory. Many studies found that adults in traditional societies did not exhibit the content-free forms of reasoning displayed

by children in Western, industrialized societies. On verbal syllogisms, for example, Scribner (1977) found that Kpelle adults reasoned from their knowledge of the premise's truth rather than accepting hypothetical, contrary-to-fact statements, a cognitive style she labelled as "empiric."

Cross-cultural investigations indicate that many *interindividual* differences are a function of particular prior experience and context—especially the tasks used and how they are presented—rather than general differences in subjects' abilities. Price-Williams, for example, found that (a) children with experience in pottery making passed a conservation of substance task (which, like pottery making, entails manipulating claylike material) earlier than children without similar experience, and (b) earlier, more intense pottery making experience resulted in transfer to other forms of conservation (Price-Williams, Gordon, & Ramirez, 1969a,b). Similarly, Gay and Cole (1967) found that the ability to estimate quantities was affected by prior experience with the material being estimated. They found that although American Peace Corps volunteers were more accurate than traditional Kpelle rice farmers were in estimating distances, the rice farmers were superior in estimating quantities of rice, an important staple of the Kpelle economy and diet.

Even within Western industrialized societies, informal educational experiences can have a cognitive impact. For example, in the United States, video game experience has been found to develop visual-spatial skills (Greenfield, in press; McClurg & Chaille, 1987; Subrahmanyam & Greenfield, in press). In both the United States and Italy, computer game experience has been found to develop skills in decoding graphical representation of scientific/technical material (Greenfield, Camaioni, Encolani, Weiss, & Lauber, 1991).

In sum, a variety of studies in a variety of cultures suggest that performance may be more variable than Piagetian theory, or any structural theory of cognition, predicts (Carraher, Schliemann, & Carraher, 1988).

There are also *intraindividual* variations in performance due to prior experience and context. Several researchers, for example, found that people may use concrete operations in some domains and not in others, and that the variability was related to their everyday activities (Dasen, 1974, 1977). Others found that individuals who fail to exhibit abilities on standard laboratory tasks often demonstrate the same abilities in their everyday activities. Brazilian children working as street vendors (Carraher, Carraher, & Schliemann, 1985; Carraher et al., 1988), for instance, easily solve the arithmetic problems they encounter in their jobs, but when presented with the same problems on a schoollike "arithmetic test," are less accurate and employ different solution strategies. Similarly, Lave (1977) found that Liberian tailors solved arithmetic problems presented in a tailoring context more accurately than similar problems presented in a schoollike context.

The cross-cultural findings of cognitive heterogeneity made the study of everyday activities—and how people reasoned in them—a respectable and important research concern. First, the findings focused attention on the important

role of everyday activities in the acquisition of cognitive skills: To understand cognitive development it is necessary to investigate what is learned in everyday activities, how that learning occurs, and how it interacts with prior knowledge. Second, by demonstrating variability of performance as a function of context, cross-cultural research suggested that reasoning in everyday activities differs from reasoning in formal contexts. That is, everyday activity is an interesting domain of investigation in its own right, and not just for the insight it provides about formal, abstract reasoning.

A review of research suggests some characteristics of everyday out-of-school cognition. Most importantly, reasoning in everyday activities is intimately associated with the context in which it occurs. It is flexible, adapting to and exploiting characteristics of the environment and problem situation. For example, in their studies of Brazilian child street vendors, Carraher et al. (1985) found that the arithmetic strategies their subjects used were influenced by the particular numbers involved in the problems. Rather than using a single algorithm for all problems, children chose strategies that simplified calculations (such as doubling, or multiplying by 10) and created easily manipulable quantities (such as 100s). Similarly, Scribner (1984, 1986) found variability in the strategies dairy workers used to calculate the cost of an order, sometimes using unit prices and sometimes using case prices. Simplification often seems to be the strategic principle guiding variations in procedures across different contexts.

Everyday cognition is also goal-oriented; goals constitute a significant aspect of context. Everyday problem solving out of school is, by definition, embedded in larger activities. Unlike school-based arithmetic, where the goal is learning to do arithmetic, in everyday settings it is used to achieve some other goal, such as determining whether one has enough money to make a purchase. The means for achieving these goals involve cognitive subgoals. Subgoals of replacing physical effort with mental effort (Scribner, 1984, 1986), or making a quick decision without exhaustively searching all possible choices (Capon, Kuhn, & Carretero, 1987, 1989; Mehan, 1984), affect both the strategies people use and how they formulate the problem to be solved—even whether or not they identify that a problem exists in the first place (Lave, Murtaugh, & de la Rocha, 1984).

Everyday cognition out of school often uses shortcuts based on knowledge acquired through past experience. The routine nature of many everyday activities encourages the use of knowledge and results from prior performance, both reducing mental effort and aiding accuracy (Lave, 1988). For instance, having once determined that a particular brand of noodles is less expensive than other brands, a shopper can base future selections on that knowledge rather than engaging in lengthy cost comparisons for each purchase (Lave et al., 1984; Murtaugh, 1985).

These characteristics of everyday cognition out of school may at first seem to contrast with the more content-free algorithms taught in school. But content-free does not mean context-free. More work simply has to be done to identify and

describe the contexts for school-based learning and the cognitive processes associated with them. When this is done, it will be found undoubtedly that school-based reasoning also is flexible, adapting to and exploiting characteristics of the formal educational environment and the problems presented in it. Similarly, school-based learning will not turn out to be less goal-oriented; the goals will simply be different (e.g., learning addition facts in order to pass a test vs. learning to make change in order to make a purchase). Finally, many shortcuts to school-based tasks are also acquired through experience, if not by direct instruction. Examples of the latter in mathematics are the instruction in short cuts to SAT math problems (received in school by the second author) and instruction in estimation skills.

Research by Stigler and colleagues (Stigler, 1984; Stigler, Chalip, & Miller, 1986; Stigler & Perry, 1988) points not to homogeneity but to cross-cultural variation in the goals of formal education, with associated cultural differences in the cognitive processes of students. For example, the most salient goal for a Japanese teacher is to provide clear explanations; this goal is very low on the hierarchy of his or her counterpart in the United States. A related cognitive difference in the students of the two societies is the Japanese students' significantly greater ability to discriminate relevant from irrelevant information in solving a problem (Stigler, 1991).

Furthermore, formal systems of symbolic representation cannot be used to separate in-school and out-of-school cognition. Everyday cognition outside of school can involve formal systems of symbolic representation, even in cultures without formal education. Two examples are the writing system of the Vai in Liberia (Scribner & Cole, 1981) and the numerical system of the Oksapmin in New Guinea (Saxe, 1982a, 1982b). These examples give an idea of the heterogeneity of everyday cognition. At the same time, an important point of this discussion is to enlarge the notion of cognitive processes beyond those applied in school and testing contexts, and simultaneously place school-based tasks in a common conceptual framework.

The increasing evidence that thinking skills are affected by participation in everyday activities has led researchers to focus attention on issues of *transfer*: How far reaching are the cognitive effects of participation in routine activities outside of school? How does the breadth of transfer compare with that produced by schooling? Researchers have asked, for example, if weaving experience promotes generalized pattern-representation skills (Childs & Greenfield, 1980; Greenfield & Childs, 1977; Greenfield, Brazelton, & Childs, 1989), if tailoring apprenticeship experience promotes generalized arithmetic skills (Lave, 1977), and if experience in handling and measuring rice promotes generalized measurement skills (Gay & Cole, 1967).

Greenfield and Childs (1977), Childs & Greenfield (1980), and Lave (1977) also compared the effects of different educational experiences, both formal and informal, on transfer. Lave found limited but symmetrical transfer of both tailoring and school experience. Tailoring experience had a large impact on the ability to solve math problems met by tailors (direct effect) but had a much more limited impact on the ability to solve schoollike math problems (transfer effect). School, in contrast, had a large impact on the ability to solve schoollike math problems (direct effect) but had a much more limited impact on the ability to solve math problems used in tailoring (transfer effect). Greenfield and Childs found that weaving a very limited stock of patterns led to less generalization of pattern representation skills by Zinacanteco girls than by Zinacanteco boys, who did not weave, but whose lifestyle included more travel, participation in a market economy, and exposure to a wider range of fabric patterns. Schooling in Zinacantan added nothing to the transfer of pattern representation skills beyond what was contributed by the informal education of boys.

