A CULTURAL-HISTORICAL STUDY OF LEARNING AND DEVELOPMENT: THE ARITHMETIC PRACTICES OF RURAL NEPALI ADOLESCENTS AND ADULTS IN TRANSITION BETWEEN SCHOOL AND WORK ACTIVITIES

by

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Abstract

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The dissertation develops and uses a methodology for examining individual learning and development in relation to societal change, building on cultural-historical theory and activity theory. The methodology has four core concepts: heterochronicity or the relative times of appearance and rates of change between society, activities, and individuals, critical periods which are times marked by societies undergoing rapid change relative to the individual's development, leading activity which refers to whether an activity is role defining for a particular individual, simulation or the modeling of selected aspects of societal change and inducing learning and development through participation in the simulation.

The relation of learning and development in school to that at work is a central concern for most societies today. School-work transition is also a

promising arena for studying human learning and development in relation to societal change.

Three interrelated questions are addressed by the study. One, what are the relations between societal change, school and work activities, and paths taken by individuals in transition between the activities, and the implications of these relations for individual learning and development? Two, does transfer reconceptualized as transformation, continuity, and discontinuity adequately describe the epistemology of students becoming workers and workers becoming students? Three, what are the strengths and weaknesses of the methodology for studying individual learning and development in relation to societal change?

The study begins with a demographic survey of students, farmers, and shopkeepers in a rural Nepali village, and ethnographies of the related activities. Farmers and shopkeepers with no prior schooling enrolled in an adult education class. A second group of farmers and students with no prior shopkeeping experience apprenticed to shopkeepers. These transitions were simulations of changes in Nepali society. Tracking tasks appropriate to the new activities were used to follow changes in the participants' arithmetic over.

Findings indicate that students apprenticed to shopkeepers created a new arithmetic form during transition whereas shopkeepers attending adult education classes added to their repertoire of existing strategies. Findings are further interpreted further in terms of the relative statuses of arithmetic forms, leading/non-leading activities, and the mediating role of shopkeeping.

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The extraordinary generosity, support, and kindness of my adopted Nepali family headed by Bal Bahadur Gharti Magar, and my community, the village of Bherighat, made this research possible. It is to them that this study is dedicated.

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My son Skip Beach and Lin Blair shared Nepal with me, putting up with my long absences from Kathmandu and tolerating illnesses that at times made me question my very priorities in being there. Skip permitted me to see Nepal through a child's eyes for the first time and made the common things of curiosity and wonder.

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I. INTRODUCTION

The relation of learning and development in school to learning and development at work is a central concern for most societies today. It is frequently expressed at the national and policy levels as a concern for knowledge and skill "relevancy", "generalizability", and "appropriateness." This concern has grown with the development and coexistence of work and secular education as societal institutions. Historically, labor was the first and therefore prototypical cooperative human activity (Woolfson, 1982). Education, activity with learning as its centerpiece, evolved with, and in large measure because of the gradual collectivization and specialization of labor.

In addition to their societal import, transitions between school and work are promising arenas for studying human learning and development as part of a larger system that includes societal change. Following the social science adage of "if you want study something, kick it" (or less prosaically, to fully understand phenomenon in a system you need to alter the phenomenon), transitions between school and work activities provide a natural "kick" to human learning and development by way of societal change. This is because school-work transitions stand squarely at the interface between the individual and society.

Broadly, this dissertation is concerned with how people make the transition between school and work in society, the artifacts they use and reconstruct in the process, and what the implications of studying this are for how we characterize human learning and development. It holds to the basic premise of a cultural-historical theory of mind in this concern; that

> ...the distinctive characteristics of human beings as a species are, one, their special ability to modify the environment in which they live through the creation of artifacts and, two, the corresponding ability to transmit the accumulated modifications to subsequent generations through precept and procedure coded in human language." (Cole, 1991, p. 1).

Clearly there are many aspects to particular people making a transition between particular school and work activities in a particular society during a particular historical period. Some involve official gate keeping procedures such as grading, certification, and job qualifications. Some involve economic concerns. There are others that are related, but are unofficial and invoke status, class, race, family, and caste. Learning and developing knowledge and skills is yet another facet, related to the others, and will be the central focus of this dissertation..

By taking a systems approach, learning and development are inseparable from the school and work activities except for temporary analytic purposes. At the same time, the learning/development of individuals and activity are not reducible to each other and require different forms of explanation. A focus on learning and development therefore determines which aspects of the school- work transition are to be simulated and which are to be induced through that simulation in order to study them. In the case of this study, learning and development is induced through a simulation of the other facets. This implies as overall methodology for the dissertation.

Two bodies of psychological theory and research come to the forefront when considering a study of human learning and development in school-work transitions. The first exists around the construct of transfer. Growing out of the earliest behaviorist paradigms through genetic epistemology and information processing and on into some recent cognitive science, it attempts to describe and explain how it is that people come to use knowledge and skills gained in one place in a new place. Today the construct appears problematic in its descriptive and explanatory power when it is limited to well defined tasks with analytically severed relations to broader contexts. The construct is clearly not viable for generating descriptions and explanations of what happens to persons' knowledge and skills when they move between school and work activities; whether it is used analytically or simply as a metaphor. **Chapter II** provides a discussion and critique of existing theorizing and research on transfer.

The weakness of the transfer construct is in large part due to its assumption of continuity and discontinuity between situations based on perceived or achieved similarity. It can not account for the possibility that new knowledge and skills are constructed; derived from neither the first nor the second situation but constructed through the process of transition between the two. Thus transfer might be more viably portrayed as encompassing transformation as well as continuity and discontinuity in learning and development across situations.

School and work situations provide structure to the transfer process in conjunction with individuals' knowledge and skills; thereby affording transformation as well as continuity and discontinuity. A theory of situations (Lave, 1988) is therefore central to this reconceptualization of transfer. This brings us to activity theory, the second major body of psychological theory and research important to this study.

> Activity is the nonadditive, molar unit of life for the material corporeal subject. In a narrower sense (i.e. on the psychological level) 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. (Leont'ev, 1979, p. 46).

Though activity theory currently cannot provide us with the desired "theory of situations", it does furnish psychology with a scientific object of study, one that possesses a temporal dimension that generally extends beyond the lifespan of individuals and even generations. It provides a molar unit with its own developmental history; one that is both socially and cognitively complex in structure. It serves as an active mediator between societal change and the learning and development of individuals. These characteristics combine to give a past and a future to learning and development that is not reducible to the individual nor to the society.

For the purposes of this dissertation, learning and work activities are objects of study rather than explanations of school and work at the level of activity theory. As objects of study they support the development of activity theory. In particular, the role of leading or psychological dominant and non-leading activity is refined by examining learning and development in transition between school and work activities. **Chapter III** outlines the reconceptualization of transfer as transformation, continuity, and discontinuity, and related to this, the concept of leading and non-leading activities.

Chapter IV lays out the three general research questions that I explore in my dissertation: the viability of the proposed reconceptualization of transfer, the relation of leading and non-leading activities to paths taken between school and work activities and the implications for a person's learning and development, the benefits and shortcomings of a methodology that uses activities to induce learning and development and simulates societal change.

These lines of inquiry evolved out of my experiences and misadventures as a mathematics and science teacher and later as a researcher in rural Nepal. It seemed very natural, then, to look toward Nepal and the domain of arithmetic for the cultural and cognitive "content" of my dissertation. There were also principled scientific reasons for this choice. These are discussed in **Chapter V** which lays out the methodology of the study.

Five specific operational research questions were generated from rural Nepal and the discipline of arithmetic on the one hand, and the set of broad research questions discussed in Chapter IV on the other. A multi-phase design drawing on a number of methods was used. The design was based in part on Scribner's three-step research strategy for studying practical activities: observation, simulation, experimentation (1984b). The study was initiated with a demographic survey of students, farmers, and shopkeepers in the village, followed by an ethnography of several mathematics classes in a rural Nepali school and two work activities: farming and shopkeeping. The ethnography focused on the interrelated histories of schooling, farming, and shopkeeping activities, and within them, the practices which involved arithmetic. A quasi-experimental design was then established. Farmers, shopkeepers, and 10th class students participated in interviews and tasks from each of the three activities involving arithmetic. This was followed by a period of apprenticeship in an activity new to each group of participants. Farmers and shopkeepers attended an adult education class. A second group of farmers and students worked in shops. During the apprenticeship periods two assistants and I tracked participants' arithmetic using sets of repeated tasks. This allowed us to obtain data during the transition between school and work--during the process of transfer.

Chapters VI, VII, and VIII, IX, and X present analyses and findings from the demographic surveys and the focused ethnography, narratives on learning from the structured interviews, current knowledge of artifacts, calculation, and measurement, the initial problem-solving assessments, and the apprenticeships with the tracking tasks, respectively. Each chapter builds on relevant data and findings from the previous chapters in its analyses and in the summary at the end of each. In this way the Chapter X summary includes findings drawn not only from analyses of the tracking task data, but tracking task data analyzed in conjunction with data from the previous chapters.

The final chapter, **Chapter XI,** draws together the various strands of the dissertation by bringing specific findings to bear on the five research questions stated in Chapter V. It relates the findings to current work in cultural-historical research and transfer as part of this process. The chapter concludes with implications for facilitating transition between school and work activities and future research directions in this arena.

II. REVIEW AND CRITIQUE OF LITERATURE ON TRANSFER

The relation of knowledge and skills acquired in school to knowledge and skills acquired at work has become a central concern for most societies. This concern has generated a second, that of how knowledge and skills acquired in either situation can facilitate or interfere with the acquisition of knowledge and skills in the other. This in turn has implications for how we characterize human learning and development in relation to societal and cultural process.

Transfer has been the psychological construct traditionally applied to explaining learning across problems, domains, settings, and even cultures. Its relation to development has generally not been considered except as a sort of conceptual indicator of development having occurred (Piaget, 1941). A brief history of the construct is needed in order to understand the current transfer literature.

Classic Studies that Define the Construct

Early connectionist, functionalist, and associationist psychologists (Thorndike & Woodworth, 1901; Guthrie, 1935; Hull, 1935) generally asserted that the transfer of learning occurs when an effect of the original learning occurs in a new situation. The greater the actual resemblance between the stimuli and/or responses, the greater the transfer. This approach to transfer grew in large part from Thorndike's *identical* *elements doctrine* which suggested that mastering speaking, reading, and writing in school would only be used in out-of-school settings containing elements identical to those in the school setting: elements that required speaking, reading, and writing. Though the substance of the elements might be different, the procedures were reasoned to be the same. Intelligence was thought to be, in part, a measure of the transfer capacity of the individual (Hilgard & Bower, 1975).

Other functionalists (e.g. Hoffding, 1892) suggested that it was the individual learner's *perception* of resemblance across situations rather than any actual resemblance that was critical to understanding the issue of transfer. Hoffding's work was later extended by the Gestalt psychologists as the *law of similarity* (Koffka, 1935).

Problem resemblances or isomorphism serve as the basis for many of the later information processing studies of transfer (Reed & Ernst, & Banerji, 1974; Hays & Simon, 1977; Rumelhart & Norman, 1981).

A second general approach to transfer posited that learning across problems depended on the level of generality or abstraction of knowledge and skills from a given problem or situation: the greater the generality the greater the transfer. This approach too has its origins in early psychological theorizing and experimentation such as Judd (1908), a student of Wundt's. Generalization mechanisms, particularly analogical reasoning serve as the basis for many of the recent information processing-approaches to transfer (e.g. Belmont, Butterfield, and Borlowski, 1978; Collins, Warnock, Aiello, & Miller, 1975; Gick & Holyoak, 1980; Gentner & Gentner, 1983).

Last, most of the current cognitive science-inspired "situated" and "contexted"approaches to transfer continue to rely heavily on the isomorphism, generalization, or a combination of both approaches at their core (Perkins & Saloman, 1989; Greeno, Smith, & Moore, In Press; Pea, 1987; Brown, Collins, & Duguid, 1989).

The isomorphism and generalization approaches overlap for the most part with current spatial and hierarchical metaphors characterizing transfer as "near/far" and "specific/general." What is commonly referred to as "near" or 'specific" transfer is most often tied to the isomorphism approach. The two problems resemble each other in some fairly overt way and the transfer of knowledge procedures occurs as a function of this resemblance, whether it be actual or perceived. "Far" or "general" transfer is usually associated with the generalization approach. Here the two problems usually do not overtly resemble each other. Therefore some sort of cognitive activity and/or intervention is needed to relate the two through analogy or some other form of reasoning or representation.

The rub, as we shall see, occurs when tasks do not result in the transfer of knowledge and skills between them, even when they are explicitly designed to do so.

While this study is concerned with site-to-site transfer, the origins of the constuct are deeply rooted in research within school settings for which problem-to-problem transfer is of primary interest. For this reason the critical review of literature will first address problem-to-problem transfer.

Empirical Evidence For and Against Problem-to-Problem Transfer

Singley and Anderson (1989) reviewed literature from Thorndike to the present and found some evidence for specific transfer, but little or no positive evidence for far or general transfer beyond that provided by several flawed studies. A review of the literature on the transfer of training and skills from school to the workplace (Baldwin & Ford, 1988) suggests that even so-called near transfer rarely occurs between school and work. Lave (1988), Wagner and Sternberg (1984), and Detterman (In press) make similar points in their reviews of the theoretical and empirical literature. Discussion of a few representative studies should therefore suffice as illustrations.

Reed, Ernst, & Banerji (1974) presented college students with the now classic "Cannibals and Missionaries" problem as well as a "Jealous Husbands" problem which was a slightly more complicated but structurally isomorphic version of the former. In the first problem, five missionaries travel through a jungle to find a river with a boat at the landing. the boat can only hold three people. There are five cannibals on the opposite bank waiting to cross the river in the other direction. The boat can be used to relay both missionaries and cannibals across the river. The difficulty is that the cannibals may never outnumber the missionaries on either bank if the missionaries are to avoid being eaten. In the Jealous Husbands task, the cannibals and missionaries are replaced with husbands and wives.

Subjects failed to transfer when they were not told about the relations between the problems. Furthermore, when told about the similarities they were only able to transfer from the complex to the simpler version. Similar negative findings occurred in a more recent study by Reed and colleagues (Reed, Dempster, & Ettinger, 1985) in which the domain was algebra word problems.

Hayes and Simon (1977) found transfer across only certain forms of a "Tower of Hanoi"-type problem isomorphs and not others. They were unable to provide an explanation for the differences in transfer beyond the level of specific problem descriptions.

Gick and Holyoak (1980) presented college students with two story problems, each of which could be solved from the other by analogy. Those who successfully solved the first problem were usually unsuccessful in solving the second problem unless they were given hints to generalize by analogy from the previous problem. The students did not spontaneously search to construct a set of analogic correspondences between the problems.

Gentner & Gentner (1983) were only slightly more successful in finding students who would spontaneously create and generalize an analogy from a fluid flow model to electrical circuits.

Taken collectively, these studies suggest that humans simply do not do much transferring of knowledge and skills from one problem to another. This, of course, is patently absurd in the face of our knowledge about how children and adults learn and develop in a society that affords partnerships with individuals and presents novel situations and episodes which are successfully learned from, adjusted, and adapted to. As noted by Shweder:

> The everyday mind accomplishes a very difficult task. It looks out at behavioral world of complex., context-dependent interaction effects and unsubstantial correlations among events, yet it perceives continuities, neat clusters, and simple regularities. (1980, p. 77)

Some recent research, however, has indicated that under the proper circumstances transfer can occur among three-and four-year-old children as well as adult college students (Palinscsar & Brown, 1984; Schoenfeld & Herrmann, 1982; Lehman, Lempert, & Nisbett, 1988). What all of these studies have in common are, one, the problem space affords the construction of transfer rather than an all-or-none recognition of similarity or analogy and two, the problem space includes other people's knowledge and actions.

Detterman (In press) discounts studies such as those cited above, arguing that true transfer should occur spontaneously, that there are few instances of spontaneous transfer in the research literature, and that transfer with the assistance of others is simply another case of learning. Therefore, he reasons, transfer is epiphenomenal. Detterman then uses this to argue his position: that basic biologically- determined cognitive abilities underlie and cause what is commonly referred to as transfer. Educational intervention, in Detterman's view, should therefore attempt to compensate for less adequate basic abilities through instruction and match a person's abilities to the method of instruction rather than strive to teach higher psychological processes.

Perkins and Solomon (1989) take a different tack in addressing the current literature supporting transfer. They point out that subjects who succeed at transfer combine what they term the "low road" to transfer that depends on the practice of specific skills to near automaticity and the "high road" that depends on the deliberate mindful abstraction of principles. Their synthesis approach suggests that general heuristics need to be associated with a rich domain of specific knowledge in order for the most robust forms of transfer to occur.

Detterman makes a good case for transfer being an epiphenominal construct that rarely occurs, at least in the laboratory, and therefore adds nothing to explanations of learning and cognition. However, It does not follow that a study of biologically-determined abilities will offer the best explanation of what actually takes place when one learns across problems. In fact, his argument that transfer cannot involve the intervention of others, in order to distinguish it from learning, removes any possible explanation of knowledge and skill continuity between socially active problems or situations when persons move between them.

Perkins and Solomon also make an important point regarding the nature of transfer: it involves specific knowledge as well as general heuristics, usually in some relation to each other. However, their "a bit of both" argument does not resolve the basic shortcomings of the isomorphism and generalization approaches, nor does it provide an alternative.

