TABLE 2

Forearm Length to Meter Price Conversion n: Number of Participants Displaying Artifacts, Strategies, and GDO's Across Time (n = 13), Shopkeeping Tracking Tasks

Participant ID	Day 0 Art./Str./GDO[1]		Day 16 Art./Str./GDO		Day 32 Art./Str./GDO
1[2]	w/b/b	||*	b/b/m		b/b/m
2	w/c/e		w/c/e		w/c/e
3	w/c/e		w/c/e		w/c/e
4[2]	w/c/e		w/c/e	||	w/c/b
5[2]	b/b/m	||	b/r/m		b/r/m
6[2]	w/c/e		w/c/e	||	w/b/m
7[2]	w/c/e		w/c/e	||	w/b/m
8[2]	w/b/b	||	b/b/m	||	w/r/m
9[2]	w/c/e	||	b/c/b	||	o/r/m
10[2]	w/c/e	||	w/c/m	||	w/b/m
11	w/c/e		w/c/e		w/c/e
12[2]	w/c/e		w/c/e	||	w/b/m
13[2]	w/c/e		w/c/e	||	w/b/m

*** || indicates change**

[1] Art (Artifact): w = written, o = object, b = both
Str. (Strategy): c = column algorithm, r = reorganization, b = both
GDO (Goal-Directed Organization): e = equation, m = measurement, b = both

[2] Denotes a participant who changed their use of artifacts, strategies, and/or GDO over time in relation to becoming a fuller participant in the new activity

Artifacts,

Among the 10 students who displayed change, there was generally continuity in the use of written artifacts as they became fuller participants in shopkeeping, discontinuity in shifting from an equation GDO to a measurement GDO, and both continuity and discontinuity in the strategies displayed, moving toward a combined use of column algorithm and reorganization strategies. Examining relations bet ween artifacts, strategies, and GDO's as the developmental coupling of person and activities, we can see that a new form of arithmetic has been constructed. The form is neither a product of the individual participant, the prior schooling activity, or participation in the new leading activity of shopkeeping.

Seven of these participant-activity couplings developed forms of arithmetic that retain the relatively high social status of written calculation artifacts and their greater record permanence, with reorganization or a combination of reorganization and column algorithm strategies, and a measurement-based GDO. Figure 2 (next page) provides an illustration of this.

The three other participant-activity couplings that changed displayed a limited version of this relation between artifacts, strategies, and GDO on Day 0 prior to the start of the apprenticeship. This may be partially explained by all three having had extensive prior experience purchasing cloth; experience that would have tended to involve traditional to metric measure conversion. However, this was also true for the remaining three students who exhibited full continuity in their use of written artifacts, column algorithm strategies, and equation GDO over the entire apprenticeship. What did seem to distinguish these two groups of participants was the latter's poor performance in 10th grade school mathematics. Two of the three students had failed the final end of year exam and the third was passed by a teacher who provided five "grace" points on the final exam. Furthermore, the master shopkeeper to whom they were apprenticed described the three as "frustrating," "more interested in gossiping with customers than selling them things," and "unable to add two numbers."

Arithmetic Among Shopkeepers Becoming Students

Table 3 (page 297) displays transition patterns in the arithmetic of shopkeepers enrolled in the adult education class at Day 0, Day 16, and Day 32. The task in this case consisted of a school math exercise with 4 double by single-digit arithmetic problems each displayed in writing as an addition, subtraction, multiplication, or division equation. The exercise is considered to be a single task for the purpose of analysis. See Figure 3 (page 298) for an example from the problem that was presented to the shopkeepers.

The first pattern is based on the type of calculation artifacts used to solve the math exercise. A distinction is again made between the use of written artifacts such as numerals and equations, object-based calculation artifacts such as tallys, stones, or fingers, or the use of both. The use of written calculation artifacts was only coded as such if the person constructed the written artifact. Reading the written numerals in the exercise was not coded as written artifact use, as it was the means of introducing the task, much as an orally presented problem was not coded as using aural artifacts. None of the 13 shopkeepers enrolled as students retained objects as their primary calculation artifact throughout the apprenticeship, though 10 of the 13 participants used such artifacts exclusively at Day 0. By the end of the course 11 of the shopkeepers had adopted a combination of written and object artifacts and two had adopted the exclusive use of written artifacts.

time in

The next pattern is based on whether the participants used column algorithm strategies in their calculations, reorganization strategies such as decomposition and iteration, or both combined. Nine shopkeepers initially displayed the exclusive use of reorganization strategies, and three displayed the

Figure 2: Forearm Length to Meter Price Conversion Tracking Task at Day 32 of Apprenticeship, ID 6

Yan Bahadur is a 23 year old 10th grade high school student who has been asked to generate the price of a piece of a cloth that is 3 *haat* in length. A haat is a traditional unit of length measure that extends from the point of the elbow to tip of the middle finger. All cloth is priced based on metric length. Yan Bahadur is provided with a paper, a pencil, counting seeds, a meter ruler, and a length of cloth that is greater than the amount requested. The price of the cloth per meter (30 rupees) is written on the cardboard that the cloth is wrapped around.