These data provide no support for the idea that formal education routinely promotes more transfer than does informal education. At the same time, they show that different sorts of informal education, even within the same culture, can lead to different degrees of transfer to novel problems. The limited transfer produced by both formal and informal education have led some to suggest that the structuralist goal of describing abstract mental structures to explain diverse behaviors should be replaced with more focused investigations of links between particular activities and particular cognitive skills (e.g., see Scribner & Cole, 1981).

Structural Salvage Operations

Scribner (1986) pointed out that there are two responses to findings that reasoning is often context bound. First, there are what she referred to as "salvage" operations—attempts to retain unimodal theories of mind, often associated with the structuralist position that reasoning is a property of the individual and independent of the particular context and content that is being reasoned about. Generally, these studies have compared behavior in everyday contexts with behavior in formal, academic, or experimental settings, by looking for similarities across contexts.

Capon et al. (1987, 1989), for instance, interviewed a group of low-socioeconomic status (SES) Hispanic women concerning their preferences for various dimensions when selecting dresses (e.g., blue or brown, with or without pockets). The authors derived an ordered series of selection strategies which, they argue, represent differences in skill or efficiency. They conclude, though, that differences between subjects probably do not represent varying levels of competence but, rather, broad "cognitive styles" that should be manifested across a variety of tasks.

The ambiguity between performance and competence, between stage and style, may be an inherent problem in structural salvage operations. Another problem with structural salvage operations is the fact that, as with formal education, cognitive development in Western societies is not as context-free as had

once been thought. When presented with multiple tasks, children often do not respond at a single stage of cognitive development (Rogoff, Gauvain & Ellis, 1984).

Situationism

The second reaction to findings of variability of reasoning, referred to as "situationism" by Scribner (1986), was to abandon structural models of cognition altogether. This work has usually been conducted within functional or context-specific approaches: Thinking consists of a variety of cognitive skills, each independently acquired in socially organized activities, forever tied to the contexts in which they develop. Since variability of performance is assumed, rather than considered to be a problem in need of explanation, there has been little emphasis in this approach on comparing the everyday cognition used outside of school with the abstract reasoning emphasized in formal education. The early cultural practice model offered by the Laboratory of Comparative Human Cognition (LCHC, 1982) was an example of this approach. According to this view, structure was not in the head of the organizer, but in a socioculturally organized environment.

The New Functionalism

Having rejected structuralism on empirical grounds and dissatisfied with the extreme environmental emphasis of situationism, researchers of everyday cognition were challenged to formulate a model of learning and reasoning that extended beyond the particular activities from which it was derived. To do so, researchers had to focus on the similarities in people's thinking in a variety of everyday tasks. For instance, although one prominent characteristic of everyday cognition is its contextual variability, Lave (1985) has pointed out that "there are theoretically crucial ways in which people are similar in how they vary" (p. 172).

In her studies of dairy workers, Scribner (1984, 1986) found that the most salient property of skilled performance was its flexibility. Small changes in the problem situation gave rise to different solution modes. For instance, when filling an order of 12 quarts, a warehouse worker might remove 2 from a partial carton of 14 or add 2 to a partial carton of 10—each of which entails two steps. In contrast to this flexibility, novices tended to use algorithmic solutions, such as always creating a new carton—entailing 12 steps. The variability of skilled performance was not random variation; rather, each solution appeared to be finely fitted to the occasion. Scribner (1986) proposed that strategy selection was guided by a higher-order goal: saving effort. In the dairy, skilled workers saved physical effort (measured by the number of steps needed to fill an order) by expending mental effort (determining the best strategy). For other tasks, the least-effort principle entailed reformulating the problem or using prior solutions to simplify the arithmetical calculations involved. It is undoubtedly clear from the preceding discussion that psychological functionalism refers to the importance of goal-directed activity or intention in cognitive processes (see Bruner, 1974; Greenfield, 1971, 1980).[1]

The Next Steps

Although Scribner's search for the higher-order goals that organize everyday cognition is on target, effort saving is a goal that influences the selection of strategies, but does not explain how strategies are acquired or how they are related to conceptual understanding. Research on children's understanding of numbers illustrates that although effort-saving may be a common motive for selecting and constructing new strategies, it is only a part of the picture.

A common finding in number research is that in the early school years children spontaneously change the strategy they use to add two small numbers (Baroody & Ginsburg, 1986; Fuson, 1982, 1988). For instance, when asked to add 3 and 5, children from about 4 to 5 years of age begin counting with the first addend, 3, and then counting on the second, 5 [e.g., 3 (pause), 4, 5, 6, 7, 8]. Older children typically reformulate the problem: They save effort by beginning with the larger addend, 5, and counting on the smaller addend [e.g., 5 (pause), 6, 7, 8]. Whereas the attempt to save effort may motivate the change in strategy, it tells us little about the new conceptual understandings (e.g., commutativity) that allow children to create new strategies and have them available for selection. Endogenous factors in cognitive development cannot be abandoned.

LINKING INDIVIDUAL THINKING WITH CULTURAL CONTEXT: THE ROLE OF REPRESENTATION

At the next stage of theoretical development, the cultural practice school acknowledged the necessity to theoretically integrate individual processes of cognitive development with sociocultural context (Rogoff, 1990). A step in this direction was made by Cole (1989) in his cognitive analysis of how scaffolded

[1] Psychological functionalism is not to be confused with structural-functional formulations in anthropology criticized by Lave (1988), who shortens the term structural-functionalism to "functionalism" and transfers its implications to cognitive psychology. The anthropological formulation of structural-functionalism views society and culture as a seamless web of structures serving functions that are beyond the individual level. As a consequence, there is no room for what Lave (1988, p. 8) calls "a theory of active social actors, located in time and space, reflexively and recursively acting upon the world in which they live and which they fashion at the same time." Socialization is a process by which the younger generation passively receives the structures and functions of the sociocultural context. What Lave terms the functional approach on the sociocultural level therefore leaves no room for functional activity on the individual level. Yet it is precisely individual goal-directed activity to which psychological functionalism calls attention.

However, according to sociocultural functionalism, what society transmits to the passive individual is the social and emotional sides of behavior; rational thought is left to the individual (Lave, 1988). Whereas psychological functionalism with its emphasis on intention as the motor of cognitive activity reminds us of the active, constructional individual, the perspective of informal education highlights the interactional origins of even rational thought processes.

instruction contributes to the development of reading skill. Fischer (1980; Fischer, Kenny & Pipp, 1990) has approached such an integration from the direction of cognitive developmental theory. An important part of integrating individual learning processes with sociocultural context must involve analyzing the cognitive representations that animate everyday thinking, both in school and out, and how these representations change with development. This is the focus of the present article.

Goal Representations

The first thesis of this article is that a major way in which the sociocultural context comes to be internalized in individual cognitive processes is in the form of *goal representations*. In this way, the functional element of intention is linked with the structural notion of representation. The thesis begins with the following conceptualization of behavior itself and then examines the representational implications of this conceptualization:

> Internal goals or intentions are important in the formal organization of behavior. Means-end relationships are an important example of the hierarchical structuring that is so prevalent in human functioning. That is, responses or behavioral routines often occur in relation to higher-order goals, which in interconnected goal structures are crucial to the temporal integration of behavior, a problem posed by psychologists as divergent as Lashley (1951) and Sartre (1956). (Greenfield, 1971, p. 253)

If goals have this role in the organization of behavior itself, goals should have a parallel role in the representation of behavior, including the representations used in problem-solving situations. This hypothesis receives developmental support from Piaget's notion of "*vertical decalage*": Each stage of cognitive development represents a more abstract representation of the stage below, which then becomes its content (Piaget & Inhelder, 1956). Therefore, a later-developing representation of an action sequence will reflect the organization of the earlier-developing sequence. The point here is that the goal-oriented structure of behavior (or other life experience) is mirrored by the goal-oriented structure of representations of that behavior or life experience. Thus, the agent–action–goal structures of infant behavior become the categories of early linguistic representations. These, in turn, become elements in more extended narratives that still revolve around answering the questions of "who did what and why?" (Bruner & Lucariello, 1989).