Principal Shortcomings of Problem-to-Problem Transfer as a Construct

Transfer has largely been examined as a form or product of learning across problems that have been designed to create an optimal mismatch in the laboratory and in the classroom, i.e. the problems are not identical but are not too different. This is true for both the isomorphism and generalization approaches and is with good reason. If the problem and the individual's solution to the problem is identical and correct across two performances, no transfer can be said to have occurred. This is by definition. If the second problem is new to the individual and almost totally different from the first, but the individual's performance improves on the second because of the first, again no transfer can be said to have occurred. Rather such results are referred to as a "warmup" or "practice" effect. Yet both of these occurrences, repetition and redundancy as well as new and unusual problems are an integral part of learning across tasks and across situations such as school and work.

From the above it seems clear that nature of the tasks weighs heavily in determining what is and is not considered to be transfer. These same tasks are analytically severed from their cognitive and cultural histories, thereby disallowing the construction of adequate theories of the tasks and the situations in which they are embedded. The fact that we do not have adequate theories of task situations, at least as they relate to transfer, means that we cannot define the construct so that it can adequately aid the generation of descriptions and explanations of what it means to learn across tasks or situations.

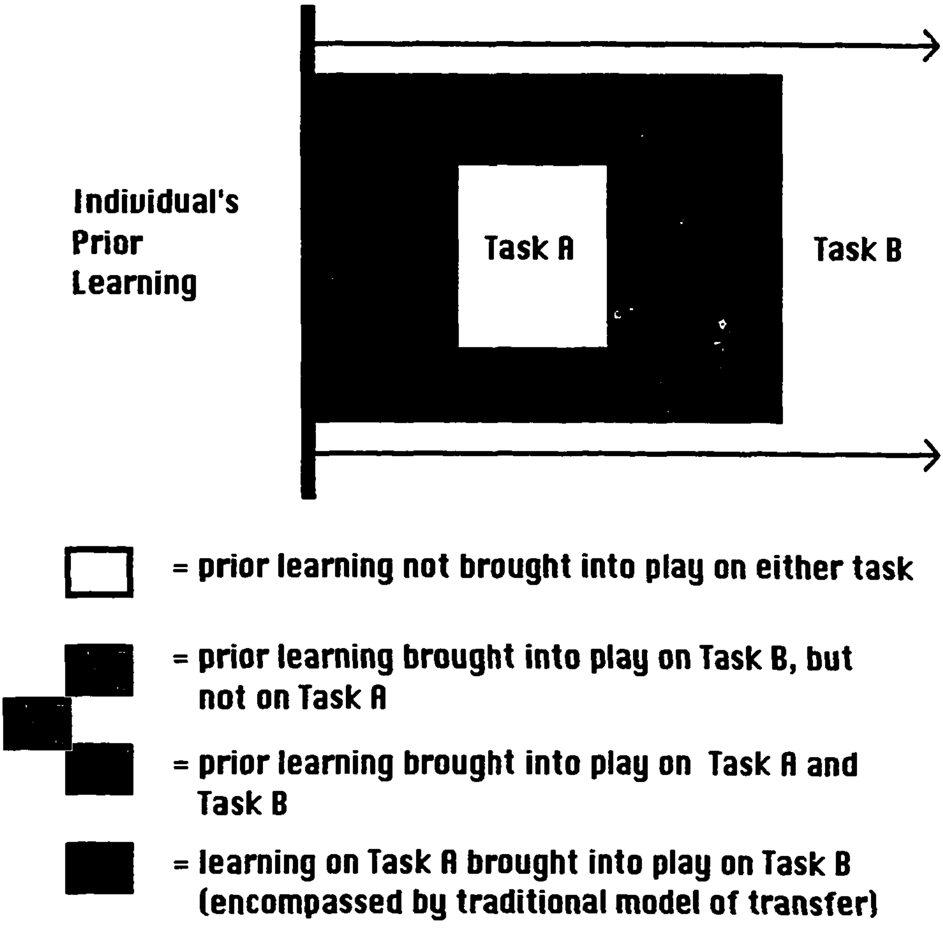
The individuals in these studies also appear without learning histories. Therefore in studying transfer from task A to task B, all that is examined is that small portion of learning that is acquired through task A and is used in conjunction with B. The individual's prior learning that is brought into play on task A, but is not learned from task A, that which is not brought into play on task A , but is brought into play on task B, and that which is selectively not brought into play on either task is integrated with that small portion of learning narrowly defined as transfer. Clearly, transfer is only a small and interdependent portion of the learning necessary to successfully perform task B, having successfully performed task. This is depicted schematically in Figure 1 below.

Perhaps the most critical weakness to be found in these studies is the one pointed to by Detterman; that transfer is epiphenominal in relation to learning, i.e. is a result of learning and is not a cause of anything. This is necessarily the case as long as transfer is seen as only involving continuities in learning unique to two optimally mismatched sequentially presented tasks.

A number of relatively recent studies construe transfer more broadly: examining site-to-site transfer within the domain of arithmetic.

Figure 1

Schematic Diagram of the Transfer Construct



Empirical Evidence For and Against Site-to Site Transfer: Arithmetic Between School and Work Settings

The shortcomings of the transfer construct for understanding problem-to-problem transfer are shared research on site-to-site transfer. In addition, site-to-site transfer has its own weaknesses as an explanatory construct.

The life history of the gifted Indian mathematician S. Ramanujan (Nandy, 1980) epitomizes the potential continuities as well as seeming discontinuities in the transfer of mathematical reasoning and its affiliated system of signs and symbols across seemingly disparate societal institutions and cultures. Ramanujan was born in 1887 to a poor Brahmin family in southern India. The young Ramanujan became intensely interested in his mother's magical manipulation of Sanskrit mathematical symbols, numbers, and matrices for various religious purposes. After exposure to European forms of mathematics through schools based on the British model and several attempts at obtaining a college degree which ended in failure, Ramanujan undertook a private study of number theory derived from his early encounters with numerology. This eventually resulted in his sending drafts of some hundred theorems to the well-known Cambridge mathematician, G. H. Hardy. Nandy quotes Hardy's reaction to receiving

Ramanujan's correspondence.

> I should like to begin by trying to reconstruct the immediate reactions of an ordinary professional mathematician who receives a letter like this from an unknown Hindu clerk...[some of the theorems Ramanujan sent] defeated me completely; I had never seen anything in the least like them before. Yet a single look at them is enough to show that they could only be written down by a mathematician of the highest class. They must be true because, if they were not true, no one would have had the imagination to invent them. (p. 52)

Ramanujan was invited to Cambridge by Hardy, became a Fellow of the Royal Society and of Trinity College, and collaborated with Hardy on several now classic papers in mathematics. Nevertheless, throughout his tenure Ramanujan was involved in his work to the point that he remained largely impervious to the cultural trappings of British society, then at the height of the Victorian Era.

Ramanujan's life was unique, but transitions between many commonplace situations display a similar mixture of discontinuities as well as continuities.

The work of Gay and Cole (1967) among the Kepelle of Liberia was among the first to describe a traditional non-Western system of numeration and quantification and illustrate its areas of incompatibility with mathematics as taught in the schools. A number of studies of relations between mathematical (usually arithmetical) reasoning at work and other everyday settings on the one and school on the other.

Scribner and Fahrmeier (1982) and Scribner (1984) carried out a study of practical arithmetic skills among workers in an American milk processing plant. Fifth and ninth grade students served as a comparison group with contemporaneous experience in school mathematics and no experience with jobs in the milk processing plant. Workers and students were given school-like math tests involving number facts as well as mental and written computation. The workers displayed a level of accuracy equivalent to the students on mental and written computations and higher than the students on number of math facts. The students tended to use standard school algorithms to carry out computations whereas most of the workers used already memorized solutions or regrouped the numbers to facilitate mental calculation.

Workers and students were also given simulations of work tasks in the plant such as computing prices for different quantities of products on delivery tickets and filling numerically represented orders for cases and cartons of milk. In these instances the workers not only achieved greater accuracy than the students, but used a greater variety of strategies that were flexibly adapted to particular problem instances. In the case of pricing delivery tickets most students used individual item prices whereas most of the workers used a combination of item and case prices to determine the price of the order, depending on the quantity of the order and the number of items in a given case. Students filled orders for milk by directly translating the numerical representation of the order into the actions required to fill the order. Workers interpreted the order representation as a quantity that could be obtained either through a direct translation of the order into action or through transforming the order in relation to the quantity of milk cartons already in partially filled cases depending on which strategy resulted in moving the fewest cartons.

These findings suggest that learning arithmetic in school may be necessary but not sufficient for the accurate and efficiently flexible use of arithmetic on the job, at least in the case of the two tasks examined in the milk processing plant. Research by Scribner & Stevens (1989) found that practice with filling milk orders enabled middle school students to learn a flexible repertoire of strategies on a simulation of the job task. The rate of learning and overall performance on the job task was again not related to their school math ability.

Secondly, the learning of flexible math strategies on the job task appeared to require a combined decontextualization/recontextualization of the order's symbolic representation and the actual array of cartons already in the cases. Any binary opposition of abstract to concrete or decontextualized to contextual representations could not account for learning the flexible repertoire of strategies.

Lave (Reed & Lave, 1979; Lave, 1982; Lave, 1988; Lave, In Preparation) has examined in some detail the relation between mathematical reasoning acquired in school and mathematical reasoning acquired on the job among Vai and Gola tailors in Liberia. Reed and Lave (1979) gave tailors with different levels of experience in tailoring and schooling tasks that were familiar to the tailors and tasks which, though they bore some resemblance to tailoring rarely occurred during their day-to-day activities. They found that level of schooling made no difference in accuracy on familiar problems, but was positively associated with accuracy on the unfamiliar problems. Level of tailoring experience was positively associated with accuracy on both the familiar and unfamiliar problems. In the first case, school-based mathematical reasoning seemed to transfer to only the unfamiliar problems, given the tailors' facility with non-formal mathematics on the familiar problems. In the second, non-formal mathematics seemed to transfer to the unfamiliar problems. Lave suggests that school math is more situation-specific than mathematics learned in tailoring, at least in terms of accuracy.

Lave (1982) also found that the level of the tailors' schooling was positively related to moving from using computational strategies such as decomposition, tallys, and finger counting toward a mixture of school-based algorithms and the aforementioned informal strategies with familiar problems. More complex problems tended to evoke school math algorithms is base ten whereas simpler problems evoked strategies using a mixture of the Vai and Gola bases of five and twenty. This suggests that school math does transfer to familiar tailoring problems, at least in terms of strategy, and but is used in an efficient flexible manner in conjunction with non-formal strategies that are assumed to not originate in school.

Lave and her colleagues (Lave, Murtaugh, & de la Rocha, 1984; de la Rocha, 1985; Murtaugh, 1985; Lave, 1988) have more recently examined arithmetical reasoning and decision-making among American grocery shoppers. Years of schooling was positively correlated with grocery shoppers' performance on a written mathematics test and years since having attended school was negatively correlated with performance on the same test. However, neither was correlated with their performance on best buy price comparisons in actual grocery shopping or on a simulation task. The shoppers only displayed 59 percent accuracy on the math test whereas their accuracy reached 98 percent on the price comparison grocery shopping and on the simulation task.

The math test problems were largely solved through the use of standard algorithms taught in school. The shoppers' comparison decisions were often arrived at through a process of "gap-closing" (Bartlett, 1958) which involves the generation and transformation of a problem as well as a potential solution which draws the problem and the solution closer together and may in some cases involve estimation. Lave used a cluster analysis to distinguish between different solutions on the arithmetic test and in price comparison grocery shopping. The only consistent division on problem-solving success was between those problems that could be solved directly and those which required transformation before solution. Success was greater on the test problems when they required no transformation prior to solution. Conversely, success was greater on the price comparison problems when they required transformation.

Gap-closing in comparison grocery shopping is similar to the flexible strategies used by Scribner's milk processing plant workers and Lave's Liberian tailors. In all cases the task goals involved not only arriving at a correct solution but some idea as to what the numerical solution should look like. Both Scribner's and Lave's research suggest that there is little correlation between school and work arithmetic in terms of solution accuracy.

Carraher, Carraher, and Schliemann (Carraher, Carraher, and Schliemann 1985;, 1987; Schliemann, 1984; Schliemann & Acioly, 1989) have carried out an elaborate series of studies on arithmetic reasoning among Brazilian students, street vendors, lottery bookies, and carpenters. Carraher, Carraher, & Schlieman (1985) found that street vendors with some school experience used various forms of informal calculation procedures involving the mental manipulation of quantities in computing the price of customer purchases and making change. When the same children were given an arithmetic test with problems formally equivalent to those solved during street vending, most of the children manipulated written numbers using place value and carrying procedures. The sample did not allow for an accurate gauging of Accuracy was much higher in the street vending situation than on the school-like test despite the formal equivalence of the problems.

Carraher, Carraher, & Schlieman (1987) replicated and extended these findings among students without street-vending experience in a more carefully controlled situation involving a simulation of street vending. The simulation most often resulted in students using decomposition (breaking problems down into smaller quantities) and repeated grouping strategies. Solutions to problems on the mathematics test were the result of already known math facts or algorithms based on the written numerical representation. They also noted that the children rejected solutions to subtraction problems on the simulation when the minuend was larger than the remainder whereas such solutions were accepted in the test situation. This suggests that the simulation permitted the students to refer back to the original object meaning of the quantities, thereby noting the impossibility of such solutions.

Both studies support the notion that the immediate problem context is integral to children's decisions as what procedure or set of procedures to use. As with the Scribner and Lave studies, solution accuracy was consistently greater on the work-based problems than on the test problems.

Interestingly, Carraher et al.'s 1987 study suggests that school children without any work experience display so called informal strategies when given problems contexts which afford their use. This contradicts a portion of their earlier (1985) study which assumes that it is the street vendors' combined experience with school and work that allow them to use column algorithmic procedures on written test problems and decomposition and regrouping on vending problems. A second issue that is raised by their studies is how local transfer or lack of transfer between problems is related to learning and development between school and work. Though little overlap was found between computation procedures used on the school and work problems, it can not be assumed that the two sets of procedures are discontinuous during the process of learning and development in school and work activities.

Schliemann & Acioly (1989) examined arithmetic reasoning among Brazilian lottery bookies with varying levels of schooling. Bookies with more years of schooling displayed a general ability to analyze and understand the relations between the elements used in the game and their probability. These bookies were able to correctly solve unfamiliar as well as familiar lottery problems and often used a mixture of decomposition, iteration, and column algorithms to do so. Bookies with less schooling were unable to analyze relations between the lottery elements and were often unable to solve the unfamiliar lottery problems. However, they displayed a high rate of success with familiar problems using the decomposition and iteration procedures alone. They also occasionally used the customer as a resource in determining the solution.

Schliemann's work with Brazilian master carpenters and apprentices (Schliemann, 1984) produced comparable findings. Time elapsed since schooling and job experience were positively associated with the use of "informal" computational procedures in determining the total amount of wood necessary to construct several beds. However, a mixture of column algorithmic as well as decomposition, and iteration procedures were used by most of the carpenters when they were required to deal with large numerical values.

Both of these studies suggest that worker's learning on the job combines with their learning in school to provide them with a broad repertoire of computational procedures. For both the bookies and the carpenters, less time spent in school was associated with a narrower repertoire of procedures and ways of looking at work-based arithmetic problems. How learning arithmetic in school combined with learning how to do tasks involving arithmetic at work was not examined, however.

Saxe (1982, 1989, 1991) has developed a research program that focuses on school and everyday math relations in association with social practices. Saxe (1982) described the use of the Oksapmin body-part counting system in the community schools of Papua New Guinea. Though instruction took place in how to solve arithmetic problems using written conventions and algorithms, children in the early grades used the body-part counting system to solve most of the arithmetic problems they encountered in school. By grade six the body-part system was only used occasionally in the classroom. When it was used, it was adapted to the base 10 system so that it could deal with the larger numbers commonly encountered in the school. This occurred through the differentiation of actual body parts from body parts as numerical signs that.

More recently Saxe (1989, 1990, 1991) has studied Brazilian candy sellers, some of who have attended school and others who have not, in an effort to look at the interplay between children learning in and out of school. He examined the children's representations of number, arithmetic computations, and the use of ratio. Saxes' research indicated that children did indeed use knowledge constructed in one context to address problems in the other context. The sellers used school-originated knowledge to generate new pricing strategies in their selling practice. They also used solution strategies from selling candy to address problems associated with school.

There was strong evidence from the candy-selling practice that social process facilitated transfer through the symbolization of number orthography on bills, coins, and candy boxes, peer collaboration, and the assistance provide by wholesale store clerks. At the same time, Saxe stressed that the individual candy sellers must make the links between school and out-of-school practices and views transfer as a developmental process, "one that involves a shifting relation between cognitive forms and cognitive functions." (Saxe, 1990, p. 232) Saxe's use of the form-function distinction refers to historically-prior forms which have the status of cultural artifacts and current problem-solving functions for which the candy sellers adapt the forms.