Playing the role of customer, the researcher asks Yan Bahadur for 3 haat of cloth and how much it will cost. Yan Bahadur first measures out 3 haat of cloth using his forearm. Then he measures the 3 haat of cloth with the meter ruler. He says "one meter twenty-nine centimeters" as he writes "129" on a scrap of cardboard with a pen. Beneath it he writes "100m [meaning centimeters]= 30 ru [thirty rupees]," the cost of one meter. He looks at his meter ruler and says out loud, "a half meter . . . 50 centimeters must be fifteen rupees . . . and half of that must be seven and a half rupees." Yan Bahadur writes "25 = 7/50" under the "129 m = 30 ru." He then says out loud "one hundred and twenty six, twenty-seven, twenty-eight, twenty-nine" while incrementing on his finger by one each time and writes "4" under the "25" on the cardboard.

129		
100m	=	30 ru
25	=	7/50
4	=	

Then he writes 4 times 30 in column algorithm format, having already decided that if one meter costs 30 rupees, one centimeter costs 30 paisa, and multiplies: "four times zero is zero, four times three is twelve, so 120 . . . one rupee and 20 paisa" which he then writes as "1/20" under the "7/50."

129			
			30
100m	=	30 ru	x 4
25	=	7/50	120
4	=	1/20	

Yan Bahadur then totals the prices of the different length portions of the cloth out loud: "thirty . . . seven, thirty-eight . . . fifty . . . seventy," draws a line under "1/20," writes "38/70," laughs and says "I'll give it to you for 40 rupees" knowing that shopkeepers generally sell cloth in even rupee amounts, and also knowing that they round the price down rather than up.

129			
			30
100m	=	30 ru	x 4
25	=	7/50	120
4	=	1/20	
		38/70	

TABLE 3

Arithmetic Exercise: Number of Shopkeepers Displaying Artifacts, Strategies, and GDO's Across Time (n = 13), Schooling Tracking Tasks

	Day 0	Day 16	Day 32
Calculation Artifact			
Written	0	2	2
Object	10	4	0
Both	3	7	11
Calculation Strategy			
column algorithm	1	1	1
reorganization	9	5	2
both	3	7	10
Goal-Directed Organization			
strategic[1]	0	4	1
solution[2]	13	9	12

[1] The Strategic GDO refers to a goal-directed organization that not only includes achieving a correct solution, but also a single proper way of arriving at the solution. Evidence of this is a participant using the same strategy-artifact combination for all four problems.

[2] The Solution GDO refers to a goal-directed organization which includes achieving a correct solution, but allows the strategies and artifacts to vary depending on the characteristics of the problem. Evidence of this is a participant using more than one strategy-artifact combination for the four problems.

use of both column algorithm and reorganization strategies. By the end of the course only two of the participants displayed an exclusive use of reorganization strategies and 10 displayed the use of both.

The final pattern is based on whether the shopkeepers used a strategic GDO or a solution GDO. The solution GDO organizes strategies and artifacts around achieving a desired solution. This permits strategies and artifacts to be adapted to the nature of each problem in relation to the participant's knowledge. The greatest challenge for shopkeepers using a solution GDO occurred in knowing what the written artifacts and equations stood for. Figure 3 (next page) provides an illustration of this. The strategic GDO organizes strategies and artifacts through the establishment of an invariant relationship between strategy, artifact, and solution. The strategies and artifacts are not adapted to the particular characteristics of the numbers as they relate to the participant's knowledge. All 13 shopkeepers began

Figure 3: Subtraction Portion of Arithmetic Exercise Tracking Task at Day 8 of Apprenticeship, ID 19

> Prem Bahadur is a 42-year-old shopkeeper working on a subtraction problem as part of the arithmetic exercise. He has worked as a shopkeeper for five years and had not attended school prior to enrolling in the adult education class. Prem Bahadur is provided with a paper, a pencil, counting seeds, and the exercise sheet on which the four problems are written.
>
> Playing the role of teacher, the researcher asks Prem Bahadur to complete the arithmetic problems on the sheet. Prem Bahadur looks at the first problem written on the paper in Devnagri numerals as:
>
> (1) 53
> <u>- 17</u>
>
> He says that he recognizes the number 17, but not the other number or the line to the left of the 17. The researcher tells him that the other number is 53 and the line to the left of the 17 means to subtract. Prem Bahadur asks which number from which. The researcher tells him 17 from 53.
>
> He begins to write something in the empty space to the side of the problem, stops and says "twenty, fifty, take away twenty is thirty, so thirty-three." Then Prem Bahadur looks at the problem on the paper and uses the finger joints on his right had, beginning with the first joint of his little finger, touching each with his thumb "thirty-three, thirty two, thirty-one, thirty...the answer is thirty."

with a solution GDO and all but one ended the course using a solution GDO, though four of the participants displayed a strategic GDO on the Day 16 task.

Table 4 (opposite) displays relations between artifacts, strategies, and GDO's over time and allows the reader to directly trace patterns of individual change. In it we see that none of the 13 participants exhibited full continuity in the artifacts, strategies, and GDO's used throughout their participation in the adult education course. All 10 of the participants who began by exclusively using object artifacts on Day 0 changed to using a combination of written and object calculation artifacts by the end of the course. Two of the three participants who had begun on Day 1 by using both types of calculation artifacts changed to exclusively using written artifacts by the end.