At the same time, goals are a defining aspect of culture. Every culture contains a world view that expresses what is valued and what is devalued. Cultural values are then translated into goals that guide individual and group behavior. Leont'ev's (1981) link between individual cognition and the goals of cultural activity is foundational to the cultural practice approach.

The sociocultural context includes social institutions as well as cultural values. Institutions also provide goals that can be internalized as representations to guide individual behavior. However, as Lave (1988) points out, these goals are not passively accepted. We must envision an interactional construction process by which social transmission and internal representation take place.

The Example of Deductive Logic. Cheng and Holyoak's conceptualization and research on pragmatic reasoning schemas provide a strong demonstration that goals are an intrinsic part of problem representations. They provide a most elegant model for the integration of everyday cognition and formal reasoning skills in the problem-solving behavior of adults. They propose that

> people often reason using neither syntactic, context-free rules of inference, nor memory of specific experiences. Rather, they reason using abstract knowledge structures induced from ordinary life experiences, such as "permissions," "obligations," and "causations." Such knowledge structures are termed *pragmatic reasoning schemas*. A pragmatic reasoning schema consists of a set of generalized context-sensitive rules which, unlike purely syntactic rules, are defined in terms of classes of goals (such as taking desirable actions or making predictions about possible future events) and relationships to these goals (such as cause and effect or precondition and allowable action). (Cheng & Holyoak, 1985, p. 395)

In one of their studies, Cheng and Holyoak (1985) gave university students in the United States and Hong Kong problems that could be solved by applying either formal procedures of deductive logic or a "permission" schema to a rule that served as the premise of the problem. The authors hypothesized that lack of familiarity with the goal of the rule would cause the rule to be seen as arbitrary and block application of the permission schema. Familiarity with the rule and its goal or purpose would, in contrast, evoke the permission schema. The effect of everyday experience, according to their hypothesis, is not a direct one; instead, relevant experience improves deductive performance by supplying a goal or purpose which triggers the relevant schema.

An example of a rule (based on Johnson-Laird, Legrenzi, & Legrenzi, 1972) used in Cheng and Holyoak's experiment is "If a letter is sealed, then it must carry a 20-cent stamp." University students in both Hong Kong and the United States were given this rule with a context, but with no purpose or goal (i.e., without what the authors termed a "rationale"):

> You are a postal clerk working in some foreign country. Part of your job is to go through letters to check the postage. The country's postal regulation requires that *if a letter is sealed, then it must carry a 20-cent stamp*. In order to check that the regulation is followed, which of the following four envelopes would you turn over? Turn over only those that you need to check to be sure.
>
> The above paragraph was followed by drawings of four envelopes, one carrying a 20-cent stamp, a second carrying a 10-cent stamp, a third one labeled "back of sealed envelope," and a fourth one labeled "back of unsealed envelope." (Cheng & Holyoak, 1985, p. 400)

The correct answer is the sealed envelope and the envelope with the 10-cent stamp. This answer can be derived either from the rules of the permission schema (i.e., if the action is to be taken, then the precondition must be satisfied) or from the rules of formal logic (i.e., modus ponens).

Students in Hong Kong were familiar with the postal rule because a similar rule had recently existed in Hong Kong; students in the United States had no experience with this type of rule. Under these conditions, the Hong Kong students performed much better than the students from the United States, a demonstration of the role of prior, culturally mediated experience in this problem-solving task.

However, Cheng and Holyoak (1985) also found that the provision of a rationale or goal (another condition of the experiment) could improve the U.S. students' performance. In the rationale condition, subjects were told, "The rationale for this regulation is to increase profit from personal mail, which is nearly always sealed. Sealed letters are defined as personal and must therefore carry more postage than unsealed letters" (p. 400). Given this rationale, U.S. students achieved the same level of performance as the Hong Kong students. The experimenters created an interactional context (Lave, 1988) in which they provided subjects with a representation of an institutional goal. This externally-presented goal representation embedded in the communication process from experimenter to subject could then be incorporated into the construction of a problem-solving schema. The provision of the goal by the experimenter and its putative transformation by the subject into a part of the problem representation constitutes a process of informal education. These experimental conditions and the processes they instigate constitute an experimental simulation of the processes that took place outside the laboratory for students living in Hong Kong.

These results indicate that prior cultural experience affects formal reasoning by providing the goal, a function for the structure to serve. We have already provided evidence that everyday cognition is goal oriented. The important point that Cheng and Holyoak's study makes is that *formal problem solving is goal oriented too.* Our interpretation of their results is that, for the Hong Kong students, the culture provided the functional goal, whereas for the U.S. students, the experimenter provided the functional goal. The effect of the experimental manipulation was to show that in each case the goal was internalized to become part of the problem representation. The fact that the U.S. students did as well in the rationale condition as the Hong Kong students validates Cheng and Holyoak's hypothesis: The critical factor is *not* the memory of specific experiences (which students in the United States lacked) but a goal representation that will evoke the relevant schema.

Without the presentation of a goal in the social context of the experiment (Lave, 1988), the U.S. students presumably had to fall back on the procedures of formal logic to solve the problem. The low success rate indicates that formal logic does not describe the processes by which problems are normally solved.

This experiment demonstrates that there is not a rigid line between everyday cognition and formal reasoning. To theorists, formal reasoning may have appeared to be context-free and independent of functional goals because the processes of formal reasoning were simply not understood well. Cheng and Holyoak's (1985) experiment blurs the line between everyday cognition and formal reasoning by showing (a) that a functional goal is just as critical to success at a laboratory reasoning task as it is in everyday cognition and (b) that a functional goal may be supplied by experimental manipulation as well as it is by past cultural experience. The critical issue is whether or not a goal becomes part of the problem representation.

In short, this experiment confirms our view that structure and function cannot be separated: that abstract logical structures do not exist in isolation, but function rather as means to attain goals. These goals may be, but do not have to be, culturally specified. Furthermore, the goal or function is not outside the individual's problem representation, but an intrinsic part of it. Structural considerations are not sufficient; any description of logical cognition must include functional goals in a structural description.

Most recently, Cosmides and Tooby (Cosmides, 1989; Cosmides & Tooby, 1989) have gone one step further: They demonstrate how changes in goal structure associated with adaptively important social contexts can modify not just the degree but also the very qualitative nature of logical reasoning. As an example, Cosmides (1989) noted that a social contract context generates its own conditional rule ("look for cheaters") that does not always conform to standard logic. For example, Cosmides presented subjects with rules having the form of a standard social contract: "If you take the benefit (p), then you pay the cost (q)." In each problem, subjects were presented on separate cards information about four people; one side of each card told whether that person paid the cost. Subjects had to turn over the minimum number of cards to know whether the rule was being broken. Under these conditions, standard logic ("If p, then q"; modus ponens, modus tolens), as well as a "look for cheaters" procedure, dictated the same strategy: Turn over the p card to see if the cost was paid when the benefit was taken; turn over the not-q card to make sure the benefit was not taken when the cost was not paid. However, if the rule was switched to the form, "If you pay the cost (p), then you take the benefit (q)," the situation was quite different. Formal logic (the logical consequences of "if p, then q") still dictated turning over p and not-q. However, the "look for cheaters" strategy necessary to maintain a social contract dictated the reverse strategy: turning over (a) the not-p card to make sure the benefit was not taken when the cost was not paid and (b) the q card to see that the cost was paid when the benefit was taken.

Subjects' selections were in accord with formal logic when formal logic did not conflict with the logic of social exchange. However, when there was a conflict between formal logic and the logic of social exchange, subjects overwhelmingly acted in accord with the logic of social exchange. Further studies by

Tooby (1991) have found still other qualitatively distinct logical forms supporting the goals of other social contexts central to human adaptation. Cosmides and Tooby's research indicates that variability of thinking from context to context is not simply a performance limitation in unfamiliar contexts; it can also be a matter of matching the nature of reasoning to the requirements of the goal of a particular sociocultural context. Cosmides and Tooby stress the domain—or context—specificity of logical strategies and the importance of evolving specific logical strategies for dealing with social contexts that are central to the human way of life. Under this theory, context specificity of cognitive processes is as relevant to the universals of human culture as it is to its cross-cultural variability.