In short, Saxe acknowledges the role of both individual learning history and genetically-prior cultural forms or artifacts in structuring transfer between school and work and that transfer can occur in both directions. By his own assessment, what is missing from his account is an understanding of the *process* of transfer over time. Both his work and the work of Lave, Scribner, the Carrahers, and Schliemann describe transfer after the fact. There is an additional need for an account of societal changes in practice as they afford changes in transfer. Saxe describes Brazil's runaway inflation as requiring candy sellers' to deal with extremely large numbers in their computations and new wholesale prices. He does not, however, address the implications of this for the transfer of arithmetic knowledge between school and candy selling. Last, it is unclear whether the decomposition and iteration strategies Saxe associates with candy vending rather than schooling are truly a function of candy selling, or are developed in school as well.

Principal Shortcomings of Site-to-Site Transfer as a Construct

Though these recent studies have made major inroads toward understanding transfer between societally-structured sites, highlighting the importance of culturally-designed structures , they generally maintain isomorphism and generalization approaches to transfer. They therefore fall prey to most of the shortcomings of research on problem-to-problem transfer previously discussed. Problem A and Problem B become Site A and Site B. However, the enormous complexity of school and workplace sites and their partially shared societal histories contribute an additional set of problems that appear as methodological shortcomings.

The usually high degree of accuracy achieved on tasks involving arithmetic in work settings presents a problem for the use of correlational models examining transfer between school and work. There is far too little variance in accuracy among experienced problem-solvers' performances in work settings to afford a test of shared variance in accuracy between school and work arithmetic. This reflects a deeper more substantive distinction between school and work. School arithmetic curriculums are designed to consistently present students with challenges. It is built into the epistemological motives of school as a societal institution that accuracy should vary. Learning is a "marked" activity in school. Problems at work involving arithmetic are not intentionally arrayed as challenges for learning. Accuracy is expected to be consistently high, though strategies and procedures may vary widely.

All of the studies required a definition of what arithmetic procedures, strategies, and representations originated in the school and which originated in the workplace. Because transfer for the participants had ostensibly occurred before the onset of these studies, these origin definitions must be post-hoc relative to the participants, growing out of an analysis of school-based arithmetic independent of work and of work-based arithmetic independent of school. In most cases that latter is not possible. Most Americans have spent time in school before entering the workplace. Even in nations with a significant percentage of the work force not attending school, the mere existence of schools usually disallows the workplace as independent from school-based procedures, strategies, and representations that rapidly permeate a society. Constructing origin definitions also assume that there can be no parallel evolution of procedures and strategies in school and the workplace.

This leads to what is perhaps the most serious shortcoming of site-to-site studies to date: their reliance on post-hoc indicators and remnants of transfer rather than studies of the actual process over time. This has two implications for transfer as a construct. One is that it can only be realized in terms of continuities or discontinuities between the two sites; excluding the possibility of a constructive process in which something new in created. The other is that it must necessarily be seen as a linear extrapolation between two points rather than a process with detours, disruptions, dead ends, negotiations, fall backs, fine tunings, and the like. These in turn imply that while transfer between sites may have something to do with the generalization of learning, it has little to do with learning or development, either as learning and development per se or as a special instance of learning and development: supporting Detterman's critique of transfer as an epiphenomenon.

III. RECONCEPTUALIZATION OF TRANSFER IN RELATION TO THE CULTURAL HISTORICAL THEORY OF MIND AND ACTIVITY

From Chapter II it is clear that the transfer construct needs to be reconceptualized in order to describe and explain learning and development among individuals in transition between societally-constituted situations such as school and work.

First, we need an alternative to current conceptions of the transfer process as simple continuity in learning between situations. The alternative needs to encompass transformation: in this case the construction of new knowledge and procedures from "old" personally transformed experiences in one situation through activity in a new situation. It requires a system or systems of structure in the situations in addition to the person's own prior learning and development for transformation to be possible. Otherwise we are left with the classic developmental problem of how qualitatively different structures evolve from prior structures.

This requires the second aspect of the reconceptualization, a working theory of societally-constituted structures-in-situations that constrain and afford learning and development and is relevant to the situations' own developmental histories in relation to broader societal changes.

The proposed alternative to the generalization and isomorphism approaches conceives of transfer as a changing alliance of artifacts, goal-directed organizations, and procedures expressed as the construction of continuities, discontinuities, and transformations across situations. The term "artifact" refers to symbols, tools, and devices that exist as part of a system that is transmitted from generation to generation. Goal-directed organization refers to an arrangement of procedures adequate to the achievement of a conscious goal. The procedures are the behavioral processes which, when adequately organized, lead to the achievement of the goal. Goal formation is not currently encompassed by this model.

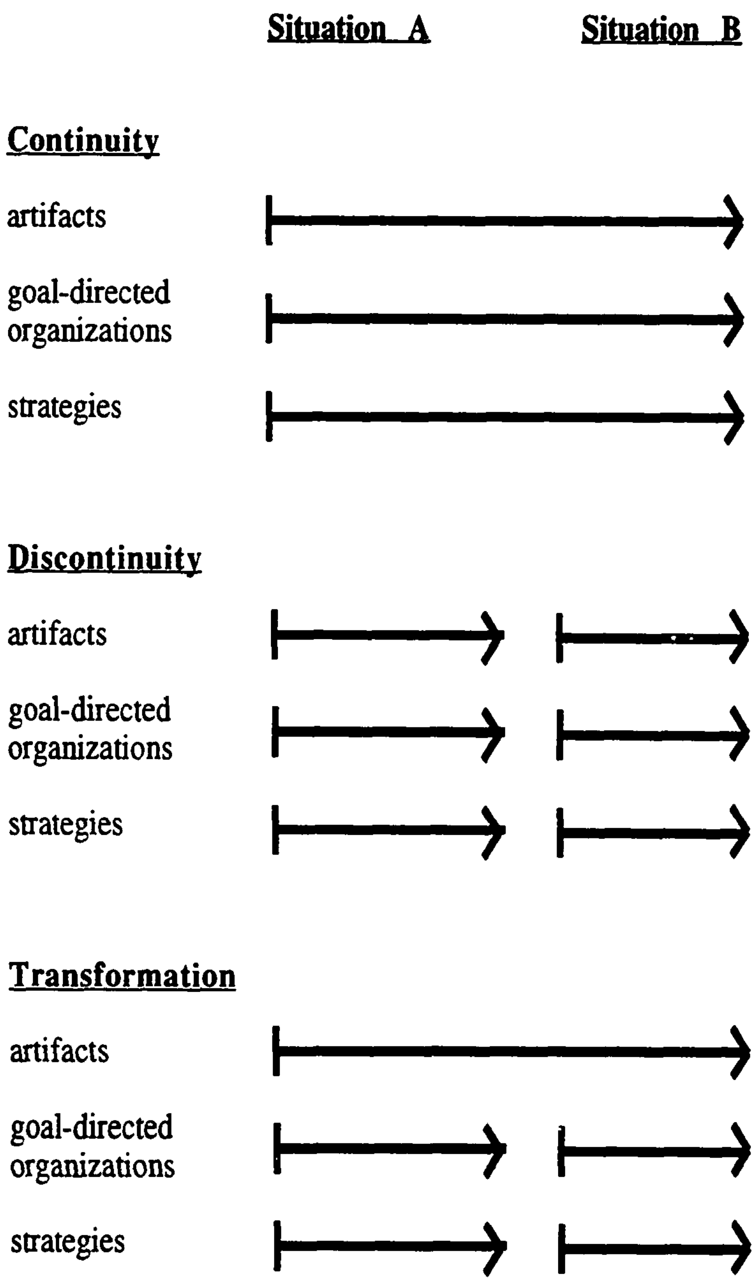
Both school and work situations partially share the artifacts, goals, and procedures of their collective subjects through their broader history as part of a society. However, the individual who just graduated from school and is learning a job for the first time will draw on and transform existing artifacts, goal-directed organizations, and procedures in ways different from a worker with little or no formal schooling attending school for the first time.

The situations are not additive with respect the learning and development of individuals in transition between them. Rather, individuals moving between school and work situations not only display continuities and discontinuities in artifacts, goal-directed organizations, and procedures, but also transformations among them. These transformations are neither a product of school or work, but are a part of the process of transition between them. Figure 2 provides a schematic illustration of continuity, discontinuity, and transformation. It does not, however, illustrate the complex fall backs, convolutions, and leaps of faith that are possible when viewing transfer as a long term process.

This then, gives transfer a developmental role as well as well as a hand in learning because qualitatively new entities can be constructed in the process of transition between the situations. Old artifacts are used with a new goal-directed organization and set of strategies, for example. The new entity could not have been predicted from their person's previous use and understanding of artifacts, goals, and procedures alone, nor is it absolutely predictive of future development. This is a key distinction between learning and development. Prediction, in this case, requires considering the history of situations themselves, a new plane of analysis, in relation to individual learning and development at a particular set of points in time.

Figure 2

Schematic Illustration of Continuity, Discontinuity, and Transformation



Learning and development in transition between situations is not "normal" in the sense that both individuals and societies recognize and maintain boundaries between situations like school and work and these boundaries, permeable and open to transformation as they may be, have much to do with how we learn and develop during a period of transition between them.

Lave (1988) has suggested, correctly I believe, that we need a "theory of social situations" if we are to reconceptualize transfer in such a way that it facilitates our describing human learning and development across institutions like as school and work. I would add that we also need a theory of learning and development adequate to that theory of social situations and that the two cannot be isomorphic to each other.

Activity theory expressed in the work of Leont'ev (1981), Scribner (Scribner & Beach, 1992), Cole (1990), Engstrom (1991) , Davydov, (1990) and others does not currently provide a theory of social situations adequate to describing learning and development across them. However, it does provide a number of necessary components toward building such a theory. It provides a relative 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 learning, 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 an 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 point in the individual's developmental history at which she participates in the activity.

The co-determined nature of leading activities and non-leading activities is perhaps clearest during times of rapid societal change and upheaval. The current economic crisis in the U.S. is such an instance. For example, dealing with massive blue- and white-collar worker layoffs in the automobile industry, the State of Michigan is currently having to face the prospect of large numbers of workers returning to school for retraining. School learning is usually a leading activity for American children. At this point in the lives of Michigan workers, however, school learning is less a leading learning activity than it is an activity in the service of obtaining work.

A related concept, referred to here as heterochronicity (a term originally coined by Hutchins, in preparation) addresses the characteristic cycling times of societies, activities, and persons in terms of their rate of persistence and change. Society generally changes more slowly than an activity which, in turn, changes more slowly than a person. This is not always the case, however. For example, the lifespan of a person may cover a time of unusually rapid societal change with the introduction of new activities, hence adjacent generations of individuals may participate in very different sequences of activities. Heterochronicity therefore affords different entry points between activities--entry points that have a lot to do with how a person learns and develops as in transition between activities.

Another concept to be used in this study is the critical period, a time marked by societies and activities undergoing rapid change relative to the individual's development. Mead (1975) has refered to them as periods during which there are cross-generational reversals in roles, such as when children teach their parents about computers. Societies and activities generally change slowly relative to the individual, giving them the appearance of "surrounding" the individual, as in a context. Critical periods afford the analytic separation of individual, activity, and society in ways that other periods can not because the individual can be seen as traversing periods of rapid change in societies and in activities rather than being reducible to them.

Last, the concept of structural coupling borrowed from recent developments in evolutionary biology (Varela, Thompson, & Rosch 1992) allows us to locate learning and development in the coupling of persons and activities over time, rather than in the person, the activity, or in their interaction. Stated differently, the person and the sociocultural environment are seen as systems that are always linked, and that linkage, or coupling develops over time. The concept of coupling permits the conceptualization of continuity, discontinuity, and transformation without requiring that the person be a carrier of knowledge and skill from one activity to another.

The proposed reconceptualization of transfer as transformation, continuity, and discontinuity will be used in conjunction with the concepts of leading activity, heterochronicity, critical period, structural coupling, and simulation to examine arithmetic practices in the transition between school and work activities.

IV. GENERAL RESEARCH QUESTIONS AND THEIR SIGNIFICANCE

(A) What are the relations between societal change, school and work activities, and paths taken by individuals in transition between the activities, and the implications of these relations for individual learning and development?

This question addresses the broadest of issues: the relation between societal-level transformations and individual learning and development. The question assumes that both sociogenesis and ontogenesis are planes or systems of behavioral organization that possess their own histories and explanatory principals and are therefore not reducible. It further assumes that neither society, the individual, nor the activities that mediate them can be reduced to the cause or the outcome of the other, yet acknowledges that societies, activities and individuals do influence the construction of each other across time. Last, the question assumes that the individual is more than a set of activities and social practices arrayed in time, but still accepts those practices as integral to the learning and development of the individual.

(B) Does the proposed reconceptualization of transfer as transformation, continuity, and discontinuity adequately describe the epistemlogy of students becoming workers and workers becoming students?

This question addresses the issue of what happens to artifacts, goal-action organizations, and strategies as part of an individual's system of knowledge and skill in transition from one activity to another. It assumes that learning is reflected in both continuities and discontinuities whereas development is reflected in transformation, i.e. new knowledge and skill that is not decomposable into prior units and involves influence from beyond the immediate problem space.

(C) What are the strengths and weaknesses of the methodology that induces learning and development mediated by constrained activities that are in turn simulating a set of societal-level changes?

This question takes up the issue of how the initial creation of a methodology to examine relations between societal-level change and individual learning and development relates to sociohistorical theory on the one hand and to the phenomenon we are seeking to describe and explain on the other. In particular it focuses attention on the strengths and shortcomings of the methodology and how it may be further articulated as part of future research efforts.

V. METHODOLOGY

The term **methodology** refers here to that which provides the linkage between a particular theoretical framework and the research questions to be addressed through data and theory. Methodology becomes more than a recipe of methods and has overlapping relations with the theory, the questions being addressed and through the questions, the data. This differs from the "application of methods" approach which assumes that methodology can be considered separate from theory and, consequently, that it is "applied" to the reality of data rather than being part of the data construction (Kinderman and Valsiner, 1989).

The account of this study methodology attempts to make explicit its ties to the cultural-historical theory of the development of mind and the related reconceptualization of transfer as continuity, discontinuity, and transformation. It also attempts to make explicit the principled compromises that are inherent in its construction of the data. What follows from this is an account of the choice of research site, the design, and of the selection of participants as well as a description of the methods employed.

Choice of Site

A rural village in the Kingdom of Nepal was chosen as the site for the study. The reasons for this choice fall in to three categories: achieving a partial separation of the acquisition of arithmetic in learning and work activities, affording a simulation of learning and development in relation to societal change, taking advantage of the personal history of the researcher.

Addressing the first category of reasons, learning and work activities in the Nepali village are not wholly confounded. It was possible to identify villagers who were involved in work activities, but had not participated in learning activity at school as well as villagers who were involved in learning activity at school, but had not participated in work activity beyond the home. This afforded an initial look at arithmetic in learning and in work activities separated by different personal developmental histories. This was a necessary analytic prelude to looking at the transformations, continuities, and discontinuities of arithmetic in transition between learning and work activities. As we will see, however, this does not mean that arithmetic in learning and work activities necessarily exist in historical isolation from one another at either the level of the person or the activity.

The second reason for choosing a village in Nepal as the site for the study is that rural Nepal is undergoing a period of rapid cultural and societal change. The details of this will be discussed further on in this document. What is important here is that during periods of rapid change, not only are traditional cultural sequences and patterns altered so that, for example, a younger generation may instruct their elders in some ways of the world (Mead, 1970, Fisher, 1990), but several generations are simultaneously introduced to new activities rather than an activity evolving with a particular generation. This allows for an analytic distinction to be made between the development of particular activities and the learning and development of individuals. This state of affairs, in addition to the changes themselves, affords a simulation of societal changes in learning and work activities in relation to the learning and development of individuals and does so without resulting to reductionistic explanations of either in terms of the other.

The simulation is afforded by the chosen site in two senses. In one sense, the nature of a person's current participation in a particular activity can be taken as a representative of the more universal participation of an earlier generation in that activity. It is in this way that Luria (1976) considered his research during the time of rapid agricultural collectivization in Soviet Central Asia to simulate a cross-historical comparison. Luria compared the performances of unschooled and schooled Uzbeki peasants, taken to represent, respectively, the past and the future, using a series of perceptual and logical tasks.

A weakness to Luria's approach was the assumption that an unschooled Uzbeki peasant living with the presence of a school was socially and cognitively isolated from the school, and therefore equivalent to the Uzbeki peasant of the previous century. This assumption essentially collapses the history of the individual and that of the activity. As farming in Soviet Asia had developed without the influence of schooling, the assumption went, so did the Uzbeki farmer in the presence of a school if he or she did not actually attend. It is unclear from Luria's writings whether or not this assumption was warranted with regard to the Uzbeki peasant of Soviet Central Asia in the 1930's. It is clearly unwarranted for most societies undergoing rapid change today, however. Today in Nepal, unschooled adults are often seen learning from their children who attend school, sit on various school committees, and attend non-formal education classes. Therefore not only must the history of a particular activity within a society be considered and the person in relation to that history, but so must the ontogenetic history of the person as he or she moves between activities afforded by that society.

The site affords a simulation in a second sense as well: a necessary compliment to the first. It follows the logic, though not the specifics of Vygotsky's microgenetic method as discussed by Catan (1986). Vygotsky's microgenetic method, motivated by Werner's (1948) close studies of changes in extremely brief periods of behavior, was intended to simulate large-scale developmental processes, particularly those related to the historical development of literacy in a society. This was accomplished by experimentally inducing them within a short span of time (Luria, 1928;

Vygotsky, 1931).