Of the 11 participants who displayed the use of both types of calculation artifacts at Day 32, all but two also displayed the use of both column algorithm and reorganization strategies in completing the arithmetic exercise. Of those who displayed the use of a combination of calculation artifacts and a combination of strategies at Day 32 ($n = 9$), only one had displayed the use of both types of strategies at Day 0, and none had displayed the use of both types of calculation artifacts at Day 0. This suggests that there was an overall direction toward incorporating written artifacts and column algorithms into a arithmetic repertoire along with object artifacts and reorganization strategies. All nine of these participants also displayed solution GDOs at Day 32, as they did at Day 0.

Of the ten shopkeepers who exhibited change from Day 0 to Day 16, four shifted from a solution GDO to a strategic GDO. All others maintained the solution GDO they displayed on Day 0. Three

TABLE 4

Arithmetic Exercise: Number of Participants Displaying Artifacts Strategies, and GDO's Across Time (n = 13), Schooling Tracking Tasks

<table>
<tr><th>Participant ID</th><th>Day 0 Art./Str./GDO1</th><th></th><th>Day 16 Art./Str./GDO</th><th></th><th>Day 32 Art./Str./GDO</th></tr>
<tr><td>14[2]</td><td>o/b/so</td><td>||*</td><td>b/b/so</td><td></td><td>b/b/so</td></tr>
<tr><td>15[2]</td><td>o/r/so</td><td></td><td>o/r/so</td><td>||</td><td>b/b/so</td></tr>
<tr><td>16[2]</td><td>o/r/so</td><td></td><td>o/r/so</td><td>||</td><td>b/b/so</td></tr>
<tr><td>17[2]</td><td>b/c/so</td><td>||</td><td>b/b/st</td><td>||</td><td>w/c/so</td></tr>
<tr><td>18[2]</td><td>o/r/so</td><td>||</td><td>b/b/so</td><td></td><td>b/b/so</td></tr>
<tr><td>19[2]</td><td>o/r/so</td><td>||</td><td>b/b/so</td><td></td><td>b/b/so</td></tr>
<tr><td>20[2]</td><td>o/r/so</td><td>||</td><td>b/b/so</td><td></td><td>b/b/so</td></tr>
<tr><td>21[2]</td><td>o/r/so</td><td>||</td><td>b/b/so</td><td></td><td>b/b/so</td></tr>
<tr><td>22[2]</td><td>b/b/so</td><td>||</td><td>w/r/st</td><td>||</td><td>b/r/so</td></tr>
<tr><td>23[2]</td><td>b/b/so</td><td>||</td><td>w/c/st</td><td>||</td><td>w/b/st</td></tr>
<tr><td>24[2]</td><td>o/r/so</td><td></td><td>o/r/so</td><td>||</td><td>b/r/so</td></tr>
<tr><td>25[2]</td><td>o/r/so</td><td>||</td><td>o/r/st</td><td>||</td><td>b/b/so</td></tr>
<tr><td>26[2]</td><td>o/r/so</td><td>||</td><td>b/b/so</td><td></td><td>b/b/so</td></tr>
</table>

*** || Indicates change**

1 Art.(Artifact): w = written, o = object, b = both
Str.(Strategy): c = column algorithm, r = reorganization, b = both
GDO(Goal-Directed Organization): st = strategic, so = solution

2 Denotes participants who changed their use of artifacts, strategies, and/or GDO over time in relation to becoming a fuller participants in the new activity.

of the four participants who changed to the use of a strategic GDO on Day 16 had displayed some use of written artifacts and column algorithms on Day 0, prior to their participation in the adult education course.

Eight of the 13 participants changed strategies from Day 0 to Day 16: six to using both strategies when only one had been used at Day 0, one to exclusively using a column algorithm strategy at Day 16 when both strategies had been used at Day 0, and one to using a reorganization strategy exclusively on Day 16 when both had been used at Day 0. The latter participant had also changed to using a strategic GDO at Day 16. Of the seven participants who exhibited change from Day 16 to Day 32, three shifted from a strategic GDO to a solution GDO. Note that all three had initially displayed solution GDO's on Day 1. Of the seven, five changed from the exclusive use of a single type of calculation artifact to the use of both types of artifacts from Day 16 to Day 32. Of these seven shopkeepers, four changed from the exclusive use of a single strategy type to the use of both strategy types.

The participants generally displayed continuity in their use of the solution GDO during the adult education course. Though four of the shopkeepers changed to a strategic GDO on Day 16, all but one had returned to the use of a solution GDO by the end of the course. Their use of calculation artifacts and strategies generally shifted toward the use of both artifact types and both types of strategies in solving the four problems in the exercise, exhibiting both continuity and discontinuity across time. This may have been afforded by the relative continuity of the solution GDO over time; a GDO that supports the flexible use of a variety of calculation artifacts and strategies.

We again see that a new organization of arithmetic has been constructed during the process of transition, in this case from work to school. The arithmetic is not a simple product of the individual, prior shopkeeping activity, or new schooling. Nine of the participant-schooling couplings that changed demonstrate this transformation most clearly: displaying the use of both written and object artifacts, a combination of reorganization and column algorithm strategies, and a solution GDO. These 9 participant-activity couplings developed an arithmetic organization that permitted a high degree of adaptive flexibility over time and events, and incorporated multiple artifacts and strategies into an already flexible arithmetic repertoire. There was no apparent consistency to how the remaining four participants differed from these nine.