The Example of Formal Operations. Inhelder and Piaget (1958) originally proposed that the most advanced stage of cognitive development, formal operations, would involve context-free logical processes. In 1972, Piaget raised the possibility that formal operations might occur in different contexts for people with varying formal educational backgrounds (Piaget, 1972). However, it continued to be thought that formal educational background of some sort was required for formal operations to develop and that formal operations were independent of the functional goals that are part of everyday cognition. Given the goal-oriented organization of deductive reasoning present in the research of Cheng and Holyoak (1985) and of Cosmides and Tooby (Cosmides, 1989; Cosmides & Tooby, 1989; Tooby, 1991), it seems possible that formal operations also have such an organization and may therefore be manifest and developed in the goal-oriented activities of everyday life.

Carraher et al. (1988) carried out research in Brazil that bears on this question. They investigated proportional reasoning, a formal operational skill, in two occupational groups, construction foremen and fishermen, both of whom must use proportions in their occupations. When subjects were given problems in which goal structures were clearly stated and related to their occupations, there was strong evidence that proportional reasoning concepts could flexibly transfer to new problem types. In both occupational samples, proportional reasoning performance was independent of years of schooling.

This research suggests that functional goals may be part of the representation of even formal operational problems. More importantly, it shows that formal operational skills are not restricted to school environments; they may also be developed in everyday contexts where goals require their use. Even in the area of formal operations, function and structure seem to be but two sides of the same coin.

Representation of Cultural Instruments

Cognitive processes require means as well as ends. A second major way in which the sociocultural context comes to be internalized in individual cognitive processes is when mental operations carried out on an imagistic representation are

derived from physical operations carried out earlier with a cultural tool. Stigler (1984) demonstrated this phenomenon with Chinese children's abacus use. Through an elegant series of studies (Stigler, 1984; Stigler, Chalip & Miller, 1986), Stigler showed that, as a result of intensive and extensive formal training in abacus use (physical and mental) for calculation, physical operations on a wooden abacus became internalized as mental operations on an abacus image. What remains to be shown is how the cognitive processes required for the physical and mental abacus develop with age. Clearly, the Chinese have a theory about cognitive developmental "readiness" for abacus training: Abacus instruction in Taiwan begins in fourth grade, 3 years after the onset of instruction in conventional methods of calculation.

Conclusion

It has now been demonstrated that a major way in which context influences cognitive processes is through the internalized representation of goals and mental operations. These goals and mental operations have their origins in culturally defined situations and artifacts. They are internally constructed by the individual through processes of social communication and physical action. These construction processes take place in situations of both formal and informal education.

TRANSFER

Here, we continue to integrate two lines of research concerning learning and transfer: (a) the cultural practice approach, and (b) recent work in cognitive psychology, focusing now on work in analogical transfer and the development of expertise in problem solving.

Situationism suffered from two interrelated problems. First, our experience of the world is not as disjoint as the approach implies: Although we are continually confronted with new experiences and new problems, there is a coherence and unity to our perceptions and understandings. This coherence must be constructed by the individual, using acquired knowledge to interpret and make sense of novel experience. Second, situationism contributed little to understanding the mechanisms of transfer (Rogoff et al., 1984). Its general conclusion was that there is transfer only to problems that are familiar or similar to the everyday cultural practices in which the skills were originally acquired, although what constitutes familiarity or similarity is either unspecified or described concretely, such as the similarity of task materials or procedures. Although the belief that transfer occurs only between tasks that share "identical elements" (Thorndike & Woodworth, 1901) has a long history in the study of learning, recent work has demonstrated that surface similarity between problems is neither sufficient nor necessary for transfer (Brown, 1989; Holyoak, Junn, & Billman, 1984).

A recent version of the cultural practice approach articulated by Lave (1988) corrected the first flaw of situationism—in acknowledging continuity of activity

across situations. However, Lave proposed that "learning transfer is not the central source of continuity" (p. 187). Having reduced its importance, she did not find it necessary to subject its processes to further analysis.

Brown and Campione (1984) distinguished between vertical and lateral transfer, a distinction this article borrows and modifies. In the next section vertical transfer is discussed—the use of existing knowledge and skills in the construction of new knowledge and skills. Of concern is the interplay between conceptual and procedural knowledge in the acquisition of both new concepts and new problem-solving procedures. In the following section lateral transfer is discussed—the application of existing problem-solving skills to new domains. Again, the emphasis is on the role of knowledge representation in transfer.

Vertical Transfer

Brown (1989) argued that transfer—or the lack of transfer—varies with the type of knowledge under consideration. On the one hand, theoretical knowledge, a coherent explanatory network of interrelated concepts such as causal explanations, is always transferred to new situations. Theoretical knowledge is a necessity for creating coherence out of novel experiences. On the other hand, isolated rules learned in particular situations are less likely to be transferred, protecting against unwarranted interference and generalization. Only when isolated rules are supported by a coherent theoretical framework will transfer be likely.

While Brown's distinction between types of knowledge is useful in understanding transfer across domains, it does not provide information on the *development* of new theoretical knowledge. Indeed, for Brown, it appears there is little development of conceptual knowledge; rather, development is primarily the accessing and application of existing knowledge to ever wider spheres of functioning (Brown & Campione, 1981).

The Interaction Between Procedural and Conceptual Knowledge. One thing that is needed from a developmental (and cultural) perspective is a framework that allows for the development of new conceptual understanding through the practice of procedural skills. Hatano's (1982, 1988; Hatano & Inagaki, 1986) discussion of the interaction of procedural and conceptual knowledge provides a useful framework. Hatano defined procedural knowledge as "a procedure routinely used for solving problems in a domain" and conceptual knowledge as "a mental model representing the world involving the object of the procedure" (Hatano, 1982, p. 15). Although performance of a procedural skill does not directly influence the development of related skills, through practice people may gain new insight into the corresponding conceptual knowledge underlying the skill.

This new knowledge, in turn, provides additional understanding of the utility of the skill. Through this process the skill gains meaning and becomes available for use in new domains. Thus, development proceeds through the cyclic interaction of procedural and conceptual knowledge: "We assume that people can form the conceptual knowledge through performing the procedural skill, and through that conceptual knowledge they can 'invent' other procedural knowledge" (Hatano, 1982, p. 16).

Hatano's (1982) distinction between routine and adaptive expertise is useful in understanding why the cognitive effects of participating in practical activities can be so limited. *Routine expertise* arises from the mechanical repetition of a skill in typical situations. Although performance becomes faster and more accurate, *procedural* skills remain tied to those contexts in which they were learned. In contrast, when the skill is supported by *conceptual* understanding it can be used flexibly, resulting in *adaptive expertise*. Adaptive expertise requires examination of the results of systematic variation in the use of the skill. Hatano argued that the conditions fostering adaptive expertise are often missing from everyday practices.

The elaboration of conceptual knowledge through variation in the use of practical skills is most likely to occur in times of cultural change (Hatano, 1982; Luria, 1976). For instance, Saxe (1982a, 1982b) documented how the introduction of a money economy influenced the numerical understandings of the Oksapmin, a nontechnological society in Papua New Guinea. Through a comparison of subjects varying in their participation in the money economy, Saxe showed that the indigenous Oksapmin numeration system—based upon correspondences between a limited set of body parts and objects—is being adapted and elaborated for new forms of computation. For instance, although the traditional numeration system is adequate for simple addition calculations with objects present, there is no way to keep track of the addends when objects are not present. With experience in the money economy, the Oksapmin are developing new conceptual understandings, such as new correspondence operations. Some of the subjects designated a subseries of body parts to refer to the second addend; this subseries was then used to count on to the first addend until the value of the second addend was reached. Similarly, the numeration system is being elaborated to include a base structure, an acquisition allowing for more complex calculations. Other studies have documented the elaboration of children's indigenous forms of knowledge upon their introduction to Western-style schooling (Brenner, 1985; Saxe, 1985). New experiences, such as participation in new forms of exchange or education, are contexts for individuals to modify their existing procedural knowledge in the service of novel goals, resulting in the construction of new conceptual knowledge.