Rapid changes in rural Nepali society have furnished future participants in the research with initial learning and/or work experiences as well as activities new to their generation. This then means that by inducing particular participants' transitions between particular learning and work activities, it is possible to simulate cultural-historical trends in movement between learning and work activities and track participants' learning and development in relation to the simulated societal changes.

The final reason for choosing Nepal as a site comes from the researcher's personal history in relation to a particular Nepali village. He has lived and worked in the village for four years spread over a period of ten years prior to the inception of the study. For a portion of this time he had taught mathematics and science at the secondary level in the village school. Through this he gained facility with the Nepali language, knowledge of the arithmetic curriculum used in the schools, a working knowledge of village life, a time-lapse view of change in the village, and familiarity with arithmetic beyond the confines of the school in farming and shopkeeping. Close personal ties with many of the villagers made the logistics of carrying out the study manageable and provided the high level of cooperation and trust that was necessary for the study to be carried out.

Description of the Setting

A brief description of the setting is necessary for the reader to understand the design, participants, and methods that follow. A more detailed, but focused description of the village and activities in the village is included as part of the study results.

The Country

Geographically, Nepal is roughly a rectangle 497 miles long and from 56 to 136 miles wide, bent to follow the curve of the Himalayan Mountain Range. It is sequested between Tibet (now a part of the People's Republic of China) to the north, India on south and west, and Sikim (now a part of India) on the east. Nepal is divided into three diverse climatic regions. The northern Mountain Region consists of four ranges of the Himalayan Mountains with over 240 peaks rising above 20,000 feet and an arctic climate. The Middle Hill Region immediately to the south consists of hills ranging from several thousand feet to over 10,000 feet and is heavily eroded by rivers and streams flowing out of the Himalaya with an average of a temperate climate. The Terai Region to the south is a continuation of the Gangetic Plain and as such, is barely above sea level, flat, and tropical in climate.

Culturally, Nepal is an interstitial zone between the Tibeto-Burman groups of Central Asia and the Indo-Aryan groups of South Asia. It is the meeting place of two major intellectual and religious traditions: Hinduism and Buddhism. Because of its interstitial character as well as the extremes of climate and mountain barriers, Nepal encompasses a variety of cultural and linguistic niches that is perhaps unequaled by any other region of the world. The Sanskrit-based Nepali language is understood by a majority of Nepal's population and is therefore its lingua franca, though it is a first language to only half the population. Almost 90 percent of Nepal's 18.7 million inhabitants are Hindu, though the Buddhist, Muslim, Jain, and Sikh faiths and ways-of-life are represented as well. The Hindu majority carries with it a modified and more loosely interpreted form of the system of caste than occurs in India, though discrimination based on caste is outlawed by the current Nepali constitution.

Nepal has existed as a united nation since its unification under Prithvinarayan Shah in the late 1700s. It was during his military conquests that the Gorkhali soldier came to prominence, leading to the Gurkha mercenary regiments of current fame. Before this period, Nepal existed as a series of feudal kingdoms. From the mid-1800s to the mid-1900s Nepal was ruled by the Rana oligarchy (Sharma, 1990). The Rana prime ministers ranged in style from harsh dictatorial to dictatorial with liberalizing tendencies. The latter, however, never retained power for an extended period of time.

With the overthrow of the Rana oligarchy in 1950-51, the Shah lineage regained power and furnished three Hindu Kings. Each was said to be an incarnation of the Hindu deity Vishnu. The current Shah King was forced to relinquish control of the government in 1990 by an opposition movement with strong popular support. Nepal is currently a constitutional monarchy with an elected prime minister and panchyat (parliament).

The Kingdom's introduction to a national system of secular education began in the mid-1950's under the current King's grandfather. A team of educators, primarily from the University of Oregon, entered the Kingdom in the early 1950's to formulate a national education system that drew heavily upon the British school model in force at that time (Reed, 1971). Prior to this period European-style education had been available only to members of the Rana court and those in their favor for the most part (Sharma, 1990). Schools were outlawed in many cases. Parochial Buddhist and Sanskrit educational institutions existed before, during, and after the Rana oligarchy and continue today, though greatly reduced in form and influence.

Economically, urban Nepal relies heavily on foreign aid and tourist income in the urban areas, while the remaining 92.6 percent of the country relies largely on rural subsistence agriculture. At the same time, rural Nepal clearly represents a transitional market society in which the profit motive has begun to appear and work is increasingly based on working for money rather than subsistence (Applebaum, 1984). There is little manufacturing, though the mercantile sector in both urban and rural areas has grown over the past three decades with increased access to foreign goods. The per capita income in 1989 was $180 US.

In 1971 Nepal was classified by the United Nations as one of the "least developed" and poorest states in the world and one whose overall economic and social condition gave great cause for concern. Several economists have argued convincingly that Nepal is undergoing a process of underdevelopment (Seddon, 1987; Blaike, Cameron, & Seddon, 1977). Within the next decade serious over-population relative to employment opportunities, ecological collapse in the densely populated and highly vulnerable hill areas, the elimination of natural resources such as timber, and increasing reliance on and decreasing ability to afford imported goods will be major components of the crisis.

Relations between these components have an active social context. This means that the lives of the economically impoverished in rural Nepal are not merely lives of passive disadvantage, but rather can be accurately characterized as

> ...lives of struggle. This struggle takes many forms and is waged on many fronts in many different contexts and at many different levels, although one might see it as divided, broadly, into struggles for survival, struggles for control, and struggles for social transformation; in the case of Nepal, to date, the

first two forms predominate. (Seddon, 1987: xii)

In addition to class struggles of various forms, other categories of activity are needed in order to grasp the individual's place in Nepali society.

> ...an individual can be at the same time a woman, a member of an 'untouchable' caste, a farmer, a migrant laborer and a mother; each category at different points affects how and when other categories apply at a particular conjuncture. (Seddon, 1987: xiii)

The conjuncture of persons and collective activities in relation to societal change is where our analyses will focus.

The Village

The village chosen as the site for the study is located in Surkhet District in the Middle Hills Region of Western Nepal. The center for the district within which the village is located is a two hour "regularly scheduled" flight from Kathmandu. The village itself is a 9 hour trek from the district center, and a 10 hour trek by foot, dugout canoe, and bus to the Indian border in the south. The village will be referred to as "Bherighat" within the context of this study: an appropriate pseudonym given the village's location on the Bheri River, a major river that flows out of the Himalayan Mountains and eventually into India's Ganges River. Bherighat proper is currently contained within a valley surrounded by hills ranging up to 9000 feet on three sides and the Bheri River on the fourth.

The original residents of the village were Magars and Gurungs of Tibeto-Burman stock who migrated from a district further to the east in Nepal late in the previous century. The precise reasons for the migration are unclear. Some village elders state that the settlers were given a land grant in Surkhet as payment of military services rendered. Others suggest that it was to escape persecution in the East. Yet others say that traders from the East simply liked the area and decided to settle.

Prior to the 1960's the village was located on a hillside facing the valley where the village currently resides. The valley was a malarial jungle that was gradually cleared for agriculture. Residents of the hillside village worked the valley fields during the day, but returned to the hillside at night to avoid mosquitos which were malaria vectors. With the eradication of malaria in the early 1960's the villagers shifted their residences from the hillside to the valley floor where most currently reside.

The village contained approximately 7200 residents living in 889 households in 1988. Magar and Gurung remain the predominate ethnic groups in the village, though Indo-Aryan caste groups such as Brahmin, Chetri, and Thakuri as well as Newar and so-called "untouchable" groups such as Kami, Sunar, Damai, Badi, and Sarki have been represented increasingly in the village over the last two decades.

The Activities

A multitude of activity types exist within village space and time: work, politics, celebrations, sports, learning, playing. However, three activities figure most prominently in the communal life of Bherighat in terms of their overall economic importance, opportunities for social mobility, time devotion, and potential for being dominant or leading. They are also the dominant village instantiations of the categories of work and learning activity.

The dominant form of labor and income generation in Bherighat is subsistence agriculture, much as it has been for hundreds of years, though the percentage of crops and livestock sold for cash has increased considerably over the last two decades. Almost all village life is either defined or permeated by farming. Shopkeepinghas become a source of cash income for many of the villagers. The number of tea shops and general stores have grown from none two decades ago to over fifty today. Most are concentrated in two bazaar areas of the village and serve local villagers as well as members of several neighboring villages and travelers passing through. Studying in secular schools associated with a national system of education has appeared and grown in influence during the last two decades in Bherighat. There are currently over 600 students attending the village's four primary schools and single lower and upper secondary school.

Not only do farming, shopkeeping, and studying activities figure prominently in the lives of most of the villagers and refract institutions in Nepali society, but relations between the activities, particularly those which constitute ties between learning and work activities, are the loci of many of the changes experienced by the Bherighat in the last two decades. Arithmetic figures prominently in all three of three of these activities and, as a marked or unmarked domain of knowledge, has a key role to play in making a transition between learning and work activities in the village. For these reasons the activities of farming, shopkeeping, and studying in Bherighat are the activities focused on in this research.

Specific Research Questions

These research questions reflect the broader questions discussed in chapter IV, but are specified further in relation to the choice of Nepal and within it, Bherighat village and the activities of farming, studying, and shopkeeping.

1. What is the relation of a) the history of arithmetic within Bherighat farming, studying, and shopkeeping activities to b) broader changes in Nepali society? (A)

2. What is the relation of a) evolving ties in arithmetic between farming, studying, and shopkeeping activities to b) the paths taken by persons between the activities? (A)

3. What is the relation of a) the paths taken by persons between studying and shopkeeping activities to b) continuities, discontinuities, and transformations in their arithmetic practices? (A and B)

4. As a reconceptualization of transfer, how adequately do continuity, discontinuity, and transformation capture the transitions between studying and shopkeeping, at least within the domain of arithmetic? (B)

5. What are the benefits, shortcomings, and implications of a methodology that simulates relations between changes in Nepali society changes and the learning and development of Nepali villagers through learning and work activities? (C)

Overall Design

The study invokes three levels of process analysis in order to answer the specific research questions that have been posed: the emergence of school and work in Nepali society, the emergence of school and work activities in Bherighat, the learning and development of Bherighat villagers between school and work. The study design draws on both the microgenetic method of Vygotsky (1931/1978) and Luria (1928/1978) and Scribner's three-phase strategy for research on practical activities (1984) to accomplish this.

Vygotsky's microgenetic method was motivated by Werner's (1948) close studies of changes in extremely brief periods of behavior. Vygotsky's method was intended to simulate large-scale developmental processes, particularly those related to the historical development of literacy in a society, by experimentally inducing them within a short span of time through miniaturization and acceleration (Catan, 1984). The method emphasized tracing the process of learning and development as it unfolds, rather than looking at its products and inferring the process post hoc.

Drawing on the microgenetic method, the methodology <u>simulates</u> one level of process. Departing from the microgenetic method, the methodology <u>induces</u> a second level of process. Here <u>simulation</u> refers to a modeling or abbreviated representing of certain core features and processes of an existing phenomenon. <u>Inducement</u>, however, refers to providing that which is necessary for the creation of a phenomenon rather than modeling that phenomenon per se. Miniaturization and acceleration are not used to simulate developmental and learning processes in relation to evolving societal trends. Rather the methodology creates simulations by selecting key activities that can be constrained and arranged in sequence to model changes in society and by that same sequence of activities, induce persons' learning and development. The methodology does not rely wholly on researcher-constructed simulations for villagers' participatory experiences, but draws on existing activities, albeit in a constrained form.

The methodology simulates societal trends that affect school-work relations and induces the learning and development of persons in transition between learning and work activities. It accomplishes this through constrained versions of existing learning and work activities. Particular activities (studying, farming, and shopkeeping) and specific relations between them are chosen to reflect societal trends in relations between learning and work activities and also because they can be used to induce current and future paths of learning and development taken by Bherighat villagers. Activity therefore not only provides the mediating entity between sociogenesis and ontogenesis (Raenthal, 1990), but also the methodological entry point into relations between the two.

The chosen activities are modified and constrained by requiring fixed and consistent times for participation in them by each participant, all participants with experiences in the same initial activities to participate in the same new activity, and by specifying the experiences of the instructing shopkeeper or teacher in the new activities. The methodological relation of the constrained activities as they mediate between and simulate societal changes and induce learning and development are depicted in Figure 3 below.

Using the constrained activities of farming, studying, and shopkeeping, four clusters of societal trends in relations between school and work activities can be simulated at the level of activity.

1. increasing economic demands for cash income, the inability of agriculture to satisfy this demand in some cases, increasing accessibility of wholesale shop merchandise,

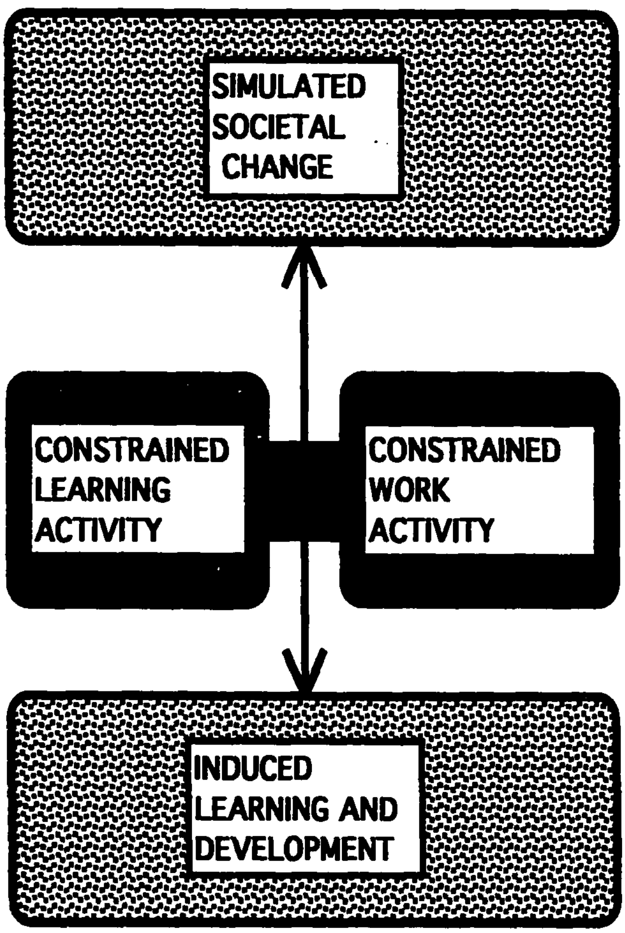
2. increasing demand for cash income, increasing growth of crops for cash in some cases, increasing need for detailed record keeping and large-number calculation in agriculture,

3. increasing numbers of students who are unable to go on to higher education, decreasing appeal of working full time in agriculture after having attended school for a number of years, increasing availability of cash for purchasing goods,

4. increasing availability of cash for purchasing goods and increasing accessibility to a wide variety of wholesale goods, increasing size and complexity of rural shops, increasing need for detailed record-keeping and large-number calculation.

Figure 3

Relation of the Constrained Activities to Simulated Societal Change and Induced Learning and Development



These societal trends which shape school-work relations in Nepal can be simulated in a diverse set of ways at the level of relations between the constrained activities. For example, referring to trend number 3 above, students who can not go on to higher education can grudgingly work at agriculture full time or open a shop in the village. It is the inducement of persons' learning and development within the confines of simulated societal change that determines the particular path taken by persons between the constrained learning and work activities. The particular inducements are determined by the research questions.

Here the inducement of learning and development is driven by two of the research questions discussed in chapter IV. One question requires examining the implications of leading (and non-leading) activities for learning and development. This can be achieved by contrasting students becoming shopkeepers with shopkeepers becoming students. For the former, shopkeeping is becoming a leading activity. For the later, studying in school is clearly non-leading with respect to shopkeeping. This is in line with societal change clusters 3 and 4 above.

The other research question involves examining continuities, discontinuities, and transformations in arithmetic between learning and work activities. Given that most villagers in rural Nepal are actively involved in farming, involvement in studying at school or in shopkeeping always occur in conjunction with it and cannot be analyzed separately. In a very real sense, schooling in rural Nepal is always schooling/farming, just as shopkeeping is always shopkeeping/farming for the person.

It might appear that a quasi-experimental design could be invoked to analytically separate farming experience in arithmetic from shopkeeping experience: comparing villagers with farming experience alone to those who have experience studying in school along with experience in farming. Stated differently, farming experience with arithmetic would cancel out and experience with arithmetic studying in school should be left. This would require making the assumptions that, one, farming and studying in school bear no historical relation to each other as activities and, two, a person's development is not mutually constituted through these two activities. The two sets of experiences with arithmetic would have to reside separately in the person. These assumptions reduce the person to the level of the activity in some sense--as if the person is a passive recipient of that which exists in an activity. This is clearly counter to the cultural-historical approach to learning and development, an approach in which these processes are driven by dissonances and contradictions that occur between persons and activities.