Discussion

Overall, these findings indicate that shopkeepers attending adult education classes developed a flexible repertoire of artifacts and strategies that were both continuous and discontinuous across activities, supported by the continuity of the solution GDO. Relative to shopkeepers in the classroom, students apprenticed to a shopkeeper displayed limited development of a flexible repertoire of artifacts, strategies, and GDO. Continuity lay in their use of written artifacts across the activities. Both discontinuity and continuity existed in students use of calculation strategies and GDO's, transformed by their continued use of written artifacts.

The person-activity couplings of students becoming shopkeepers and shopkeepers becoming students transformed arithmetic in ways that are not accounted for solely by individuals or activities. Explanations invoking individual abstraction/generalization processes and isomorphic task relations that have been among hallmarks of the transfer construct are similarly inadequate. This is an appropriate point at which to return to the concepts of leading and non-leading activity.

Students who were apprenticed to a shopkeeper were in transition from one leading activity to another, following a school-to-work sequence that will be characteristic of generations of students to come in rural Nepali society. However, the activities of studying in school and shopkeeping were defined by motives and objects that were not fully linked within the Bherighat community. The motives were learning, with learning also being the object of the activity, and becoming a shopkeeper, with profit generation as the object. Their weak relation allowed arithmetic originating with students and school-based activity to achieve a status disconnected from and beyond that originating with shopkeeping and shopkeepers. This was reflected in the development of a form of arithmetic that both acknowledged and conserved the high social status of written artifacts, while some degree of adaptive flexibility in calculation strategies and goal-directed organizations was created.

In marked contrast to this, shopkeepers enrolled in the adult education class were in transition from a leading activity to a non-leading activity, following a work-to-school sequence that is perhaps characteristic of only the current generation of shopkeepers in Bherighat. The motives and objects of the two activities were strongly linked through the lives of the shopkeepers. They were the motive of learning with an arithmetic that facilitates increased profit as the object, and the motive of maintaining a viable shop with profit generation as the object. This linkage was reflected in the development of an arithmetic form that was adaptively flexible, consisting of an extensive repertoire of artifacts, goal-directed organizations, and strategies. This form acknowledged the need for arithmetic reasoning that was closely tied to the nature of numbers and measurements encountered during sales practices.

The two developmental couplings between persons, school, and work described in this study are different in their directions. Resulting transformations in arithmetic knowledge are also different, but exist and are explained within this larger framework. The directionality, or telos is co-determined by the period in peoples' lives during which they participate in particular activities and the broader sociocultural changes embodied through those activities. This is captured by the concept of leading and non-leading activity as it has been developed in this study.

The study also offers an alternative to the construct of learning transfer in its attempt to understand change in personal knowledge across situations: a concept of developmental coupling between persons and activities that encompasses epistemological continuities and discontinuities, and their qualitative transformation to new knowledge. Coupling is not an interaction between person and environment, located in an additive relation between the two, but rather is their developing relation over time. It enacts and brings forth a new world by rearranging relations between personal and activity developmental systems. This is done without reducing one to the other and without holding the person or the environment constant. Verula, Thompson, & Rosch (1992) elaborate the concept of coupling and provide a wonderful analogy to the coupling of persons and activities—the coevolution of bees and flowers as developmental systems.

> On the one hand, flowers attract pollinators by their food content and so must be both conspicuous and yet different from flowers of other species. On the other hand, bees gather food from flowers and so need to recognize flowers from a distance. These two broad and reciprocal constraints appear to have shaped a history of coupling in which plant features and the sensorimotor capacities of bees coevolved. It is this coupling, then, that is responsible for both the ultraviolet vision of bees and the ultraviolet reflectance patterns of flowers. Such coevolution therefore provides an excellent example of how environmental regularities are not pregiven, but are rather enacted or brought forth by a history of coupling (p. 202.)

The concepts of leading activity and coupling are as yet rather blunt explanatory instruments. Unlike the coupling of bees and flowers, explanations of developmental coupling between persons and activities lie within broader patterns of sociocultural change and their embodiment in activity. Nevertheless, the ability of these concepts to move the discussion forward and away from assumptions of a static and somehow additive set of social situations, toward activities as mediating sociocultural change and individual development is productive and worthy of further inquiry.

Notes

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[1]An earlier version of this paper was presented as a part of the symposium "Transforming Boundaries: Social Constructivist Expansions Beyond the Transfer Construct" at the 1992 Annual Meeting of the American Educational Research Association.

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Activity as a Mediator of Sociocultural Change and Individual Development: The Case of School-Work Transition in Nepal

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This study explores how sociocultural change and individual development are mediated by activities in a process complicated by temporal transitions in environment and in the activity which leads, or is psychologically primary. Based on research among rural Nepali high school students becoming shopkeepers and among rural shopkeepers attending adult education, the author suggests a cultural-historical alternative to transfer in understanding the continuity and discontinuity of personal knowledge across situations and over time.