Abacus training in Taiwan represents an example of conditions fostering both routine and adaptive expertise. First, the intensive and extensive practice creates routine expertise, based on procedural knowledge. In Taiwan, this expertise is in itself an explicit cultural goal transmitted by means of social institutions such as after-school abacus programs and interschool competitions (Stigler et al., 1986). But, second, procedural knowledge of the abacus is an alternative to the conven-

tional representation of numbers and arithmetic operations. As such, it provides variation in the use of calculation and the representation of numbers (Stigler et al., 1986). This would seem to explain why procedural knowledge of abacus use enhances conceptual knowledge of numbers and the number system (Stigler et al., 1986). Our theoretical formulation leads to the hypothesis that, in earlier times, when abacus training and use were part of informal, rather than formal education, it would have led to procedural rather than conceptual knowledge and to routine rather than adaptive expertise.

Learning and Knowledge Representation

Several lines of research have demonstrated that children's learning is constrained by the state of their existing knowledge. For example, training studies have consistently found that children benefit from instruction one step beyond their assessed abilities, whether that ability is conceptualized as cognitive structures (Beilin, 1976) or systems of rules (Siegler, 1976). Vygotsky's writings on "the zone of proximal development" (Vygotsky, 1978; Wertsch, 1984) stressed that effective instruction must be sensitive to the learner's state of knowledge. Vygotsky-inspired investigations stress that the learner and tutor often have different conceptualizations of a task and that effective learning and teaching is made possible through negotiation over the course of task activity: The tutor must simplify the task so that the learner is capable of participating, while the learner adjusts his or her behavior in accord with the tutor's instruction. By solving the task under the guidance of more knowledgeable partners, learners restructure their task definition in accord with that provided by the tutor.

Thus, vertical transfer is implied in much of the research on informal education referred to earlier. However, observations in situ often have no way of measuring changes in cognitive representation that result from the well documented interaction of children with more knowledgeable partners. Piagetian studies of cognitive development have filled this gap. Through processes of conflict resolution with a more knowledgeable peer, representations become demonstrably concrete operational when a child's preexisting representations have been transitional between preoperational and operational forms (e.g., Miller & Brownell, 1975; Mugny & Doise, 1978; Mugny, Perret-Clermont, & Doise, 1981). The use of pretest and posttest assessments document vertical transfer in children with transitional representations, thus demonstrating the relevance of existing knowledge and skills to the construction of new knowledge and skills.

Recently, Saxe, Guberman, and Gearhart (1987) have extended the Vygotskian framework to the study of social factors in early number development of American preschoolers. Central to their work is a concern to understand the goals children bring to typical number activities—goals that are often very different from the goals their parents have—and how the goal structure of an activity is altered through social interactions. The negotiation of the activity's goal structure allows children to participate in problem-solving activities beyond their independent abilities, a participation that allows for the construction of new conceptual understanding (Wertsch, 1984). Rogoff discusses the role of guided participation in "providing bridges from known to new" (Rogoff, 1990, p. 65).

Common to these studies is the finding that, when confronted with new situations, people attempt to apply their existing knowledge and procedures. Whether through independent activity, such as the assimilation of experience to existing knowledge and the accommodation of that knowledge to novel experiences (Piaget, 1970), or through socially organized and mediated experiences (Rogoff, 1990; Saxe et al., 1987; Vygotsky, 1978; Wertsch, 1984), the use and modification of existing knowledge is a ubiquitous property of intelligent functioning and an essential component of learning. This is the heart of vertical transfer.

Lateral Transfer: The Role of Schema Representation

Although vertical transfer is a common feature of most accounts of cognitive development, there is more controversy concerning lateral transfer. Studies of analogical transfer have typically demonstrated that subjects, both children and college students, are unlikely to spontaneously transfer a known solution to solve a structurally similar problem (Brown, Kane & Echols, 1986; Gick & Holyoak, 1983).

Several researchers (e.g., LCHC, 1983; Rogoff & Gardner, 1984) have taken this lack of transfer as evidence that independent spontaneous transfer is a rare phenomenon. Rather than transfer being a capacity of the individual problem solver, they argue, transfer is determined by the social and cultural organization of experience: "*Transfer is arranged by the social and cultural environment.* This shift of focus does not so much solve the transfer problem as it dissolves it" (LCHC, 1983, p. 341). The cultural practice approach cites the "massive redundancy and repetitiveness" (LCHC, 1983, p. 342) of everyday experience, therefore minimizing the need for spontaneous lateral transfer in most functioning.

Research on the zone of proximal development, discussed previously, is one example of how the social environment structures experience: Adults arrange sequences of progressively more complex activities for children and, in some cultures, point out the similarity of activities from diverse domains (Rogoff & Gardner, 1984). Transfer may also be arranged socially through language, which encodes a culture's concepts of the categories of experience: "Children master their culture's theory of the connections between contexts as they master their language" (LCHC, 1983, p. 341). Studies on analogical reasoning support both the role of language and social interaction in facilitating transfer: Although there may be little spontaneous transfer, when an experimenter provides a hint to use the solution to the first problem in solving the second, both children and college students demonstrate considerably more transfer (Brown, 1989; Brown et al., 1986; Crisafi & Brown, 1986; Gick & Holyoak, 1983).

Cultural tools may also either facilitate or impede transfer across domains. For instance, Gay and Cole (1967) studied measurement among the Kpelle of Liberia. Although the Kpelle have typical forms of measurement, the units vary with the item being measured. For instance, cloth and rope are measured in armspans, smaller items in handspans, and other items in footlengths. Moreover, there is no systematic relation between the units. When asked to estimate various lengths using each unit, the Kpelle were quite inaccurate. Americans, in contrast, were much more accurate, using the systematic relations between inches, feet, and yards to mediate their estimates. On the other hand, the Kpelle do have an interlocking system for the measurement of rice, an important economic commodity. When asked to estimate various quantities of rice, the Kpelle were more accurate than an American comparison group. They were also more accurate in the unfamiliar task of estimating the number of stones in various piles, which shows that a cultural tool—interlocking measurement units—facilitates spontaneous transfer.

Although much transfer may be socially facilitated, it is unlikely that all transfer is socially determined. While much of everyday experience may be redundant and repetitive, intelligent functioning refers to the ability to deal with just those (perhaps relatively rare) situations for which a solution is not readily available, either from past experience or from more knowledgeable others. Hatano's (1982) discussion of the role of conceptual knowledge in the development of adaptive expertise suggested that an understanding of lateral transfer must be grounded in an examination of how knowledge is structured by the problem solver and accessed in novel situations. Recent work in cognitive psychology, especially in analogical problem solving and the acquisition of expertise, also emphasized the role of knowledge structures in problem solving and transfer. This research demonstrated that the conditions fostering flexible transfer of knowledge across domains are frequently absent in the practice of everyday, practical skills.

Conditions Fostering Adaptive Expertise

Recent work on analogical transfer has identified some of the conditions that promote flexible use of knowledge across structurally similar problems that differ in their surface properties. In a series of studies, Brown and her colleagues (Brown, 1989; Brown et al., 1986; Crisafi & Brown, 1986) found that preschoolers given prior experience with multiple functions of a tool were more likely to use it creatively to solve a similar but novel problem than were children who had used the tool in only one of its functions, especially if that was the tool's typical function.

Multiple functions promote conceptual transfer more generally. For example, in an experiment on ways to teach the meaning of the term *square*, young children who were asked to carry out three different actions with the square piece were better able to generalize their learning to new situations than were children who always carried out the same action (Greenfield, 1971).

Other conditions that facilitate analogical transfer include (a) asking children if the previously solved analog could help solve the new problem, (b) asking children to state the solution rule, (c) providing multiple examples of the solution, and (d) pointing out and asking children to reflect on the similarity between analogs. Brown (1989) suggested that these conditions promote transfer by forcing attention to the common "underlying deep structure" of the problems.

Additional studies by Brown and her colleagues indicated the elements that may constitute "deep structure." Children who were either directed to reflect on the common goal structure of the problems (i.e., the protagonists, goals, obstacles and solutions) or abstracted it spontaneously were more likely to use a variant of the learned solution in solving a novel problem than were children who did not focus attention on the goal structure. According to Brown (Brown et al., 1986), transfer depends upon the acquisition of a representation of the problem at a sufficient level of abstraction.