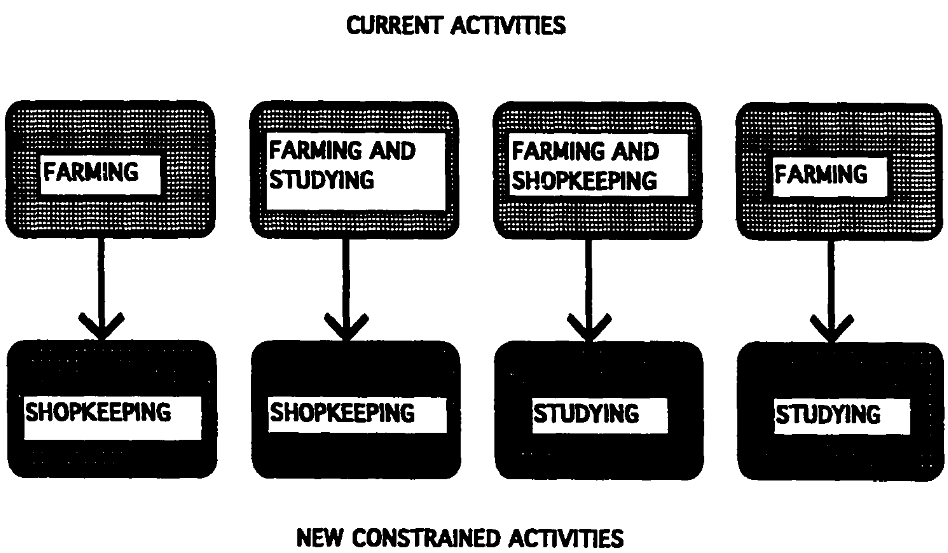
A quasi-experimental design can be used, however, to compare groups of persons with different clusters of activity experiences. Using the design in this manner, the farming experiences of the two groups do not cancel out. Rather, the comparison becomes one of farmers with farmers/students in terms of both groups learning a new activity. Any differences between the two groups are the result of having participated in farming rather than farming/studying, with no claim to farming experience being equivalent across the groups. A group of farmers becoming shopkeepers and a group of farmers becoming students will therefore be included as part of the design. This is in line with societal change clusters 1 and 2.

Figure 4 below illustrates the specific paths to be taken between the activities in simulating the societal change clusters and inducing persons' learning and development of arithmetic such that it is possible to address the research questions.

A broader framework is need to encompass the simulation and inducement portion of the methodology if it is to successfully address the research questions. These questions involve different levels of process (societal, activity, and individual) which are interrelated, but carry their own cycling times, phenomena, and explanatory principles. Methods must necessary be diverse, but methodologically interrelated in order to encompass the three levels of process in a coherent manner. Here the study expands on Scribner's

Figure 4

Paths to be Taken Between the Activities in Simulating Societal Change and Inducing Learning and Development

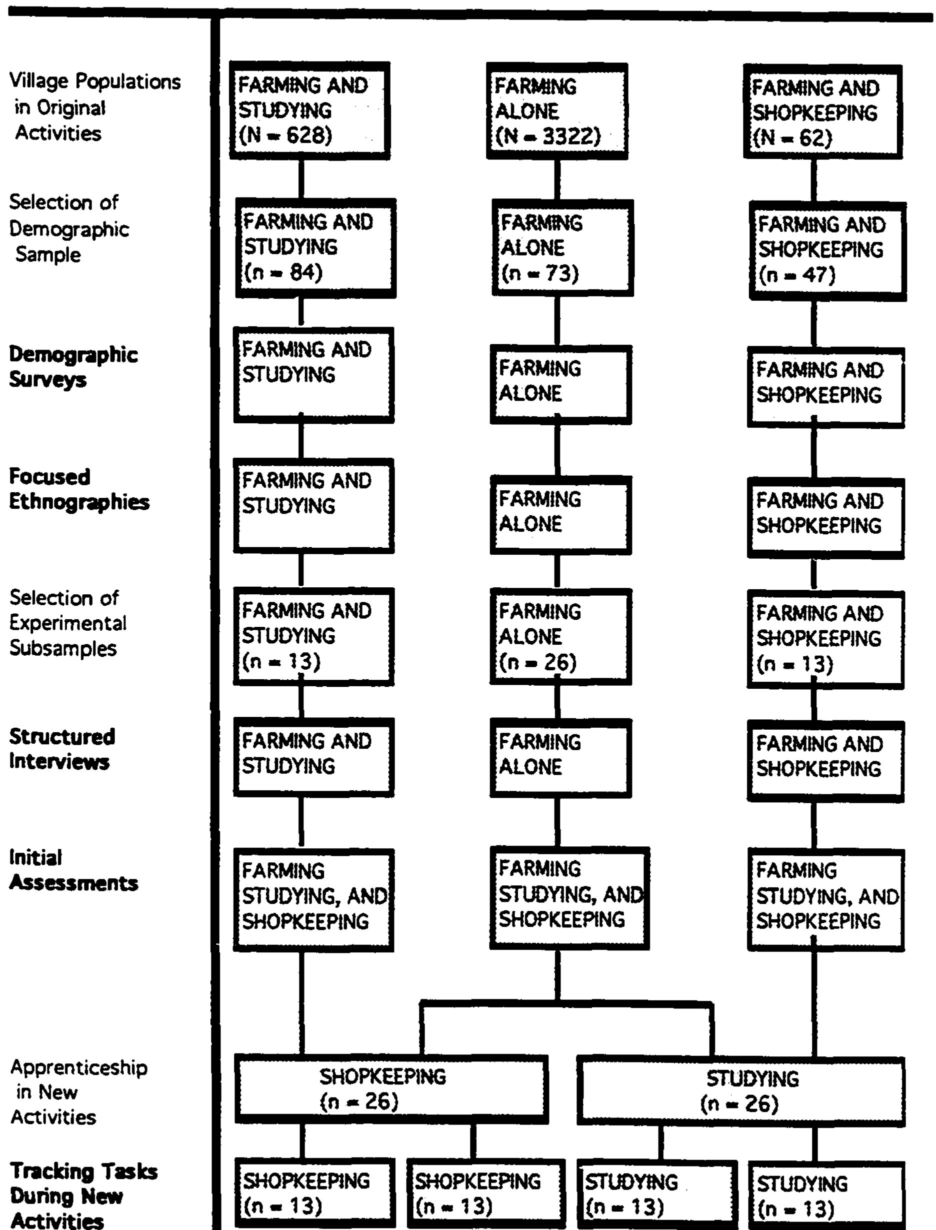


(1984, 1988) three-phase research strategy of in situ observation, simulation of key features and/or isolation of tasks based on observations, and experimentation.

A sequence of eight phases are used in the study: five associated with data collection, two associated with sample selection, one associated with apprenticeship. The sequence is depicted in Figure 5 below. Of the five data collection phases, the demographic surveys and focused ethnographies

Figure 5

Research Design and Sequence



are used largely to address society-activity relations and to locate possible interview, assessment, and tracking questions and problems. The structured interviews, initial assessments, and tracking tasks during new activities are used primarily to address activity-person relations and draw on a quasi-experimental design. Though groups of phases roughly address different levels of process, each phase draws on the previous phases for information, not for direct explanation, but rather to assist in its conception and design. This reflects the relative narrowing of the unit of analysis for arithmetic in transition from school to work from society, to activity, to person.

The remainder of the chapter will touch upon each of the eight phases, focusing on the structure of each as well as the reasons behind its design. Details regarding the specific contents of each phase are included as appendices. Coding procedures are not addressed until Chapter VI under results. This is necessitated by the length of the study and a desire to avoid separating details of the coding from the data analyses and results by a large expanse of text.

Selection of Demographic Samples

The overall purpose of the study was discussed with the local village panchyat leadership during the selection of the demographic samples before the demographic surveys were actually carried out. The researcher as well as two assistants, one from a neighboring village and one from Kathmandu, participated in the discussion. The leaders' questions as well as suggestions for presenting the study to the village at large and constructing the samples were taken into account. The leaders were consulted throughout the year and a half duration of the research project.

One clear concern that surfaced in the meeting was that many villagers, including some of the leaders present, did not consider what they did with numbers to be math because it did not involve written numerals. This will be taken up in more detail as a finding in Chapter VI, but it resulted in our presenting our project at the outset as one that was interested in how people use numbers at school and work rather than mathematics or arithmetic. The village leaders communicated the understanding that we constructed with them to the rest of the village. The Bherighat leadership unofficially served as a liaison between the project and the village, though many of the villagers freely approached the researcher and his assistants with their questions and concerns.

The village police, responsible to the district police office and, through the district, to the monarchy rather than the village wished to be consulted and included in a liaison role on the project as well. However, the police were not accepted as members of Bherighat, were justifiably mistrusted by the villagers, and would have been more detrimental to the project and the villagers through their inclusion than through their exclusion. They were consulted to the minimal extent necessary by the project and were not used as a liaison.

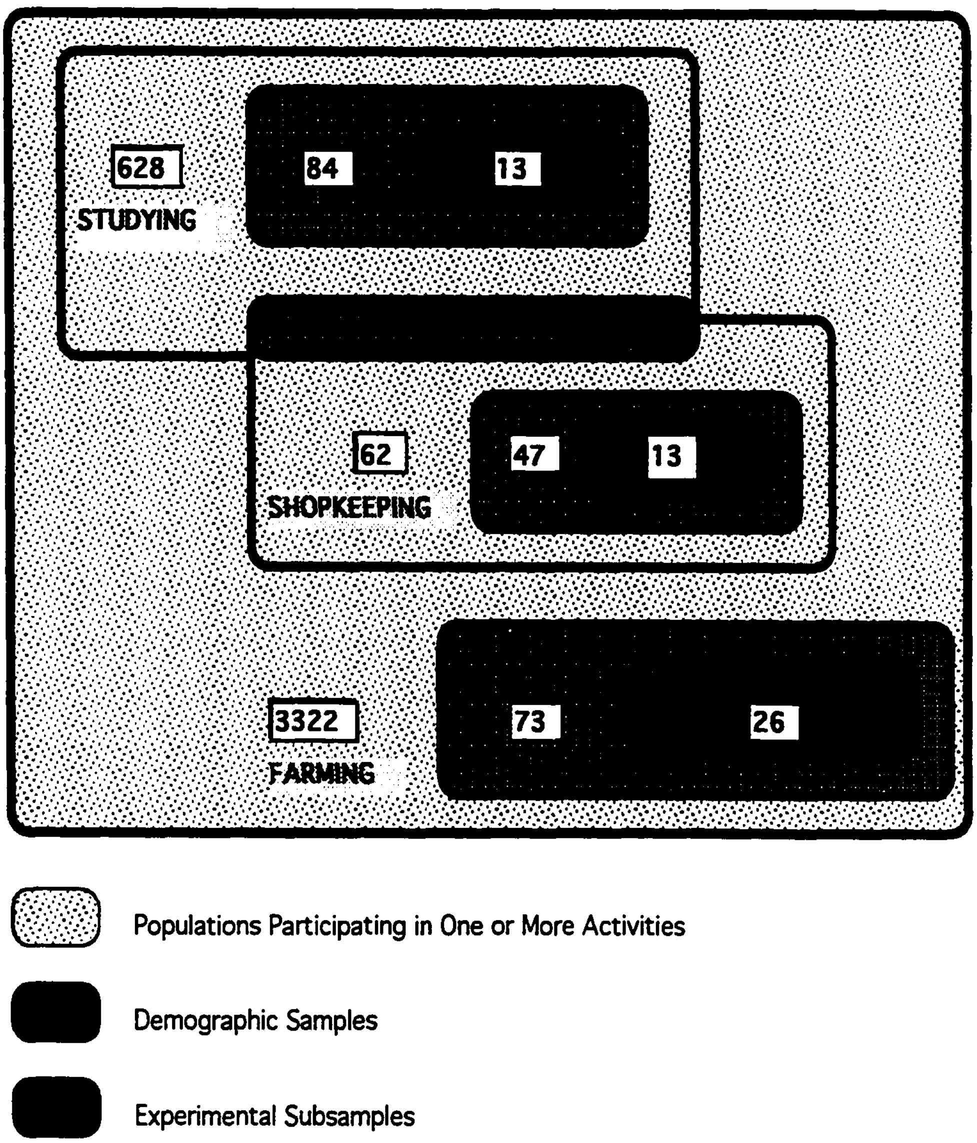
The public view of the project had a number of facets that were displayed over time. One was that the researcher, known to most of the villagers, needed to do the project to get a university degree. Two, was that the project involved the researcher and his two assistants trying to understand how we use numbers in school and at work. Three, the "Bherighat Number Project" as it came to be known was a good thing because a) we want to help the researcher get his degree, b) it is important to have our traditions and knowledge recorded, and/or c) it will help Nepali children in general/our children in particular learn better in school and get better jobs. We attempted to downplay the latter interpretation in terms of its immediacy.

Occasionally a negative view of the project was expressed, usually around the theme of "they are really interested in numbers because they want to determine our incomes so the government can tax us." Such views, while rarely aired (and presumably rarely held), were always expressed by villagers who were not in some way involved with the project. The insider-outsider distinction was one that concerned us and was gradually rectified through weekly video shows of scenes and occasions around

Bherighat, shown with the permission of those who had been recorded and open to anyone interested. No data video tapes were shown.

Figure 6

Populations and Samples



As indicated in Figure 6, Bherighat populations over the age of 6 years that were involved in farming alone, farming/studying in school, and farming/shopkeeping constituted 3322, 628, and 62 villagers, respectively. This was an approximation based on local government records for the year 1987.

In order to get a sense of the breadth of farming, studying, and shopkeeping activities in Bherighat and who the villagers were constituting these populations, a sample of villagers from each populations was selected to be surveyed. These demographic samples were later drawn from to construct the experimental subsamples. Figure 6 illustrates the relations between the populations, demographic samples, and the experimental subsamples.

The farming/studying sample (n = 84) was drawn from the 104 9th grade male students attending high school out of 628 male Bherighat children and adolescents attending school. The male 9th grade students not included in the sample were involved in shopkeeping and/or were absent during the week in which the survey was carried out. Tenth grade is the highest grade in Nepal's high schools, after which most rural students return to the work force on a full time basis. Only 9th grade Bherighat students were included in the demographic sample because most would be in the 10th grade the following year before returning to the work force.

Choosing 9th grade students allowed us to apprentice a subsample of the then 10th grade students to shopkeepers in the following year, simulating this particular transition between learning and work activities.

The farming/shopkeeping sample (n = 47) was drawn from the 51 shops in Bherighat which employ 62 male principal shopkeepers. Assistants were not included. Those principal shopkeepers not included in the sample had either attended school at some point in their lives or had declined to participate in the survey. Only one shopkeeper declined to participate.

The farming sample (n = 73) was drawn from the 178 principal male farmers above the age of 15 in one of the nine wards of the village out of 3322 male farmers above the age of 13 in the village. "Junior" farmers, usually those who were not head of a household, were not included. A single ward was selected both for the representativeness of its farming population and its geographical proximity to the school and many of the shops. The principal farmers not included in the sample were absent during the survey, were involved in shopkeeping, and/or had attended school at some point in their lives.

Females were excluded from the study at the outset. Though Bherighat girls and women were heavily involved in farming and in studying and shopkeeping to a lesser extent, the nature of their involvement in these activities as well as the activities themselves were quite different. It calls for a separate study and reflects gender distinctions in Hindu culture that range far beyond Nepali society. Further, the researcher and his two assistants were male and therefore would not have had access to women for the level of participation required by this study. An equivalent study would need to be carried out by female investigators.

Demographic Surveys

Each of the demographic survey questionnaires included questions designed to touch on the following areas: informant characteristics, characteristics of informant's household, household's agriculture, informant's mathematics, informant's use of calculating devices, informant's knowledge and use of measures. Those involved in farming/studying were asked an additional set of questions regarding their participation in school. Those involved in farming/shopkeeping were similarly asked a set of questions regarding their participation in shopkeeping. Appendix A contains the specific demographic questionnaire items asked of each group of informants.

Each questionnaire was initially written in Nepali and piloted with villagers who would not be included in the demographic sample. The questionnaire and the responses were only later translated into English for the purposes of communicating with an English audience. Back translations were done only when it seemed that a particular translation into English was problematical. This procedure was followed for all of the instruments in the study.

A different method of approach was used by the researcher based on whether the interview site was an informant's house, shop, or school. In all cases it was made clear to the informant that he could chose not to participate in the interview. The researchers would arrive at a house, sit on the veranda, and ask for a drink of water. This is a common socially acceptable way of instituting a conversation that does not initially have a shared purpose. Eventually the conversation would get around to a mutually agreed purpose, answering some questions for our project.

When the researchers arrived at a shop, tea and/or cigarettes would be purchased and consumed while our conversation came around to a mutually shared purpose regarding the questionnaire.

In approaching students in school, a general statement about the project and the questionnaire was made by the headmaster at morning assembly. Students who wished to be interviewed were then sent by teachers to meet with the researcher and an assistant in an empty school room.

The presentation of the questions and the informants' responses were oral. The informant's responses were recorded in writing. The researchers alternated their roles as interviewer and as recorder across informants.

Table 1 provides the general demographic characteristics of the three

Table 1

General Characteristics of Informants: Demographic Samples

Informant Characteristics	Farmers n = 73 Mean (SD)	Farmer/ Shopkeepers n = 47 Mean (SD)	Farmer/ Students n = 84 Mean (SD)
Age (yrs.)	38.7 (12.5)	36.9 (11.0)	19.7 (2.3)
Farming Experience (yrs.)	29.4 (8.9)	28.4 (12.2)	11.1 (4.5)
Shopkeeping Experience (yrs.)	0	2.7 (2.7)	0
Schooling Experience (yrs.)	0	0	11.0 (10.4)
Size of Family	7.5 (3.0)	5.4 (2.9)	8.7 (3.7)
Size of School-Age Family	4.1 (2.4)	3.5 (2.3)	5.9 (2.4)
Education of School-Age Family Members (yrs.)	1.8 (2.2)	3.2 (2.2)	3.6 (1.5)
Education of Male School-Age Family Members (yrs.)	4.8 (3.1)	4.8 (3.3)	6.0 (2.0)
Education of Female School-Age Family Members (yrs.)	1.5 (2.3)	1.5 (2.2)	.6 (.9)

samples.