This research is an exploration of how people learn and develop during transitions between school and work. At the broadest level, this exploration is about how sociocultural change and individual development are mediated by activities, molar historical phenomena that possess their own developmental courses, and principles of explanation. At its most specific level, this exploration suggests a cultural-historical alternative to learning transfer in understanding the continuity and discontinuity of personal knowledge across situations.

Some of the issues involved in tying together these two levels of exploration will first be sketched. Then changes in arithmetic reasoning will be analyzed among rural Nepali high school students becoming shopkeepers and among rural shopkeepers attending adult education classes. These analyses will be used to illustrate how two forms of activity, leading and non-leading, mediate between societal and individual change, and how the two forms of activity are differentially related to transformations in personal knowledge of arithmetic across situations.[1] These data and analyses are part of a larger study reported elsewhere (Beach, 1995).

The construct of learning transfer has been used to describe whether and how knowledge, strategies, and representations learned through one task are applied to a new task. A number of critiques of the problem-solving literature have deemed transfer to be an infrequently occurring epiphenomenon (for example, Detterman, 1992) or a rare occurrence when using problem isomorphs and hypothesized psychological processes of abstraction/generalization (for example, Lave, 1988). Others (Brown & Kane, 1988; Palincsar & Brown, 1984; Schoenfeld, 1982) have opted for the design of instructional environments that include tasks as a method both to study and to foster transfer. In contrast to much of the problem-solving literature, their research has fairly consistently indicated that transfer is obtained when reasoning principles are taught in conjunction with self-monitoring practices, potential applications to a variety of contexts are discussed, and resemblances between problems are pointed out.

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A critique of the literature on task-to-task transfer will not be attempted here. Though several critiques of this literature suggests that the very concept of transfer is problematical, the point to be argued here is that current conceptualizations and inducements of transfer, successful or otherwise, are inadequate for explaining how people gain knowledge and skill across situations, particularly those embedded in changing societal institutions such as school and work. Though transfer may be inadequate as an explanatory construct, the phenomena to be explained are very real and the explanation is as important to educators as it is to social scientists, given that a primary institutional agenda of schooling is the creation of "portable" knowledge and skills (Glick, 1995) to be used elsewhere.

A major inadequacy of the transfer construct for understanding the development of personal knowledge across situations is made obvious by examining institutions such as school and work, institutions that generate historically contingent situations which change across space and time. The concept of task-to-task transfer has relied heavily on research designs and instructional goals to create the appearance of fixed relations between the target and transfer tasks. It effectively excludes the process of creating a study or doing instructional design, that which creates the apparent fixedness, from being included in the analysis of the transfer process. This exclusion often remains hidden at the level of tasks, but becomes obvious in attempting to examine transfer across what are acknowledged to be social situations.

This inadequacy is compounded by the choice of an individualist perspective on the process of transition across situations. From the perspective of the person graduating from school and taking her first full time job, school and work are easily characterized as separate situations that are vaguely related beyond the work-ready certification function of schooling. This perspective, also held to by much of the transfer research, describes learning and development as occurring in school, followed by its transfer to and application in work. Kindermann and Skinner (1992) have labeled this a "launch model" of person-environment developmental relations. Schooling developmentally launches the individual on a trajectory into the workplace. Growth in knowledge and skill at work are seen to be a function of the launch trajectory rather than ongoing learning and development. The model further assumes that school and work are unchanging situations, much like appearances lent to tasks. Therefore the individual must almost by default be responsible for transporting knowledge and skill from one situation to the next.

The individualist perspective embodied in the transfer construct is less adequate than what can be termed a societal perspective for explaining what happens when a student becomes a worker, or a worker becomes a student. From the perspective of a society, persons can easily be viewed as learning and developing from prior participation in school through current participation afforded and constrained by work activity. The school is no more privileged than the workplace in this regard. The institutions of school and work are in fact societally organized in such a manner as to make obvious the historically contingent and developmental nature of both personal knowledge and the activities of school and work.

This should not be interpreted as suggesting that all that is needed is a closer look at school and work situations from a societal perspective, however. As Lave (1988) has indicated, we do not have a theory of situations adequate to understanding the learning and development of persons nor, I would add, do we have a theory of learning and development that adequately addresses personal continuity and discontinuity across situations.

Activity theory expressed in the work of Leont'ev (1981), Davydov (1990) and others (e.g., Cole, 1990; Engeström, 1991; Scribner & Beach, 1992) does not currently provide a theory of social situations adequate to describing learning and development across them. Coupled with cultural-historical theory, however, activity theory does provide a framework that points toward the building of such a theory. It also provides a clear situational object of analysis. Using Leont'ev's own words, an activity is

> ...the nonadditive, molar unit of life for the material, corporeal subject. In a narrower sense, it is the unit of life that is mediated by mental reflection. The real function of this unit is to orient the subject in the world of objects. In other words, activity is not a reaction or aggregate of reactions, but a system with its own structure, its own internal transformations, and its own development. (1981, p. 46)

Activity theory also provides the concept of leading and non-leading activities. As Leont'ev describes it, human life

> ...is not built up mechanically...from separate types of activity. Some types of activity are leading ones at a given stage and are of greater significance for the individual's subsequent development, and other types are less important. Some play the main role in development and others a subsidiary one. (1981, p. 95)

For example, play, school, work, and retirement may be the sequence of leading activity categories characteristic of some societies. In others, the sequence may be play followed by work. This should not be interpreted as meaning that a given society defines a developmental sequence of activity categories that then dictates the individual's psychological development. Rather, whether or not an activity is "leading" and therefore psychologically dominant is co-determined by the genetic sequence of activity categories characteristic of a society and the period in the individual's development during which she participates in the activity. This study will illustrate the analytic potential of leading and non-leading activity by describing changes in personal arithmetic knowledge during school-work transition. In doing so it will locate changes in arithmetic knowledge within the developmental process that couples persons and activities over time, rather than in school, work, or the person.