Catrambone and Holyoak (in Holyoak, 1985) provide additional evidence that analogical transfer is mediated by abstract problem representations. They found that college students given two analogs before being asked to solve a structurally similar problem showed more analogical transfer than students given a single analog, but only if the students were first instructed to note the similarities between the analogs. Holyoak (1985) argued that asking students to compare several versions of a problem facilitated the induction of problem schemas—abstract representations of classes of problems that can be solved by similar procedures. Holyoak noted that much of what appears to be analogical reasoning may, in fact, not rely on accessing particular problem analogs; rather, the solution may entail categorization of the novel problem as an instance of an abstract problem schema in which its generalized solution is known. Schemas of greater abstraction may facilitate transfer because, unlike the original analogs, schemas contain only the information essential for categorization and solution (Gick & Holyoak, 1983). These processes are similar to what Perkins and Salomon (1987) call "high-road transfer."

The importance of abstract knowledge representations in problem solving has also been highlighted by research on the acquisition of expertise. For instance, in a study comparing expert and novice physics problem solvers, Chi, Glaser, and Rees (1982) found that experts tended to use their conceptual knowledge of physics to group into categories problems that may be solved by a similar set of procedures. In contrast, novices tended to categorize problems according to surface features. For the expert, problem solving is schema driven: "Solving a problem becomes a matter of categorizing the problem into one or more problem types and applying the existing subroutines" (Chi et al., 1982, p. 19).

Sweller, Mawer, and Ward (1983) pointed out that goal-driven problem solving (e.g., means–ends analysis) may impede acquisition of the problem schemas typical of expertise. Means–ends analysis, by focusing attention on the problem goal, may prevent problem solvers from noticing important aspects of the problem necessary for the formation of appropriate schemas. Sweller et al. found that

subjects acquired more rapidly expertise and problem schemas when presented with less specified problem-solving goals.

To summarize, expertise and the flexible use of knowledge are related to the acquisition of abstract problem schemas.

The Role of Representation

In this article, it has been argued that the use of existing knowledge and skills to acquire new conceptual knowledge (vertical transfer) and the application of existing knowledge and skills in novel contexts (lateral transfer) depend on how information is represented by the problem solver. The concern with how knowledge is represented has begun to be taken up by proponents of the cultural practice approach. Lave (1988) examined how the representation of task situations influenced the selection of problem-solving strategies in math. In addition, the evidence from cognitive psychology cited previously, and from work on pragmatic reasoning schemas (Cheng and Holyoak, 1985), suggests that problem solving is mediated by abstract representations of classes of problems and their associated solutions.

Task familiarity does not suffice. Although many of these classes of problems may be part of the cultural environment, their use in problem solving depends on how they are represented and accessed by individuals. Thus, for "familiarity" to serve as an explanatory construct it is necessary for researchers interested in culture–cognition links to attend to how cultural knowledge and experience are represented. Work on analogical reasoning and expertise provides a framework for understanding the relations between the cultural organization of experience and the cognitive structure of knowledge.

CONCLUSION

The theme of this article has been the relationship between everyday experience and the representation of knowledge. Our review suggests that cognitive skills may be more variable and context bound than traditionally believed. Despite the apparent obstacles, people do succeed in constructing a coherent and meaningful understanding of the world, an understanding that permits them to interpret new experience in terms of what they already know and to adapt prior knowledge in the service of new goals. How is it possible to reconcile these facts with the findings of cognitive heterogeneity and context-bound skills?

Rather than asking, "What is the relationship of knowledge and experience?", we found it necessary to ask more refined questions: "What kinds of knowledge promote transfer?" and "What are the conditions under which these kinds of knowledge are likely to be acquired?" Research in cognitive psychology suggests that conceptual knowledge or a coherent interconnected body of knowledge (Hiebert & Lefever, 1986) at a sufficient level of abstraction, but not routine procedural knowledge, will support the transfer of knowledge to new situations.

Conceptual knowledge is most likely to be acquired when conditions encourage the exploration and flexible use of procedures in a variety of activities. To the extent that practical activities do not provide these conditions, the cognitive effects of participation in these activities would be limited. Indeed, laboratory-based experiments on transfer rarely provide conditions that would foster the kind of understanding necessary for transfer (Saxe, 1990). For the same reasons, school may stimulate less transfer than is commonly assumed.

Although this article suggests that some forms of learning and knowledge are more likely than others to lead to transfer, we believe that a taxonomy of learning conditions and knowledge forms is only the first step toward providing information concerning the relationship between everyday experience, in school and out, and the acquisition and use of cognitive skills. Much more important, although complex and challenging, is to begin to understand the web of relations between different forms of knowledge (e.g., conceptual and procedural), the conditions in which learning occurs (e.g., formal and informal), and the interplay between sociocultural and cognitive processes.

REFERENCES

Baroody, A.J., & Ginsburg, H.P. (1986). The relationship between initial meaningful and mechanical knowledge of arithmetic. In J. Hiebert (Ed.), *Conceptual and procedural knowledge: The case of mathematics* (pp. 75–112). Hillsdale, NJ: Erlbaum.

Beilin, H. (1976). Constructing cognitive operations linguistically. In H.W. Reese (Ed.), *Advances in child development and behavior* (Vol. 11, pp. 67–106). New York: Academic.

Brenner, M.E. (1985). The practice of arithmetic in Liberian schools. *Anthropology and Education Quarterly, 16*, 177–186.

Brown, A.L. (1989). Analogical learning and transfer: What develops? In S. Vosniadou & A. Ortony (Eds.), *Similarity and analogical reasoning* (pp. 369–412). Cambridge: Cambridge University Press.

Brown, A.L., & Campione, J.C. (1981). Inducing flexible thinking: The problem of access. In M.P. Friedman, J.P. Das, & N. O'Connor (Eds.), *Intelligence and learning* (pp. 515–529). New York: Plenum.

Brown, A.L., & Campione, J.C. (1984). Three faces of transfer: Implications for early competence, individual differences, and instruction. In M.E. Lamb, A.L. Brown, & B. Rogoff (Eds.), *Advances in developmental psychology* (Vol. 3, pp. 143–192). Hillsdale, NJ: Erlbaum.

Brown, A.L., Kane, M.J., & Echols, C.H. (1986). Young children's mental models determine analogical transfer across problems with a common goal structure. *Cognitive Development, 1*, 103–121.

Bruner, J.S. (1974). The organization of early skilled action. In M.P.M. Richards (Ed.), *The integration of a child into a social world* (pp. 167–184). Cambridge: Cambridge University Press.

Bruner, J., & Lucariello, J. (1989). Monologue as narrative recreation of the world. In K. Nelson (Ed.), *Narratives from the crib* (pp. 73–97). Cambridge, MA: Harvard University Press.

Capon, N., Kuhn, D., & Carretero, M. (1987). Shopping styles and skills: Everyday cognition in a "noncognitive task." *The Quarterly Newsletter of the Laboratory of Comparative Human Cognition, 9*, 102–114.

Capon, N., Kuhn, D., & Carretero, M. (1989). Consumer reasoning. In J.D. Sinnott (Ed.), *Everyday problem solving: Theory and applications* (pp. 153–174). New York: Praeger.

Carraher, T.N., Carraher, D., & Schliemann, A. (1985). Mathematics in the streets and in the schools. *British Journal of Developmental Psychology, 3*(1), 21–29.

Carraher, T., Schliemann, A.D., & Carraher, D.W. (1988). Mathematical concepts in everyday life. In G.B. Saxe & M. Gearhart (Eds.), *Children's mathematics: Vol. 41. New directions for child development* (pp. 71–87). San Francisco: Jossey-Bass.

Cheng, P.W., & Holyoak, K.J. (1985). Pragmatic reasoning schemas. *Cognitive Psychology, 17*, 391–416.

Chi, M.T.H., Glaser, R., & Rees, E. (1982). Expertise in problem solving. In R.J. Sternberg (Ed.), *Advances in the psychology of human intelligence* (Vol. 1, pp. 7–75). Hillsdale, NJ: Erlbaum.