Focused Ethnography

A coherent account of the related histories of farming, shopkeeping, and studying in school in Bherighat was needed. These accounts need not be a full description of the economics, symbolism, ritual, kinship, and practices that have evolved though these activities. This would have been a daunting undertaking and one largely peripheral to the purposes of this study. The account needed to focus on two concerns in the research questions to be addressed: the changing associations among the particular activities in relation to broader changes in Nepali society and the transformation of practices involving arithmetic embedded in the activities. The account would also need to provide information on current practices in the activities that involve arithmetic. This information would be of use in designing tasks for the quasi-experimental phases.

There were no hypotheses driving the account. Rather discrepancy and anomaly needed to be sought and resolved in constructing it. There were no records preserved that could be drawn upon in constructing it. The process of ethnography utilizes an organization of methods with an underlying epistemology that supports the construction of such an account (Werner & Schoepfle, 1987).

The ethnographic account, in this case focused rather than holistic, emerges as a product of relations between the researcher, the group being researched, and the intended audience (Agar, 1986). It represents an attempt to achieve a coherent account through multiple breakdowns between the ethnographer's encounter with a tradition and the expectations by which the ethnographer's experiences are organized, as well as their resolution; so that by "changing the knowledge of the ethnographer's tradition...the breakdown is now reinterpreted as an expression of some part of a plan." (p. 25). It is not driven by the goal of testing hypotheses, though hypothesis testing may be embedded as part of the process of constructing the coherent account.

Two Nepali research assistants employed on the study facilitated the creation of interpretative breakdowns and their resolutions. One research assistant was from Kathmandu and was largely unfamiliar with rural life in Nepal. He was able to point out events and objects and problemitize them in a way that the other research assistant and the researcher were unable to because of their familiarity with Bherighat. The other research assistant was from a village near Bherighat, had attend secondary school in Bherighat, and knew many if not most of the Bherighat villagers. He was able to resolve many of the interpretative breakdowns experienced by the research team.

Data leading to a focused ethnographic account of the three Bherighat learning and work activities were collected over a seven month period. Given the historical nature of the account, particular farmers, shopkeepers, and students were approached to serve as informants, based on their particular place in the history of an activity as well as informal consensuses that they were articulate and knowledgeable about the activity and its history in Bherighat and/or could relate unique information deemed critical to the account the researcher was attempting to construct. All but three of the informants had previously been included in a demographic survey.

Data was collected using a varying combinations of observation, participant-observation, video taping and repeated viewings of video tapes, interviews with varying degrees of pre-established structure, an introspective diary, and counts of various forms of arithmetic.

The focused ethnographic account is presented in synopsis form in Chapter VI.

Selection of Quasi-Experimental Subsamples

Three experimental subsamples were constructed based on information from the demographic surveys related to the study design: farmer, farmer/shopkeeper, farmer/student. Women were not included in the subsamples because it would have been impossible for male researchers to have had sustained contact with females in the village. Because women's work is quite different from men's work in the village, it would require a separate study rather than a study which included both men and women. The criteria used in the selection of each subsample were as follows.

The farmer subsample consisted of 26 farmers between the ages of 20 and 40 years who were the principal or most senior farmer in their family, had a minimum of 8 years of farming experience, had never attended school, had never been enrolled in an adult education class, and had never worked in a shop.

The farming/shopkeeper subsample consisted of 13 farmer/shopkeepers between the ages of 20 and 40 years who had a minimum of 8 years of farming experience, had a minimum of 2 years of shopkeeping experience, had not attended a year or more of school, and had never been enrolled in an adult education class.

The farming/student subsample consisted of 13 farmer/students between the ages of 19 and 22 years, who had a minimum of 8 years of farming experience, were currently enrolled in the 10th grade, had not failed a grade more than once, and had never worked in a shop.

The farmer subsample initially consisted of 26 participants, but was later subdivided into two groups of 13 participants each. All subsample sizes were set at 13 in the belief that some participants would drop out, given the longitudinal nature of the design. With a subsample size of 13 we could be relatively certain that we would retain 10 in each group, the minimum number required by many parametric statistical comparisons. No participants dropped out of the study, however. This had to do with the cohesiveness of the Bherighat community, the researcher's place in that community, and the comradery that formed between the participants in what became known as the Bherighat Number Project.

Three separate meetings were held to enlist participants in the remaining phases of the study. One meeting was held for farmers who might potentially volunteer to be apprenticed to shopkeepers or enroll in an adult numeracy/literacy course. A second was held for farming/shopkeepers who might volunteer to enroll in the adult numeracy/literacy course. The third was held for farming/students who might volunteer to be apprenticed to shopkeepers. All invited were drawn from the demographic samples and met the criteria mentioned above. Some of those invited had served as informants in the focused ethnography.

Each meeting involved describing to the potential participants what the remaining phases of the project would be like, what their continued involvement in the project would mean, and entertaining questions. Those who would be apprenticed to shopkeepers were told that they would receive 100 rupees for working with us on the structured interviews and initial assessments and an additional 100 rupees pay for working as an apprentice in a shop over a period of a month. At the time, 200 rupees was roughly equivalent to 7.50 US dollars, but was considered fair pay for the time involved. Those who would be enrolled in the adult education class would receive 100 rupees (approximately 3.75 US dollars) for working with us on the structured interviews and the initial assessments and would receive free textbooks and instruction with the adult education class over a period of a month.

All potential volunteers were asked not to make a commitment to the project unless they thought they would be able to keep it over the remaining 7 months. They were told that they could, however, pull out of the project at any time and receive payment proportional to the amount of time they had spent with the project.

In all cases there were more volunteers than slots to fill. As a consequence, the names of the volunteers were placed in a hat and the first 13 names drawn were chosen as participants. The farming subsample was drawn from 40 volunteers, the farming/shopkeeping sample was drawn from 18 volunteers, and the farming/studying sample was drawn from 54 volunteers. Each of the 52 volunteers signed or placed their thumb print on two copies of a permission form which one of the volunteers or the researcher had read to the group. The form detailed the Project's commitments to the participants including maintenance of the participants' anonymity and their option to not participate, as well as their commitments to the project. Each participant received a completed copy of the permission form.

Table 2 provides basic demographic information on the participants in the three subsamples.

Table 2

General Characteristics of Informants: Experimental Samples

Participant Characteristics	Farmers n = 26 Mean (SD)	Farmer/ Shopkeepers n = 13 Mean (SD)	Farmer/ Students n = 13 Mean (SD)
Age (yrs.)	42.4 (8.5)	46.8 (11.9)	21.8 (.7)
Farming Experience (yrs.)	33.5 (7.8)	31.8 (10.4)	12.4 (2.8)
Shopkeeping Experience (yrs.)	0	3.5 (1.8)	0
Schooling Experience (yrs.)	0	0	10.7 (2.3)
Size of Family	6.2 (2.5)	6.8 (3.6)	8.8 (3.2)
Size of School-Age Family	4.8 (2.3)	4.5 (2.2)	6.0 (2.0)
Education of School-Age Family Members (yrs.)	2.1 (1.9)	2.9 (1.9)	3.2 (1.7)
Education of Male School-Age Family Members (yrs.)	2.9 (3.1)	4.1 (2.7)	5.3 (2.3)
Education of Female School-Age Family Members (yrs.)	1.0 (1.4)	1.3 (1.7)	.7 (.9)

Structured Interview

The structured interview was designed to obtain a range of information about how the participants learned to take part in relevant activities, learned arithmetic as part of those activities, and their knowledge and skills with various forms of arithmetic. The interview consisted of six different sets of questions.

1. Narrative Questions
2. Math Facts
3. Numeral, sign, and Problem Reading and Writing
4. Finger Calculation
5. Arithmetic Calculation
6. Measurement Conversion

Interviewing was conducted at the researcher's quarters in the house where he resided with his two assistants and an extended Nepali family. One person (either the researcher or an assistant) would present and in some cases discuss the questions with the participant while the other would operate a tape recorder and/or maintain a written record, depending on the particular question set.

The tape recorder permitted constant monitoring of the recording quality as well as the use of a noise reduction features. The tape recorder was run off of three sets of rechargeable batteries. A gas-powered generator was used to recharge the batteries every evening during the course of the interviews. One hundred and twenty liters of gasoline had been brought up from India to provide sufficient fuel for recharging batteries over the course of the entire project. An omni-directional table microphone was placed on the table between the researchers and the participant to record both the researchers' and the participant's conversation. The researcher's and the assistant's roles were purposely made interchangeable through training. This allowed the study to continue if any one project member was unable to function due to illness--a significant problem for extended and longitudinal research in South Asia.

The project members and the participant sat in chairs around a table. Tea was served several times during the interview and cigarettes were placed on the table for those who cared to smoke. The interview was completed in one or sometimes two sessions and ranged from an hour and a half to two and a half hours in length.

All interview questions and procedures were piloted with villagers not participating in the study and were revised when necessary. The Nepali language was used throughout the process. A brief description of each set of questions along with the reasons for their inclusion and the procedure associated with each set is provided below. The categories of questions were presented to the participant in the order in which they appear below.

Narrative questions

The narrative questions were used to obtain information on how the participant came to take part in particular activities, how he became experienced in those activities, the nature of those activities and how they became experienced in various forms of arithmetic in relation to those activities. They were tailored to the participant's existing experience with learning and work activities: farming, farming/shopkeeping, farming/studying in school. All participants received the same narrative questions associated with farming. Farming/shopkeepers received questions regarding shopkeeping and farming/students received questions regarding or studying in school as well. A listing of the 26 questions making up the structured interview is provide in Appendix B.

The questions were initially asked as written, but were paraphrased, elaborated, and pursued further when appropriate as the interview progressed. Participants were encouraged to elaborate and go beyond the initial questions asked in their responses. A brief written record was kept of each participant's responses as well as an audio tape record of each participant's narrative.

Math Facts

The participants' knowledge of math facts, or remembered precalculated solutions to math problems were assessed in addition, subtraction, multiplication, and division. Other research (Siegler and Shrager, 1984) has indicated that are clear relations between a person's ability to draw on math facts and the other strategies that person might bring into play to solve a problem involving arithmetic. Practicing math facts is an important part of learning arithmetic in the primary grades in Nepal but not in farming or shopkeeping. We therefore had reason to suspect strong differences between the three groups of participants in the extent of their math fact repertoire.

A total of 120 arithmetic problems were constructed: 34 addition, 36 subtraction, 34 multiplication, 16 division. For each of the four arithmetic operations there were problems which varied along the following parameters: single or double digits, inverse of problem under other operation or not, zero in one of the terms or not, two terms have a common multiple or not. These parameters were nested and vary with respect to the number of arithmetic problems that can be constructed within the categories they form for each operation. However, the goal of addressing these parameters in constructing the problems was not equating types of problems across the operation sets so much as providing the greatest variety of problems along these parameters within each operation set. The complete set of math facts problems is presented in Appendix C.

The problems were recorded on an audio tape with a low volume beep occurring two seconds after each problem was presented and an additional pause of three seconds before the onset of the next problem presentation. The problems were recorded in two formats. One was based on school verbalization techniques in which the operation was stated as such. The other was based on verbalization techniques in work settings where function rather than operation words were used, i.e. joining, taking away, joining groups, making into pieces for addition, subtraction, multiplication and division respectively. A series of eight practice problems containing two of each arithmetic operation were presented in each of the formats to each participant. The participants were asked to answer each question out loud as quickly as possible. They were told that if they could not answer before the next question was presented, to drop the question and go on to the more recent question. After having answered each set of warmup questions, each participant was asked to chose the format with which they felt most comfortable. The warmup questions were repeated in the preferred format if the participant indicated that he did not yet feel comfortable with the process of responding to the tape recorder.

The participant was then told that he would be asked a set of questions by the tape recorder that had to do with one of the four operations. Each set of questions were exclusive to an operation. The participant's answers were recorded as to whether they were given before or after the two second beep and whether they were correct or not. Two seconds does not provide sufficient time for a participant to answer any of the questions unless the solution is already known, i.e. does not have to be calculated (Scribner and Stevens, 1989). Thus correct solutions stated in less than two seconds were considered to be math facts. This procedure was repeated for the set of problems for each operation. The presentation order of the four operation sets was counterbalanced within groups.

Numeral, Sign, and Problem Reading and Writing

Orthographically representing arithmetic was strongly associated with studying in the Bherighat schools. However, a number of villagers who had not attended school themselves had developed this skill from their sons and daughters attending school and from text books. This often occured where the villagers' work activities could benefit from their development of the skill.

All of the participants were asked to write and read arithmetic numerals, signs and equations in order to assess the breadth of their skill at reading and writing arithmetic orthography. First the participants were orally presented with a series of single and multiple digit numbers (45), operation signs (5), and arithmetic problems (4). They were asked to write as many of the numbers, signs, and problems as they could. Then the participants were visually presented with the same series of single and multiple digit numbers, operation signs, and arithmetic problems in a different order. Each digit, sign, and problem was written in black 1/2 inch high Devnagri (Nepali) numerals centered on a 4 inch square of white cardboard. The participants were asked to read out loud as many of the digits, signs, and problems as they could. The writing series was always presented before the reading series under the assumption that if a participant could write a number he would also be able to read it, but that the reverse may not be true. Following this order or presentation reduced the possibility that responses in one mode affected responses in the other. A written record of each participant's response was made by the participant himself on the writing task and by a researcher on the reading task. Accuracy was recorded by a researcher in both cases. See Appendix D for a list of the digits, signs, and problems used in both series.

Finger Calculation

The skill of representing arithmetic with fingers is strongly associated with farming and shopkeeping. However, a number of students have developed this skill from farming with their families and use it studying arithmetic in school. Its use in school is frowned upon by teachers and one rarely sees its use in the upper grades.

All of the participants were asked to add, subtract, multiply, and divide using their fingers in order to assess the breadth of their skill in representing numbers and arithmetic operations with fingers. The focus was not on calculation per se, but rather on the ability to represent number and operations. However, representation is not functionally separate from calculation when fingers are used, unlike when orthography is used.

Each participant was presented with four math problems, each representing one of the four arithmetic operations. The factors of interest were whether the whole finger or the joints of the finger were used in representing number and whether a number value was fixed to a particular location or could float during the course of the calculation. During piloting it was found that villagers performances were consistent across problems within operations on these factors. Therefore only one carefully designed problem was deemed necessary for each operation. Problems involving large numbers were not used because the structure of the finger calculation system does not support their calculation, unlike an orthographic calculation system.

The problems were 4 + 9, 13 - 6, 3 x 4, and 14/7. The questions followed formats that can roughly be translated as "X plus Y equals how much, X minus Y equals how much, X times Y equals how much, X divided by Y equals how much" or "how much is X and Y joined, how much is X take away Y, how much is X groups of Y, how much is X made into Y equal pieces" depending on each participant's preference. Order of presentation was counterbalanced within each group. Each problem was orally presented and a researcher noted whether the answer was correct, the unit used (finger or joint), and the value-location correspondence (fixed or floating).

Arithmetic Calculation

Many villagers were able to use several different types of calculation tools (e.g. tally, seeds/stones, fingers, orthography) and procedures with or without the use of tools (e.g. min, iteration, decomposition, math fact, column algorithm). Often a repertoire of tools and procedures was used flexibly by the villagers, adapted to the particular problem at hand. However, studying arithmetic in school where a single tool (orthography) and singular procedures (column algorithms) are taught may, in conjunction with the societal status of the tool and the procedures, involve the deployment of a more limited repertoire than in shopkeeping or in farming. However, students studying arithmetic in school are also involved in farming.

The participants were presented with a series of explicitly mathematical arithmetic problems in order to assess the variety of tools and procedures used by the three groups of participants. By using problems marked as mathematical and presenting them as problems, we reduced or eliminated the potential use of some procedures such as estimation and asking another person for assistance. We also reduced any strategies that might be used by participants to organize relations between multiple arithmetic operations by presenting problems that could be solved under a single operation. Despite these restrictions, it did provide us with a preliminary look at some of the tools and procedures used by the different participant groups over a wide variety of math problems. Data obtained from piloting the problems indicated that the tools and procedures used by the participants from the three bore a sensible relation to many of the arithmetic tools and procedures we observed during the construction of the focused ethnography.

Eight addition, six subtraction, seven multiplication, and six division problems were included as part of the final instrument. Note that the operations defined the initial problems and not necessarily the operations actually used by the participants. The problems varied along the parameters of single or double digits and the appearance of zero. No other selection criteria could be applied in a principled manner across the wide variety of tools and procedures that might potentially be used by participants. Appendix E provides a complete listing of the problems.