The study is situated in Nepal, a Hindu nation of the Himalayan Region located at the interface of South and Central Asia. Officially opened to North Americans and Europeans only 45 years ago, Nepal is undergoing a rapid series of societal-level changes that directly affect the nature of schooling and working.

Sociocultural Change in a Rural Nepali Village

A Nepali village located in the Middle-Hills Region of Western Nepal was the site of the research. The village will be called Bherighat for the purposes of this study. The researcher has lived and worked in Bherighat for extended periods of time beginning in 1976. Nestled in a fertile valley cut through by a major river, Bherighat continues to rely on subsistence-level agriculture for its economic base, though the nature of many agricultural practices continues to change. The first Bherighat primary school was formed in 1960 as part of a national system of education based on a combination of American and British models. This was followed by the opening of a lower secondary school in 1969 and an upper secondary school in 1974. Three additional primary schools and a second middle school were functioning by 1988 at the start of this research.

The opening of general items stores and tea shops occurred with the expansion of public secular education in Bherighat. The first two tea shops were built on the perimeter of the primary school compound in 1963. With the opening of a nearby road head to India easing access to wholesale goods, the number of shops in Bherighat had increased to over 40 at the time of the research in 1988.

The first generation of Bherighat high school students graduated in 1978. These six students were unable to continue on to higher education, but at the same time did not wish to continue working solely in agriculture after having spent 10 years attending school. Shopkeeping was the occupation eventually taken up by five of these high school graduates as well as several former students who had not graduated. Some Bherighat shops were run by villagers who had spent a considerable number of years learning about arithmetic in school for the first time in the history of the village.

The earlier generation of Bherighat shopkeepers had not had the opportunity to learn arithmetic at school. Rural secular schools were quite literally outlawed by Nepal's rulers prior to 1950. As the variety and complexity of goods measured and sold in the shops increased with access to goods from India, some among this generation of shopkeepers saw economic advantages in learning written numerals, arithmetic notation, and a restricted set of column algorithms. This was viewed by the shopkeepers as a useful addition to their existing knowledge of arithmetic calculation that involved tallys, counting stones, and fingers as well as calculation without external artifacts. Much of this learning initially occurred in the home with the assistance of younger family members who were attending school. More recently, some Bherighat shopkeepers began attending adult education classes in numeracy and literacy that were occasionally held in the village.

Thus, there are two coexisting generations of Bherighat villagers that bear very different relations to the transition between school and work. One generation had spent an extensive period of time as students before becoming shopkeepers. The other had spent many years as shopkeepers before attending school for the first time.

Learning in school and working in a shop both constituted leading activities for members of the younger generation in the sense that, above all else, they defined themselves first as students and later as shopkeepers. In contrast to this, members of the older generation continued to identify themselves as shopkeepers even while participating in the adult education classes. Participation in school was a non-leading activity that was defined by what was, for them, the leading activity of shopkeeping.

Thirteen Bherighat shopkeepers who had never attended school voluntarily enrolled in an adult education class as part of a larger ethnographic and quasi-experimental study (Beach, 1995). The mean age for the group was 46.8 years (sd = 1.2 years). Thirteen 10th grade students who were prepared to graduate from high school and had never worked in a shop voluntarily apprenticed themselves to shopkeepers. Their mean age was 21.8 years (sd = .7 years). All participants were male because cultural gender restrictions limited our access to potential female participants. All participated in the new activities for roughly 30 hours over a period of a month. Their progress in arithmetic was monitored at five points during the one month interval: 0, 8, 16, 24, and 32 days. Shopkeepers enrolled in the adult education class were presented with written math problems at each of the five points in a test format derived from the numeracy curriculum. Students apprenticed to shopkeepers were presented with a variety of wholesale and retail purchase problems that involved arithmetic derived from the shops. These problems were also presented on each of the five occasions. The problems were similar in structure, but varied across the five occasions in terms of the numbers involved.

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The analyses that follow use three of the five monitoring occasions (days 0, 16, and 32), one shopkeeping task (forearm length to meter price conversion problem) and four classroom arithmetic tasks (double over single digit problems involving carrying for addition, subtraction, multiplication, and division). The tasks were derived from nine months of ethnographic fieldwork that had focused on the activities of farming, schooling, and shopkeeping in Bherighat.

Becoming a Shopkeeper

The shopkeeper who owned the largest shop in the village was chosen as the master shopkeeper to whom the students were apprenticed. The 42-year-old master had worked as a shopkeeper for nine years and had completed the 9th grade in high school. The master's shop was located in the main bazaar area of Bherighat, which consisted of 24 shops in addition to that of the master's. The shop was a large L-shaped room with doors on two sides and floor to ceiling shelves on the other four sides. A glass display case was centered in one section of the "L." The other section had open floor space where the master sat on a cushion next to a money box. The customers and apprentices sat or squatted on the floor around the shopkeeper.