Childs, C.P., & Greenfield, P.M. (1980). Informal modes of learning and teaching: The case of Zinacanteco weaving. In N. Warren (Ed.), *Studies in cross-cultural psychology* (Vol. 1, pp. 269–316). New York: Academic.

Cole, M. (1989). Cultural psychology: A once and future discipline. In J. Berman (Ed.), *Nebraska symposium on motivation: Cross-cultural perspectives* (Vol. 37, pp. 279–335). Lincoln, Nebraska: University of Nebraska Press.

Cole, M., Gay, J., Glick, J.A., & Sharp, D.W. (1971). *The cultural context of learning and thinking*. New York: Basic Books.

Cosmides, L. (1989). The logic of social exchange: Has natural selection shaped how humans reason? Studies with the Wason selection task. *Cognition, 31*, 187–276.

Cosmides, L., & Tooby, J. (1989). Evolutionary psychology and the generation of culture, part II. Case study: A computational theory of social exchange. *Ethology and Sociobiology, 10*, 51–97.

Crisafi, M.A., & Brown, A.L. (1986). Analogical transfer in very young children: Combining two separately learned solutions to reach a goal. *Child Development, 57*, 953–968.

Dasen, P.R. (1974). The influence of ecology, culture and European contact on cognitive development in Australian Aborigines. In J.W. Berry & P.R. Dasen (Eds.), *Culture and cognition* (pp. 381–408). London: Methuen.

Dasen, P.R. (1977). Are cognitive processes universal? A contribution to cross-cultural Piagetian psychology. In N. Warren (Ed.), *Studies in cross-cultural psychology* (Vol. 1, pp. 155–201). New York: Academic.

Duranti, A., & Ochs, E. (1986). Literacy instruction in a Samoan village. In B. Schieffelin & P. Gilmore (Eds.), *The acquisition of literacy: Ethnographic perspectives* (pp. 213–232). Norwood, NJ: Ablex.

Fischer, K.R. (1980). A theory of cognitive development: The control and construction of hierarchies of skills. *Psychological Review, 87*, 477–531.

Fischer, K.R., Kenny, S.L., & Pipp, S.L. (1990). How cognitive processes and environmental conditions organize discontinuities in the development of abstractions. In C.N. Alexander and E.J. Langer (Eds.), *Higher stages of human developments* (pp. 162–187). New York: Oxford University Press.

Fuson, K.C. (1982). An analysis of the counting-on solution procedure in addition. In T.P. Carpenter, J.M. Moser, & T.A. Romberg (Eds.), *Addition and subtraction: A cognitive perspective* (pp. 67–81). Hillsdale, NJ: Erlbaum.

Fuson, K.C. (1988). *Children's counting and concepts of number*. New York: Springer-Verlag.

Gay, J., & Cole, M. (1967). *The new mathematics in an old culture*. New York: Holt, Rinehart & Winston.

Gick, M.L., & Holyoak, K.J. (1983). Schema induction and analogical transfer. *Cognitive Psychology, 12*, 1–38.

Greenfield, P.M. (1966). On culture and conservation. In J.S. Bruner, R.R. Olver, P.M. Greenfield et al., *Studies in cognitive growth* (pp. 225–256). New York: Wiley.

Greenfield, P.M. (1971). Goal as environmental variable in the development of intelligence. In R. Cancro (Ed.), *Intelligence: Genetic and environmental influences* (pp. 252–261). New York: Grune & Stratton.

Greenfield, P.M. (1972). Oral vs. written language: The consequences for cognitive development in Africa, the United States, and England. *Language and Speech, 15*, 169–178.

Greenfield, P.M. (1980). Toward an operational and logical analysis of intentionality: The use of discourse in early child language. In D.R. Olson (Ed.), *The social foundations of language and thought* (pp. 254–279). New York: W.W. Norton & Company.

Greenfield, P.M. (1984). A theory of the teacher in the learning activities of everyday life. In B. Rogoff & J. Lave (Eds.), *Everyday cognition: Its development in social context* (pp. 117–138). Cambridge, MA: Harvard University Press.

Greenfield, P.M. (in press). Representational competence in shared symbol systems: Electronic media from radio to video games. In R.R. Cocking & K.A. Renninger (Eds.), *The development and meaning of psychological distance*. Hillsdale, NJ: Erlbaum.

Greenfield, P.M., Brazelton, T.B., & Childs, C.P. (1989). From birth to maturity in Zinacantan: Ontogenesis in cultural context. In V. Bricker & G. Gossen (Eds.), *Ethnographic encounters in Southern Mesoamerica: Celebratory essays in honor of Evon Z. Vogt* (pp. 177–216). Albany: Institute of Mesoamerican Studies, State University of New York.

Greenfield, P.M., Camaioni, L., Encolani, P., Weiss, L., & Lauber, B. (1991, April). *Video game as tool of cognitive socialization: A cross-cultural comparison in the United States and Italy*. Paper presented at the biennial meeting of the Society for Research in Child Development, Seattle, WA.

Greenfield, P.M., & Childs, C.P. (1977). Weaving, color terms, and pattern representation: Cultural influences and cognitive development among the Zinacantecos of Southern Mexico. *Interamerican Journal of Psychology, 11*, 23–48.

Greenfield, P.M., & Lave, J. (1982). Cognitive aspects of informal education. In D.A. Wagner & H.W. Stevenson (Eds.), *Cultural perspectives on child development* (pp. 181–207). San Francisco: Freeman.

Greenfield, P.M., Reich, L.C., & Olver, R.R. (1966). On culture and equivalence: II. In J.S. Bruner, R.R. Olver, P.M. Greenfield et al. (Eds.), *Studies in cognitive growth* (pp. 270–318). New York: Wiley.

Hatano, G. (1982). Cognitive consequences of practice on culture specific skills. *Quarterly Newsletter of the Laboratory of Comparative Human Cognition, 4*, 15–18.

Hatano, G. (1988). Social and motivational bases for mathematical understanding. In G.B. Saxe & M. Gearhart (Eds.), *Children's mathematics: Vol. 41. New directions for child development* (pp. 55–70). San Francisco: Jossey-Bass.

Hatano, G., & Inagaki, K. (1986). Two courses of expertise. In H. Stevenson, H. Azuma, & K. Hakuta (Eds.), *Child development and education in Japan* (pp. 262–272). New York: Freeman.

Hiebert, J., & Lefever, P. (1986). Conceptual and procedural knowledge in mathematics: An introductory analysis. In J. Hiebert (Ed.), *Conceptual and procedural knowledge: The case of mathematics* (pp. 1–27). Hillsdale, NJ: Erlbaum.

Holyoak, K.J. (1985). The pragmatics of analogical transfer. In G.H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 19, pp. 59–87). New York: Academic.

Holyoak, K.J., Junn, E.N., & Billman, D.O. (1984). Development of analogical problem-solving skill. *Child Development, 55*, 2042–2055.

Inhelder, B., & Piaget, J. (1958). *The growth of logical thinking: From childhood to adolescence*. New York: Basic Books.

Johnson-Laird, P.N., Legrenzi, P., & Legrenzi, S.M. (1972). Reasoning and a sense of reality. *British Journal of Psychology, 63*, 395–400.

Laboratory of Comparative Human Cognition (1983). Culture and cognitive development. In P.H. Mussen (Ed.), *Handbook of child psychology: Vol. 1. History, theory and methods* (pp. 295–356). New York: Wiley.

Lashley, K.S. (1951). The problem of serial order in behavior. In L.A. Jeffries (Ed.), *Cerebral mechanisms in behavior: The Hixon Symposium* (pp. 112–146). New York: Wiley.

Lave, J. (1977). Cognitive consequences of traditional apprenticeship training in West Africa. *Anthropology and Education Quarterly, 8,* 177–180.

Lave, J. (1985). Introduction: Situationally specific practice. *Anthropology and Education Quarterly, 16,* 171–176.

Lave, J. (1988). *Cognition in practice.* New York: Cambridge University Press.

Lave, J., Murtaugh, M., & de la Rocha, O. (1984). The dialectic of arithmetic in grocery shopping. In B. Rogoff & J. Lave (Eds.), *Everyday cognition: Its development in social context* (pp. 67–94). Cambridge, MA: Harvard University Press.