Each participant was told that he would be asked a series of questions involving numbers and calculation and that he could take as much time as he felt necessary to answer each question. The questions followed formats that can roughly be translated as "X plus Y equals how much, X minus Y equals how much, X times Y equals how much, X divided by Y equals how much" or "how much is X and Y joined, how much is X take away Y, how much is X groups of Y, how much is X made into Y equal pieces" depending on each participant's preference. A paper and pencil and a box of dried corn were provided. The participant was told to answer the orally-presented questions in any way he felt, whether it be "in his head", with his fingers, on paper, and/or with the seeds. The researcher emphasized that he was more interested in how the participant went about answering the question than whether the answer was right or wrong. For this reason the participant was asked to "talk his numbers" while arriving at an answer so that the other researcher might tape record his procedure. When it was unclear from the participant's thinking out loud what procedure was used, the interviewing researcher would ask the participant to describe how he generated the solution after the fact. The recording researcher operated the tape recorder and provided a written record of each participant's answers as well as calculation tools. Procedures were coded from transcriptions of the tape record.

Measurement Conversion

Most arithmetic in farming and shopkeeping activities occurs around various forms of measurement. This is not the case for arithmetic studied in school. It is devoid of units of measure except for a small number of word problems and a textbook chapter at each grade that is devoted to measurement. Only metric measures are included in the school arithmetic curriculum. Traditional units of measure predominate in farming activity.

Shopkeepers, on the other hand, must constantly deal with measurement conversion between traditional and metric systems on the one hand and price on the other.

Differences in knowledge about traditional and metric measures would be expected between the three groups of participants. Whether these differences are tied to differences in arithmetic practice in relating units of measure to each other was less clear. Therefore the participants were presented with a series of measure conversion problems to assess both their knowledge of the various units of measure as well as their procedures for converting between the units.

Each participant was presented with 59 conversion problems across the dimensions of time, length, weight, dry and wet volume, area, and money. The problems varied on whether they required a close or far conversion (centimeters in a meter vs millimeters in a meter), whether they were metric, traditional, or across the two systems, and whether they were within or across a dimension. The problems were piloted and revised when necessary. Appendix F contains a complete list of the measurement conversion problems.

Each participant was told that he would be asked a series of questions involving measurement and that he could take as much time as he felt necessary to answer each question. Each question followed the format

"How many (units) are in (unit)?" A paper and pencil and a box of dried corn were provided as in the arithmetic calculation tasks. The participant was told to answer the orally-presented questions in any way he felt, whether it be "in his head", with his fingers, on paper, and/or with the seeds. The researcher emphasized that he was more interested in how the participant went about answering the question than whether the answer was right or wrong. For this reason the participant was asked to "talk his numbers" while arriving at an answer so that the other researcher might tape record his procedure. When it was unclear from the participant's thinking out loud what procedure was used, the interviewing researcher would ask the participant after the fact to describe how he generated the solution. The recording researcher operated the tape recorder and provided a written record of each participant's answers as well as the calculation tools used. Procedures were coded from transcriptions of the tape record.

Initial Assessments

From the focused ethnography and the structured interviews it was clear that the three groups of participants have developed different arithmetic knowledge and skills through their differential participation in farming, shopkeeping, and studying in school. Therefore, before apprenticing them to shopkeepers or enrolling them in an adult education class it was necessary to assess their problem-solving skills involving arithmetic in their activities of experience. However, no villager lived in total isolation from farming, shopkeeping, or studying in school. For example, all villagers bought items in the village shops and all either had or knew children who attend school. Therefore all of the participants were presented with problem-solving tasks potentially involving arithmetic from all three activities.

The focused ethnography and the structured interview allowed us to develop three sets of problems with their origins in farming, shopkeeping, and studying activities. To the extent possible, each set was to be presented at a site representative of the sites at which each activity took place. A frequency count of various problem types was made over a period of a week in each activity as part of the focused ethnography. This was used to select the initial pool of problems for piloting. While frequency is not the only nor necessarily the best measure of the social and cognitive salience of various problems for an activity, it was useful for selecting those which were most commonly dealt with. All problems selected for piloting were at or above the 30th percentile in frequency in their given activity, eliminating those which were unique, unusual, and/or accidental.

The problem of what constitutes "a problem" extracted from a given activity clearly needs to be addressed as well. For the purpose of this study, the term "problem" does not necessarily refer to a folk category that is marked as a problem by the participant, i.e. it need not be an out of the ordinary occurrence that is disruptive and needs to be corrected. Rather, we follow Newell and Simon's (1972) definition of a problem as that which a person wants to accomplish, but does not immediately know what actions are needed to accomplish it. It assumes that certain information is available to the person who has an interpretation of that information;: an interpretation which includes a goal. However, the use of "problem" in this portion of the study goes beyond the information processing "problem" as least as it has been instantiated in research.

First, a problem in the context of this study must be extracted from a phenomenon that has its genesis and continuance as part of an already existing activity. Second, the extracted problem must have a beginning and an end point that can be recognized by the participant as reoccurring in form, though not necessarily content, during the normal course of an activity, even if the participant has had little contact with the activity from which it was extracted. Third, the problem must afford its reconstruction by the participant using tools, procedures, and strategies that have their origins in the participant's own experience and/or the activity in which the problem's phenomenon was given birth.

This allows the problem to be extracted from the activity for purposes of experimentation: providing a model form and the potential for affording many of the potential contents of that form. Unquestionably the problem is different from the phenomenon it represents as part of an activity. Over arching goals and meanings are altered in the conversion from phenomenon to problem and the development of the phenomenon as part of the activity is frozen. However, the problem bears clear structural and semantic relations to its phenomenon-in-activity, both for the participant and, analytically, for the researcher.

The setting, problems set, and procedures are discussed below for each of the three activities. The order of presentation for the farming, shopkeeping, and studying problems are counterbalanced within groups.

Farming Problems

he farming problems were presented in a field normally used for agriculture that was left unplanted. It was surrounded by planted fields on three sides and a house on the fourth. Straw mats were provided for sitting and the instruments associated with the various problems were located at different points in the uncut filed. All of the phenomena represented by the problems would normally occur out of doors in a planted or unplanted area.

Two researchers and the participant moved to each problem site in the unplanted area. One researcher presented the problems and the other researcher noted the participant's response on a record sheet along with any external calculation devices the participant may have used. The recording researcher used a highly directional shotgun microphone attached to a clipboard to record the researcher's and the participant's conversations. The participant was told that we were more interested in the procedure by which he solved the problem than the correctness of this solution. He was asked to "talk his thoughts" while solving each problem so that the other researcher might record him. When it was unclear from the participant's thinking out loud what procedure was used, the interviewing researcher would ask the participant to describe after the fact how he generated the solution.

There are 24 farming problems in all that fall into five categories: estimating and measuring the volume of unhusked rice (1), estimating the seed needed to sow a field and its yield (12), weighing and dividing meat (2), word problems involving the four operations (8), and correcting the measurements of a plow (1). The categories of problems were presented to the participant in the order given above. A brief description of each category of problem is given below. A complete description is provided in Appendix G.

Estimating and Measuring the Volume of Unhusked Rice. The participant was shown a pile of unhusked rice (approximately 14.5

kilograms in weight) and asked to estimate the amount of grain using a traditional dry volume measures. Then he was asked to actually measure the amount of grain using three traditional dry volume measuring containers, two of which reflect a dry volume standard (maana and pathi) and are made of copper and a commonly used larger container made of grape vines that could be standardized in terms of the first two if the participant so chose.

Estimating the Seed Needed to Sow a Field and its Yield. The participant was shown a planted field (220 square meters in area) in a moderately well irrigated area with average quality soil. Each corner of the field was marked by a flag. He was asked to estimate the amount of corn, wheat, and rice needed to sow the field and the amount of the yield. Then he was asked to suppose that the field was down by the river side. River side land has excellent irrigation and soil. The same questions regarding amount of seeds needed to sow and the yield were asked of this situation.

Weighing and Dividing Meat. The participant was shown a pile of partially filled cloth bags and a single pan scale placed on a set of straw mats. He was asked to suppose that the bags were goat meat. The bags were filled with a mixture of rice husks and sand and were of several different sizes. This partially separated weight from size, much as it is partially separated with actual meat, e.g. fat weighs less than muscle. The single pan scale, or tulo consisted of a pan suspended from one end of a metal bar with tradition weight markings along it (ser, bisoli, dharni) and a weight at the end opposite that from which the pan was suspended. A string looped around the arm was used to suspend the entire scale from the person's hand and could be slid to any of the marks to achieve a balanced fulcrum between the weight on the one end and the pan and the meat on the other.

For the first problem the participant was told that he had to give the same amount of meat to five people who had bought in to the goat, including himself. There were 10 bags of two different weights which coincided with the traditional weight units marked on the single pan scale. The second problem the participant was told that he had to give the same amount of meat to six people who had bought in to the goat, including himself. There were 16 bags of two different weights.

Word Problems Involving the Four Operations. The eight word problems were presented to each participant while the participant and the researchers sat facing each other on straw mats. A pencil, paper, and a box of dried corn were made available for the participant's use if he so chose. Two each of problems which afforded addition, subtraction, multiplication, and division were orally presented to the participant.

The content of the word problems centered on grain measures, crop yields, field labor, and money.

Correcting the Measurements of a Plow. The participant was shown a wooden plow leaning up against a tree. The plow had been constructed for the study with seven clearly incorrect dimensions. The participant was asked whether he could use the plow and if not, why not. Then he was asked to demonstrate what the correct dimensions should be, either using traditional forearm, hand, and finger measurement units or a meter stick which had been placed next to the plow.

Shopkeeping Problems

The shopkeeping problems were presented in a simulated shop that was constructed for the purpose of the study. The shop was located near but set off from the field where the farming problems were presented. The researchers and the participant sat facing each other on straw mats in the shop enclosure. A two pan scale, money in a box, and shop goods along with paper, pencil, and a box of dried corn were arrayed to the side and to he back of the participant. The participant was asked to play the role of the shopkeeper. One of the researchers played the role of customer and presented the problems while the other made audio and written records. A lapel mike attached to the participant's shirt was used in making the audio records.

The participant was told that we were more interested in the procedure by which he solved the problem than the correctness of this solution. He was asked to "talk his thoughts" while solving each problem so that the other researcher might record him. When it was unclear from the participant's thinking out loud what procedure was used, the interviewing researcher would ask the participant to describe after the fact how he generated the solution.

There were 22 shopkeeping problems that fall into seven categories: item price knowledge (1), creating a measurement standard (1), weighing sugar (6), cloth measure conversion (1), profit/loss (5), purchase total/change (4), unit/subunit pricing (4). A brief description of each category of problem is given below. The categories of problems were presented to the participant in the order given above. A complete description is provided in Appendix H.

Item Price Knowledge. The participant was asked to state, estimate, or guess the prices of 17 objects which were sold in 80 percent or more of the shops in Bherighat.

Creating a Measurement Standard. The participant was given a large can of chewing tobacco and several smaller empty containers of varying sizes. Given the price the large container of tobacco would be sold for, he was asked to figure out what combination of small containers could be used to measure out portions of tobacco that sold for a specified lesser amount of money.

Weighing Sugar. The participant had access to a two-pan scale suspended from the ceiling of the shop, metric weights, a tin of sugar, a cup for pouring, and three sealed bags of sugar. The participant was asked to weigh out the different specified amounts of sugar. The metric weights that were accessible required the placement of weights on the sugar pan as well as on the opposing pan in one of the three problems. The participant was also asked to determine the weight of three bags containing different amounts of sugar. Again, the solution to one of the three problems required weights to be placed on both scale pans and, in this case, subtracted from each other.

Cloth Measure Conversion. The participant had access to a meter measuring stick subdivided into centimeters and a bolt of cloth. The participant was told by the researcher/customer that he wanted to purchase 2 haat (forearm) lengths of the cloth. If the cloth cost 14 rupees a meter, how much would the cloth cost him.

Profit/Loss. The participant was presented with a series of five problem scenarios in which the shopkeeper's profit or loss needed to be determined or the profit set. The items involved in the profit/loss determination or profit setting were made accessible to the participant during the presentation of the problem scenarios.

Purchase Total/Change. The participant was presented with a series of four problems in which the researcher/customer requested a number of items for purchase. Each item had its price marked on it. The participant was told to ask the recording researcher the price if he has difficulty reading it. Once the participant had calculated and told the researcher/customer the total price, the customer/researcher gave the participant a predetermined amount of money from which the participant was asked to make change.

Unit/Subunit Pricing. The participant was presented with a series of four problems that entailed determining the price of item subunits based on the unit price and/or unit price based on the price of the subunits. The items involved in the unit or subunit pricing were made accessible to the participant during the presentation of the problem scenarios.

Studying Problems

The studying in school problems were presented in a room in a house next to the sites where the farming and shopkeeping problems were presented. The participant and the researchers sat in chairs around a table in the room, roughly approximating a school setting. The participant was presented with a blank pad of paper, several pencils, a box of dried corn, and a four page arithmetic test. The participant was asked to play the role of the student. One of the researchers played the role of teacher and presented the problems while the other researcher made an audio and written record. A lapel mike attached to the participant's shirt was used in making the audio records.

Initially, the test papers were handed to the participant and he was told to number and write the answer to each question on the blank pad of paper. He was also told that if there was anything he did not understand, the researcher would assist him. It was expected that many, but not all of the participants who had not attended school would have difficulty interpreting the pictures and the orthography which model those in school arithmetic textbooks and tests. Therefore a method of guided participation, similar to Campione and Brown's (1987) dynamic assessment method was used to provide informational clues of greater and greater specificity as needed by each participant. For example, "do problem number 1", "this is problem number 1 (point to)", "this is a plus sign", "the plus sign means add all of the bricks together", "how many bricks are there here all together (circle with finger)." This provided us with information about each participant's unassisted performance as well as what information was needed by the participant in order to solve the problem. At no point were the participants given a procedure or strategy by the researcher to solve a problem. This procedure did constitute a teaching intervention that could conceivably affect later arithmetic performance. However, we were more concerned with putting the participant at ease and not misrepresenting a participant's lack of knowledge about the institutional conventions of representing arithmetic problems in school as lack of calculation knowledge. Participants' later initial performances on studying tracking tasks suggested that this intervention had not had a lasting impact.

Each participant was told that we were more interested in the procedure by which he solved the problem than the correctness of this solution. He was asked to "talk his thoughts" while solving each problem so that the other researcher might record him. When it was unclear from the participant's thinking out loud what procedure was used, the interviewing researcher would ask the participant to describe after the fact how he generated the solution.

There were 30 arithmetic studying problems that fall into five categories: quantifying piles of bricks (4), adding, subtracting, multiplying, and dividing with pictures (4), determining fraction with pictures (3), addition, subtraction, multiplication, and division with orthography (16), measurement word problems (3). A brief description of each category of problem is given below. The categories of problems were presented to the participant in the order given above. A complete description of the problems is provided in Appendix I.

Quantifying Piles of Bricks. The participant was presented with three problems, each of which depicts several rectangular stacks of bricks that are separated by addition signs. The participant was expected to arrive at the total number of bricks.

Adding, Subtracting, Multiplying, and Dividing with Pictures. The participant was presented with four problems, each representing one of the four arithmetic operations. Each problem combined a standard orthographic representation of the problem side-by-side with a pictorial representation. The participant was expected to arrive at the solution to each problem.

Determining Fraction with Pictures. The participant was presented with three problems, each of which consisted of a circle divided into several equal parts with one or more parts shaded in. The participant was expected to state what portion of each circle is shaded.

Addition, Subtraction, Multiplication, and Division with Orthography. The participant was presented with sixteen arithmetic problems depicted using orthography. Each operation was represented in four of the problems. The participant was expected to solve each problem.

Measurement Word Problems. The participant was presented with three word problems in which the number of centimeters, milliliters, and grams in, respectively, a meter, a liter, and a kilogram was stated. This was followed by a request for the number of smaller units in a half or a quarter of the larger unit.

Participation in New Activities

The farming group consisting of 26 participants was subdivided into two groups of 13 participants each in preparation for the quasi-experimental phase of the study. The farmers were first paired according to similar ages. One member of each pair was then randomly assigned to one of the two apprenticeship groups (studying or shopkeeping) with the other member being assigned to the other group by default. Thus four groups were constructed: farmers to study in an adult education class (**farm-class**), farmers to be apprenticed to shopkeepers (**farm-shop**), farming/shopkeepers to study in an adult education class (**farm/shop-class**), farming/students to be apprenticed to shopkeepers (**farm/class-shop**).

Two constrained activities were established by the researcher for the purpose of this study: becoming a shopkeeper as an apprentice to a shopkeeper, becoming literate and numerate as a student in an adult education class. Each constrained activity is discussed in more detail below.

Shopkeeping

The shopkeeper who owned the largest shop in the village was chosen as the master shopkeeper to whom the farm/student-shop and farm-shop participants would be apprenticed. The 42 year old master had worked as a shopkeeper for 9 years and had completed 9th class in high school. He was chosen as master for several reasons.

1. He was widely considered to be the most experienced shopkeeper in Bherighat by the other shopkeepers.

2. We had detailed information regarding his arithmetic tools, strategies, and procedures as well as his shop and his life history from the focused ethnography.

3. He was representative of the Bherighat shopkeeping trend in that he had attended school and was working as a shopkeeper.

4. His arithmetic combined mental calculations, calculations with fingers, calculation using paper and pencil algorithms, and estimation, affording a repertoire that was flexibly adaptive to not only different shopkeeping practices, but also to apprentices with widely varying experiences with arithmetic.

5. His shop provided an extremely diverse range of goods: candies, spices, cloth, ready-made clothes, cooking utensils, soaps, biscuits, footwear, cigarettes, nails, toothpaste, kerosene, sugar, and many others. These goods required equally diverse measuring instruments: two pan scale, traditional volume measures, liter measures, his and the customers' body parts, meter stick.