The master shopkeeper agreed that these apprentices' training should model that of past apprentices he had trained. By the end of the 32 day period all of the student apprentices had spent at least some time managing the store on their own. Instruction in the shop was highly permeable in three ways. One, the apprentice always had the master's practice before him in its entirety, quite independent of the apprentice's degree of knowledge and skill. Two, during busy times in the shop the apprentice was often expected to deal with customers on a level beyond that which would be expected of him at quieter times. Third, training varied with the "availability" of relevant customer purchases. Portions of some purchase events were simulated by the master if they did not occur through customers. Others were not or could not be simulated.

Observations of, and discussions with, the participating students early in their apprenticeships indicated that they were viewing participation as something that was related to school, and they were struggling to use column algorithm strategies and written artifacts in conjunction with new shop-based goals. However, they saw their learning as relevant to shopkeeping rather than schooling—they described themselves as learning to be shopkeepers. In fact, five of the student participants eventually went on to open stores of their own in Bherighat or neighboring villages.

Becoming an Adult Education Student

One of the project's Nepali research assistants had attended the Ministry of Education and Culture's two-week adult non-formal education teacher training program a year prior to the start of the study. He had previously worked for five years as a primary school teacher and had run two adult literacy and numeracy programs. He was given the assignment of teaching the adult non-formal numeracy-literacy classes for the study because of his experience.

The classes were held in the local government meeting hall just off the main bazaar area. The hall contained benches, chairs and tables sufficient to seat all of the students. An additional table served as the teacher's desk toward the front of the classroom. There was a cement blackboard on the front wall that was used by the teacher. On cloudy days, two kerosene pressure lanterns were used to light the hall.

The course followed the Ministry of Education and Culture's curriculum for adult education in numeracy and literacy. A series of five texts published by His Majesty's Government of Nepal were issued to each of the participants. The texts were combination textbooks and workbooks. The research assistant was told to ignore the teacher's guide and structure the course as one would a standard school course. This was done for two reasons. One, most adult "non-formal" education courses in Nepal were taught in this manner. Our goal was to offer a veridical rather than an improved version of the course. Two, it made for a better comparison of arithmetic with students who were attending school.

Literacy and numeracy lessons alternated throughout the curriculum. Both were addressed during each class session. The arithmetic portion of the curriculum began with learning to read and write numbers and place value, and progressed through simple single digit addition and subtraction, double digit addition and subtraction without and then with carrying, simple single digit multiplication and division along with fractions, 3-4 digit addition and subtraction with carrying, and finally, limited double digit multiplication and division with remainders. Problem representations in the texts were identical to those in the school texts. Most problem representations combined pictures with numbers initially, followed by arithmetic problems depicted in standard horizontal and vertical formats and word problems. Number lines were occasionally depicted in association with the horizontal format items. Measures were associated with numbers only in the word problems. The course was mastery-based. All participants successfully completed all five texts and were presented with an adult education certificate.

Observations of, and discussions with, the shopkeepers early in their participation indicated that they viewed their participation in the course as related to shopkeeping, and that they were learning arithmetic involving written artifacts and column algorithms as a supplement to their existing arithmetic. Their greatest challenge was mastering a new system of calculation artifacts and the algorithms associated with them. Calculation and the relation between different mathematical operations was not seen as particularly problematical. They did not view themselves as becoming students, but rather as shopkeepers attending class for the sake of learning something that would allow them to expand the variety and complexity of goods that they could sell. Seven of the shopkeepers who completed the course reported several years later that they had expanded the variety of goods they sold as a result of having learned a new form of arithmetic in the course.

Arithmetic Among Students Becoming Shopkeepers

Table 1 (opposite) displays transition patterns in the arithmetic of students apprenticed to shopkeepers at Day 0 (before the apprenticeship), Day 16, and Day 32 (the end of the apprenticeship) using the number of participants. The first pattern is based on the types of calculation artifacts used to solve the cloth measurement problem. See Figure 1 (page 292) for an example of the forearm length to meter price conversion problem that was presented to the students.

A distinction is made between the use of written artifacts such as numerals and equations, object-based artifacts such as tallys, stones, and fingers, and the use of both. All problems were solved with the use of some form of calculation artifact. Nine of the 13 students apprenticed to the shopkeeper retained written numerals as their primary calculation artifact throughout the apprenticeship. Though several of the participants combined written and object artifacts in their calculations at different times,

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TABLE 1

Forearm Length to Meter Price Conversion: Number of Students Displaying Artifacts, Strategies, and Goal Directed Organizations (GDOs) Across Time (n = 13), Shopkeeping Tracking Tasks

	Day 0	Day 16	Day 32
Calculation Artifact			
Written	12	9	10
Object	0	0	1
Both	1	4	2
Calculation Strategy			
column algorithm	10	9	4
reorganization	0	1	3
both	3	2	6
Goal-Directed Organization			
equation [1]	10	8	3
measurement [2]	1	4	9
both [3]	2	1	1

[1] Equation GDO, measurement is external to problem solving other than at the beginning and the end of the process, and the social import of measurement is ignored.