Leont'ev, A.N. (1981). The problem of activity in psychology. In J.V. Wertsch (Ed.), *The concept of activity in Soviet psychology* (pp. 37–71). Armonk, NY: Sharpe.

Luria, A.R. (1976). *Cognitive development: Its social and cultural foundations.* Cambridge, MA: Harvard University Press.

McClurg, P.A., & Chaille, C. (1987). Computer games: Environments for developing spatial cognition? *Journal of Educational Computing Research, 3,* 95–111.

Mehan, H. (1984). Institutional decision-making. In B. Rogoff and J. Lave (Eds.), *Everyday cognition: Its development in social context* (pp. 41–66). Cambridge, MA: Harvard University Press.

Miller, S.A., & Brownell, C.A. (1975). Peers, persuasion, and Piaget: Dyadic interactions between conservers and nonconservers. *Child Development, 46,* 992–997.

Mugny, G., & Doise, W. (1978). Socio-cognitive conflict and structure of individual and collective performances. *European Journal of Social Psychology, 8,* 181–192.

Mugny, G., Perret-Clermont, A., & Doise, W. (1981). Interpersonal coordinations and sociological differences in the construction of the intellect. In G.M. Stephenson and J.M. Davis (Eds.), *Progress in applied social psychology* (Vol. 1, pp. 315–343). New York: Wiley.

Murtaugh, M. (1985). The practice of arithmetic by American grocery shoppers. *Anthropology and Education Quarterly, 16,* 186–192.

Ochs, E., Smith, C., Rudolph, D., & Smith, R. (in press). Narrative activity as a medium for theory building. *Discourse processes.*

Perkins, D.N., & Salomon, G. (1987). Transfer and teaching thinking. In D. Perkins, J. Lockhead, & J. Bishop (Eds.), *Thinking: The second international conference* (pp. 285–303). Hillsdale, NJ: Erlbaum.

Piaget, J. (1970). Piaget's theory. In P.H. Mussen (Ed.), *Carmichael's manual of child psychology* (3rd ed., pp. 703–732). New York: Wiley.

Piaget, J. (1972). Intellectual evolution from adolescence to adulthood. *Human development 15,* 1–12.

Piaget, J., & Inhelder, B. (1956). *The child's conception of space.* London: Routledge & Kegan Paul.

Price-Williams, D.R., Gordon, W., & Ramirez, M. (1969a). Skill and conservation: A study of pottery-making children. *Developmental Psychology, 1,* 769.

Price-Williams, D.R., Gordon, W., & Ramirez, M. (1969b). Manipulation and conservation: A study of children from pottery-making families in Mexico. In *Memorias del XI Congreso Interamericano del Psicologia* (pp. 106–126). Mexico City.

Richman, A., LeVine, R., New, R., Howrigan, G., Welles-Nystrom, B., & LeVine, S. (1988). Maternal behavior to infants in five cultures. In R.A. LeVine, P.M. Miller, & M.M. West (Eds.), *Parental behavior in diverse societies: Vol. 40. New directions for child development* (pp. 81–97). San Francisco: Jossey-Bass.

Rogoff, B. (1990). *Apprenticeship in thinking: Cognitive development in social context.* New York: Oxford University Press.

Rogoff, B., & Gardner, W. (1984). Adult guidance of cognitive development. In B. Rogoff & J. Lave (Eds.), *Everyday cognition: Its development in social context* (pp. 95–116). Cambridge, MA: Harvard University Press.

Rogoff, B., Gauvain, M., & Ellis, S. (1984). Development viewed in its cultural context. In M.H. Bornstein and M.E. Lamb (Eds.), *Developmental psychology: An advanced textbook* (pp. 533–571). Hillsdale, NJ: Erlbaum.

Sartre, J.P. (1956). *Being and nothingness.* New York: Philosophical Library.

Saxe, G.B. (1982a). Developing forms of arithmetical thought among the Oksapmin of Papua New Guinea. *Developmental Psychology, 18,* 583–594.

Saxe, G.B. (1982b). Culture and the development of numerical cognition: Studies among the Oksapmin of Papua New Guinea. In C.J. Brainerd (Ed.), *Children's logical and mathematical cognition* (pp. 157–176). New York: Springer-Verlag.

Saxe, G.B. (1985). Effects of schooling on arithmetical understandings: Studies with Oksapmin children in Papua New Guinea. *Journal of Educational Psychology, 77,* 503–513.

Saxe, G.B., Guberman, S.R., & Gearhart, M. (1987). Social processes in early number development. *Monographs of the Society for Research in Child Development, 52*(2, Serial No. 216).

Saxe, G.B. (1990). The interplay between children's learning in school and out-of-school contexts. In M. Gardner, J. Greeno, F. Reif, A. Schoenfeld, A. Disessa, & E. Stage (Eds.), *Toward a scientific practice of science education* (pp. 219–234). Hillsdale: NJ: Erlbaum.

Scribner, S. (1977). Modes of thinking and ways of speaking: Culture and logic reconsidered. In P.N. Johnson-Laird & P.C. Wason (Eds.), *Thinking* (pp. 483–500). Cambridge: Cambridge University Press.

Scribner, S. (1984). Studying working intelligence. In B. Rogoff & J. Lave (Eds.), *Everyday cognition: Its development in social context* (pp. 9–40). Cambridge, MA: Harvard University Press.

Scribner, S. (1986). Thinking in action: Some characteristics of practical thought. In R.J. Sternberg & R.K. Wagner (Eds.), *Practical intelligence: Nature and origins of competence in the everyday world* (pp. 13–30). Cambridge: Cambridge University Press.

Scribner, S., & Cole, M. (1973). Cognitive consequences of formal and informal education. *Science, 182,* 553–559.

Scribner, S., & Cole, M. (1981). *The psychology of literacy.* Cambridge, MA: Harvard University Press.

Siegler, R.S. (1976). Three aspects of cognitive development. *Cognitive Psychology, 8,* 481–520.

Stigler, J.W. (1984). "Mental abacus": The effect of abacus training on Chinese children's mental calculation. *Cognitive Psychology, 16,* 145–176.

Stigler, J.W. (1991, January). *Children's mathematics learning in Japan, China, and the United States.* Developmental psychology colloquium, University of California, Los Angeles.

Stigler, J.W., Chalip, L., & Miller, K.F. (1986). Consequences of skill: The case of abacus training in Taiwan. *American Journal of Education, 49,* 447–479.

Stigler, J.W., & Perry, M. (1988). Cross-cultural studies of mathematics teaching and learning: Recent findings and new directions. In D.A. Grouws & T.J. Cooney (Eds.), *Effective mathematics teaching* (pp. 194–223). Hillsdale, NJ: Erlbaum.

Subrahmanyam, K., & Greenfield, P.M. (in press). Effect of video game practice on spatial skills in girls and boys. *Journal of Applied Developmental Psychology.*

Sweller, J., Mawer, R.F., & Ward, M.R. (1983). Development of expertise in mathematical problem solving. *Journal of Experimental Psychology: General, 112,* 639–661.

Thorndike, E.L., & Woodworth, R.S. (1901). The influence of improvement in one mental function upon efficiency of other functions. *Psychological Review, 8,* 247–261, 384–395, 553–564.

Tooby, J. (1991, February). The logic of threat: Evidence for another cognitive adaptation? In A.A. Pontius (Organizer), *Evolution of cognitive functions in ecological-cultural context.* Paper presented at the American Association for the Advancement of Science, Washington, D.C.

Vygotsky, L.S. (1978). *Mind and society.* Cambridge, MA: Harvard University Press.

Wertsch, J.V. (1984). The zone of proximal development: Some conceptual issues. In B. Rogoff & J.V. Wertsch (Eds.), *Children's learning in the 'zone of proximal development.' : Vol. 23. New directions for child development* (pp. 7–18). San Francisco: Jossey-Bass.

Wertsch, J.V., Minick, N., & Arns, F.J. (1984). The creation of context in joint problem-solving. In B. Rogoff & J. Lave (Eds.), *Everyday cognition: Its development in social context* (pp. 151–171). Cambridge, MA: Harvard University Press.

Wood, D.J., Bruner, J.S., & Ross, G. (1976). The role of tutoring in problem solving. *Journal of Child Psychology and Psychiatry, 17*, 89–100.