[2] Measurement GDO, measurement is part of the problem space throughout, and the social import of measurement is acknowledged.

[3] Switch GDO, the participants initially attempt to solve the problem using a linear GDO, are unsuccessful, and then begin again with an unsystematic form of a measurement GDO. This is the only time during the initial tasks that both written artifacts and no artifact use co-occur within a single problem-solving episode.

Figure 1: Forearm length to meter price conversion tracking task at day 8 of apprenticeship, ID 6

Yan Bahadur is a 23-year-old 10th grade high school student who has been asked to generate the price of a piece of a cloth that is 4 *haat* in length. A haat is a traditional unit of length measure that extends from the point of the elbow to tip of the middle finger. All cloth is priced based on metric length. Yan Bahadur is provided with a paper, a pencil, counting seeds, a meter ruler, and a length of cloth that is greater than the amount requested. The price of the cloth per meter (40 rupees) is written on the cardboard that the cloth is wrapped around.

Playing the role of customer, the researcher asks Yan Bahadur for 4 haat of cloth and how much it will cost. Yan Bahadur measures his forearm using the meter ruler, coming up with 45 centimeters. He writes down 4 times 45 on paper in column algorithm format.

```
 45
x 4
```

He then calculates out loud "4 times 5, 0 (writes zero), 2 in the hand (two carried), 4 times 4, 16, 17, 18 (writes 18) 180."

```
 45
x 4
180
```

Then Yan Bahadur finds that he needs to know the price of a centimeter of cloth and writes down 100 divided by 40 (note that it should be 40 rupees divided by 100 centimeters)

```
40 ⟌100
```

Next he calculates "40 goes twice, so 80 (writes 2, then 80), have 20, so 200 (writes 200), 40 goes 5 times exactly, so 5 (writes 200, 0, and 5) and 0 (writes 0)." He calls the answer "two and a half rupees."

```
      2.50
40 ⟌100.0
     80
     200
     200
       0
```

He looks a bit askance at the figure. Then he writes 180 times 2.5 and, using a column algorithm, generates a product of 450.

```
  180
x 2.5
  900
 3600
450.0
```

Yan Bahadur scans his calculations on paper, looks at me, and says "You owe me 450 rupees for the cloth?!"

only one participant displayed the exclusive use of object artifacts, in this casse, fingers, and then only on Day 32.

The next pattern is based on whether the participants used column algorithm strategies in their calculations, numerical reorganization strategies such as decomposition and iteration, or a combination of both. Counting strategies and math facts were not displayed in isolation by any of the participants on this task and therefore were not coded as such. Initially 10 participants displayed the exclusive use of a column algorithm strategy. By Day 32 only four participants did so, whereas three participants had switched to the exclusive use of a reorganization strategy. Though three of the students initially displayed a combination of both strategies, by Day 32 six displayed a combination of strategies.

The final pattern is based on whether participants used an equation-based goal-directed organization (GDO), a measurement GDO, or switched from one to the other over time. Goal directed-organizations relate the calculation artifacts and strategies to the overall structure and direction of the practice, in this case pricing and selling a piece of cloth. The equation GDO organized strategies and artifacts through the establishment of a set of equations that were then solved for. The interpersonal aspects of the calculation process, such as justifying the price to the customer through the calculation are ignored, measurement units are often confused or forgotten, and unnecessary precision is often an outcome. The greatest challenge occurred in properly coordinating the various calculations to be performed and in ending up with the correct unit of measure. Figure 1 provides an illustration of this.

The measurement GDO organized strategies and artifacts around the characteristics of the metric and monetary systems of measures, and the particular cloth conversion task at hand. The calculations are often stated out loud so that the customer can follow the process to an extent, measurement units never removed from the process of calculation. Of the 10 students who began with an equation GDO, only 3 displayed this GDO on the task at Day 32. There was an almost mirror increase in the number who displayed a measurement GDO across the three points in time. One or more at each of the three points in time first displayed an equation DGO, but shifted to a measurement of GDO within the same task.

Table 1 does not display the relations between artifacts, strategies, and GDOs over time, nor does it allow the reader to trace directly the patterns of individual change over time. Table 2 (next page) does allow for this. In it we see that only three of the 13 participants exhibit continuity in calculation artifacts, strategies, and GDOs across the apprenticeship. OF the 10 who changed, only one changed to the exclusive use of object calculation artifacts. The rest either retained the use of written artifacts in full (n=7) or in combination with object artifacts (n=3). All 10 of these students initially displayed the use of a measurement GDO or have shifted to a measurement GDO by Day 32. All but one used reorganization strategies or combined their use with column algorithms strategies.

For the five participants who exhibited change from Day 0 to Day 16, four shifted from an equation GDO to a measurement GDO. The other participants had already displayed a mesurement GDO on Day 0. Of these five participants, only one changed strategy: two retaining a column algorithm strategy and two retaining a combination of strategies. A similar pattern occurs between Days 15 and 32. It therefore appears that the construction of a measurement GDO may be necessary but not sufficient for the use of reorganization strategies, and that the form of artifact is neither necessary nor sufficient in relation to these changes.