6. He was willing to take on twenty-six apprentices over an extended period of time and maintain our research schedule.

The master's shop was located in the main bazaar area of Bherighat. The bazaar 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 foam rubber cushion next to a money box. The customers and apprentices sat or squatted on the floor around the shopkeeper.

Twenty-six of the apprentices from each experience group worked in the shop in 12 pairs with two apprentices working singly. Each pair were from the same experience group. A schedule was established whereby each pair of apprentices was able to spend two hours in the shop with the master shopkeeper every other day over a period of 32 days. This allowed each apprentice to spend 16 days and 32 hours learning from the master shopkeeper and assisting him with customers, less 3 to 5 hours time spent participating in tracking tasks outside the shop. The every other day schedule allowed for a missed day to be made up in all but two cases. When an apprentice missed a session he usually made up that session by sitting in with one of the apprentices working singly. The period of the day during which each apprentice was in the shop was changed twice during each 6 day period so that each worked during peak as well as "off" business times during this period.

The master shopkeeper agreed that the apprentices' training should model that of past apprentices he had trained, roughly following the sequence given below.

1. Introduction to item prices, various measuring instruments, making change, and item locations in the shop through didactics and assisting the master with customers by obtaining items.

2. Handling simple purchases from beginning to end and doing a portion of more complex purchases handled by the shopkeeper, particularly measuring items and doing measure to price conversions. The master explains and gives the apprentice practice in pricing items for a profit.

3. Handling more complex purchases from beginning to end, but with the master monitoring the apprentice's performance and the apprentice checking with the master. The master allows the apprentice to cut cloth for a customer under supervision. The apprentice begins to enter information in the shop records.

4. The apprentice handles even the more complex purchases on his own and is allowed to pass out cigarettes and order tea to "good customers." The master begins to discuss with the apprentice what types of customers should and should not be granted credit and how to negotiate with wholesalers, porters, and other shopkeepers.

However, this sequence was highly permeable in three ways. One, the apprentice always had the master's practice before him in it entirety, quite independent of the apprentice's point in the sequence, though the apprentice's ability to interpret the practice varied in part with his place in the sequence. 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 situations were simulated by the master if they did not occur through customers. Others were not or could not be simulated.

The master was not explicitly asked to deal with the farming and farming/student groups differently from one another. Rather, he was asked to train both groups so that they could function as shopkeepers in his shop. He had to address the two groups differently in order to achieve this, however. The fact that five of his apprentices (two farmers and three farming/students) later went on to open shops of their own was a credit to his training.

A researcher used a checklist to note the types of arithmetic practices each apprentice was involved in every third day, beginning with the first day and continuing throughout the 16 day apprenticeship for a total of 6 notations.

Studying

One of the 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 5 years as a primary school teacher and had run two adult literacy and numeracy programs. He was give the assignment of teaching the adult non-formal numeracy/literacy classes for the study as a result of his experience.

The 13 farmers and 13 farming/shopkeepers were randomly assigned to one of two classes so that each class had approximately the same number of farmers and farming/shopkeepers. Each class met for two hours every other day for 32 days. This allowed each student to spend 16 days and 32 hours learning in the classroom, less 3 to 5 hours time spent participating in tracking tasks during class time outside of the class. The every other day schedule allowed for a missed day to be made up in all but four cases.

The classes were held in the panchyat or 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. For cloudy days, two kerosene pressure lanterns were used to light the hall.

The course followed the standard Ministry of Education and Culture's curriculum for adult education in numeracy and literacy along with information about health and ecology. A series of five texts published by His Majesty's Government of Nepal were issued to each of the 26 students. The texts were combined textbooks and workbooks designed as part of the curriculum. The research assistant was told to largely ignore the teachers guide and structure the course like a normal school course. This was done for three 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. Three, most adult education teachers in Nepal are also school teachers. Without intensive training, practice, and different expectations on the part of the adult students, classroom teachers in Nepal are destined to teach adult education classes as they teach their classes in school. The research assistant was no exception.

Literacy and numeracy lessons alternated throughout the curriculum. Both were addressed during each class session. The arithmetic portion of the curriculum begins 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, single 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 combined pictures with numbers initially, followed by arithmetic problems depicted in the 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 instructor and the students followed the standard teacher question-student response (choral or individual)-instructor evaluation of response characteristic of most classrooms today (Cazden, 1986). This structure was used more in its rhetorical form, as a lecture, rather than as a form of involving and assessing students' progress. As the students progressed in the workbook sections of their texts at their seats, the teacher would assign additional arithmetic problems to those who completed a workbook section in advance of others and individually attend to those who were struggling with a particular lesson. As both classes contained students with a diverse range of backgrounds in arithmetic, the teacher gave several sets of homework adapted to the needs of different students.

The course was mastery-based. Therefore all who successfully completed all five texts were presented with a certificate. All 26 participants successfully completed the course.

The teacher's detailed lesson plans, notes on individual students, and record of all problems used in the class were used to document the classes. A researcher sat in on each of the two courses every three days and wrote a general description of the class and a paragraph describing each participant during that class. This began with the first day and continued throughout the 16 days of class for a total of 6 sets of notations.

Tracking During Participation in New Activities

Each participant was given a set of tracking tasks appropriate to the new activity (shopkeeping or studying in school) at four equally spaced intervals (day 8, 16, 24, and 32) over the course of the 32 days. The four sets of tasks appropriate to each activity were identical in form, but differed in respect to the numbers involved. The tasks were designed to trace continuities, discontinuities, and transformations in participants' arithmetic practices from their current activities to their new activity. Further, they were designed to get at the process of transfer over time and avoid having to infer transfer from what are assumed to be its products in the aftermath.

The tasks were presented in the second floor room of a house that was a two minute walk from both activity sites. The room contained two large straw mats in one corner on which the a researcher and a participant sat. A video camera on a tripod was placed in the opposite corner of the room with an autofocus lens centered on the area between, but including the two participants. A lapel microphone wired from the tape deck across the ceiling, and down the wall behind the participant was attached to the participant's collar with enough slack to give him free movement around the straw mats. The researcher had access to the tape deck controls and a small color monitor from his position on the straw mat. This allowed the researcher to control and monitor the video recording process during the task presentation. The video camera, deck, and monitor were run off of a bank of five rechargeable battery packs. The packs were recharged by gas-powered generator every night during the course of the tracking. Two hour half inch color VHS video tapes were used to record the tracking sessions. A time code in hours, minutes, seconds, and 30ths of a second was laid on the tape during the recording process.

The general procedure followed in presenting the tracking tasks was modeled on the procedure used for the initial assessment of arithmetic in school studying activity. The participant always had access to a pad of blank paper, several pencils, and a box of dried corn. He was asked to solve the problems in the way he felt most comfortable. He was told that we were more interested in the procedure by which he solved the problem than the correctness of this solution. He was asked to "talk his thoughts" while solving each problem so that the other researcher might record him. When it was unclear from the participant's thinking out loud what procedure was used, the interviewing researcher would ask the participant to describe after the fact how he generated the solution.

The participant was also told that if he could not solve a problem, the researcher would assist him. The method of guided participation proved so fruitful in providing additional information on the participant's arithmetic knowledge and skills during the initial assessment of arithmetic in school that it was decided to use the procedure for the tracking tasks as well. A general set of rules were used to structure the guided participation.

1. Pre-planned responses are given to requests for clarification on the part of the participants, e.g. "What does that sign mean?" or "Was that price for 1 or 10 of the candies?".

2. The researcher provides the next step in a procedure (process which involves a numeric transformation) if the participant indicates that he can not generate the next step, e.g. " I know the total cost of the bag of candies [20 per bag} is 2 rupees and one candy must therefore cost 20 pisa, but I do not know how figure the price of the candy if I want to make more money and sell the bag for 5 rupees."

   A. If the participant's initial procedure step can not possibly be used to arrive at a correct answer and the participant requests the next step, he is told that they will go on to the next problem.

   B. The participant must generate a step himself after the researcher has provided a step before the researcher can assist him with yet another step in the procedure. If the participant is unable to do this he is told that they will go on to the next problem.

3. The participant is told at the completion of his solution whether or not the solution is correct and is given the opportunity to work with the problem a second time through guided participation. If a correct solution is not arrived at on the second trial, the participant is told that they will go on to the next problem.

This procedure provided information about each participant's unassisted performance as well as what was needed by the participant in order to solve each problem. It defined the tracking tasks more as a learning opportunity than a testing procedure for the participants.

It can be argued that tracking procedures should not be confounded with the treatment in their effect on the learning and developmental phenomena that are being tracked, as we have done here. However, it can also be argued that any tracking procedure has at least the potential of altering the phenomena being studied and therefore represents an unresolvable confound. This study, however, assumes the opposite premise--that tracking procedures should model the treatment and in this sense become a part of learning arithmetic through shopkeeping or through schooling rather than standing apart from it. While learning on our tracking tasks can clearly differ in a number of ways from the learning and development of arithmetic practices in shopkeeping or school, it represents a compromise and paralleled many facets of learning and development in the activities of studying in school and shopkeeping. For example, where the researcher could provide several different but equally feasible next steps in a procedure, that which had been shown to be used most frequently by a school teacher or the master shopkeeper was the step provided.

Tracking Tasks for Farmers and Farmer/Students Participating in Shopkeeping

The participant sat on the straw mats facing the researcher. A number of shop items had been placed along the front of the mat toward the camera: items for purchase, a money box, a two pan scale suspended from the ceiling, a meter stick, a bag of sugar. The participant was presented with eight problems that fall into seven categories: purchase total/change (2), cloth measure conversion (1), profit/loss (1), weighing/pricing (1)*, creating a measurement standard (1), metric weight estimation (1)*, counting 3-D array of items (1)*. The categories of problems were presented to the participant in the order given above. A brief description of the categories of problems marked with an asterix is given below. Those not marked with an asterix have been described previously under the section on initial assessments. Of the initial assessment problem categories, only unit/subunit pricing and weighing sugar were not represented in the tracking tasks. These were combined in the weighing/pricing problem. The metric weight estimation and counting 3-D array of items problems are new. They were included as problems which require knowledge and skills relatively unique to shopkeeping. A complete description of the problems and the guided participation probes is provided in Appendix E.

Weighing/Pricing. The participant was told that the researcher/customer wanted a particular piece of iron from which to make a plow tip. Iron price is based on metric length units. The participant has access to the piece of iron chosen by the customer/researcher (weight unknown), a two pan scale with weights, and is given the price of one kilogram of iron. The participant must generate the price of the piece of iron.

Metric Weight Estimation. The participant was given a bag of sugar to heft and was asked to estimate it's metric weight.

Counting 3-D Array of Items. The participant was given a set of items symmetrically arrayed in three dimensions, i.e. the array was more than one item in length, width, and height. The items were fixed in the array and unmovable. The participant was asked to determine the total number of items in the array.

Tracking Tasks for Farmers and Farmer/Shopkeepers Participating in Studying

The participant sat on the straw mats facing the researcher. No objects other than the requisite paper, pen, and a box of dried corn were present on the straw mats. The researcher handed the participant a "test" paper on which the problems had been printed. The participant was told to number and write the answer to each problem on the blank pad of paper. The participant was presented with 24 problems that fell into three categories: quantifying piles of bricks (1), addition, subtraction, multiplication, and division with orthography (8), numeral writing/recognition and place value* (15). The categories of problems were presented to the participant in the order given above. A brief description of the problem category marked with an asterix is given below. Those not marked with an asterix have been described previously under the section on initial assessments. Of the initial assessment problem categories, adding, subtracting, multiplying, and dividing with pictures, determining fractions with pictures, and measurement word problems were not represented in the tracking tasks due to time limitations, potential duplication, and/or lack of affordances for change over time. The numeral writing/recognition and place value category was new and was included to track the participants' ability to write or, if writing was not possible, recognize numerals and the understanding of place value that is inherent in being able to recognize and/or write them. A complete description of the problems and the guided participation probes is provided in Appendix E.

Numeral Writing/Recognition and Place Value. The participant was asked to write a series of 15 numbers which were presented to him orally. If the participant could not begin to write the number he was shown a card with 30 numbers arrayed on it and was asked to pick the number out of the array. The 15 numbers ranged from one to five digits. Two of the numbers always contained one or two zeros in 10's, 100's or 1000's place.

VI. RESULTS OF FOCUSED ETHNOGRAPHIC AND DEMOGRAPHIC PHASES

The focused ethnography is divided into two parts. The first part is a diachronic description of farming, schooling, and shopkeeping as they relate to each other in Nepali society, the village, and arithmetic practices. The second is a synchronic description of current farming, schooling, and shopkeeping activities and associated arithmetic practices. The synchronic description is supplemented by information from the demographic surveys.

Diachronic Description

I will invoke three brief histories in the diachronic description: a history of education and work in Nepal, a history of school and work activities in Bherighat village, a history of Bherighat villagers moving between school and work activities. I do not claim that these histories are "History", as if they existed independent of this research effort. Rather, they are specific to my efforts and focus on different levels of change between school and work in Nepal that are relevant to arithmetic. These histories are not reducible to each other, they do not recapitulate each other, and they cannot be explained using a common principal. At the same time, each history does not exist independent of the others. As we will see, they afford each other certain possibilities. (See Vygotsky, 1962; Scribner, 1985; Seddon, Blaikie, & Cameron, 1981 for elaborated discussions of history along these lines)

Education and Work in Nepali Society

Subsistence agriculture has been the primary mode of work and the economic base in Nepal for over a thousand years. A long tradition of Vedic and Buddhist education has existed at least as far back as the first or second century A.D. during the Licchavi period. However, learning marked as schooling in the European and North American vein occurred in a wide variety of restricted forms during the Rana period in Nepal form the mid-1800's to the mid-1900's (Sharma,1990). All of these, however, were "pedagogies for the select" of one form or another and did not take on the character of an education movement within Nepali society as a whole. The Ranas did, however, experience difficulties in their attempts to limit public access to education. This was due in part to outside pressure from India and Great Britain and the perceived internal alignment of public education with opposition to the Rana oligarchy. With the Ranas overthrow in the early 1950's by the Shahs, the current royal family, the development and institutionalization of national public education rapidly took place.

Until the 1950's schooling's prime function had been seen as elevating its students in social or religious status--not necessarily preparing them for work. With the institutionalization of public education came official goals of public education. These were directed toward preparing citizens to meet national needs for improved agriculture and technical skills, among other things (Aryal, 1970). There has been some degree of meshing between educational background and work in the urban sections of the Kingdom. This is due in large part to a significant percentage of urban students continuing on to higher education and the availability of urban clerical and technical jobs (Manandhar, 1987).

This has not, however, been the case for the majority of Nepal's populace which is rural. Most rural students do not pass their school leaving exams at the end of high school (IEES, 1989). Of the rural students who studied beyond the primary level in 1970, an estimate from government figures (HMG, 1984) suggests that only 5-6 percent successfully completed 10th class and their School Leaving exams. Without a School Leaving Certificate their education generally does not facilitate access to non-agricultural jobs within or beyond the villages. Therefore the prime livelihood for most of these former students remains agriculture--producing largely for their own consumption. Simultaneous with the expansion of public education and a decline in indigenous manufacturing, there was an expansion of small business enterprises in the villages, particularly repair facilities for imported goods, and retail shops (Blaike, Cameron, & Seddon, 1978). These enterprises, initially entered into by villagers with little or no formal education, are now being entered with increasing frequency by former students. Most of this 'informal sector' remains at the marginal or subsistence level and serves as a supplement to agricultural work rather than generating major capital accumulation. However, a survey we carried out in one district indicated that among those small business enterprises that operated beyond the subsistence level, a large majority were run by villagers with some degree of formal education. The reverse was true among those small business enterprises that operated at the subsistence level.

These developments in education and work at the national level were not a sum or an average of the changes that were occurring within Nepal's villages. Rather, they were directly intertwined with economic and political changes within Kathmandu Valley and beyond Nepal's borders as well as changes in the rural areas. Villages underwent their own more local changes in education and work, through they were shaped by the institution of public schooling and informal sector enterprises.

School and Work Activities in Bherighat

Bherighat is currently located in a middle hills valley in Western Nepal. It was located high on a hillside facing the valley until the eradication of malaria in the early 1960's. In 1948 Mohan Shamsher, a Rana Prime Minister, granted Bherighat a charter to open a school and provided 500 rupees annually for the salary of a teacher hired from India. The school was held in a villager's house with 10 to 15 students attending at any given point. The teacher taught math using a combination of Sanskrit and "English" systems. English was requested by a number of the villagers who had served in the British Gurkha regiments.

Tulo Barna Malla math was derived from Sanskrit instruction and involved a mixture of devnagri numerals and tallys. It was ideally adapted for shopkeeping because the tallys referred directly to anna (using the 16 anna equals 1 rupee system in force at the time) and paisa. There were no shops in the hillside village, however. Rather, each family made an annual trading trip to India for supplies. This form of math remained confined to the classroom as a result. The second system of math taught in the class involved the use of Hindu-Arabic numerals and the basic math algorithms for the four operations familiar to all of us. This form of math did not lend itself to a particular function or set of units, unlike Tulo Barna Malla math. However, its social status in Bherighat was above that of the Sanskrit-derived numeracy, due in large part to its British origins.

During this same period of time the general populace of Bherighat had few encounters with the math taught in these classes. Farming math involved the use of three different sets of devices, each with its own set of procedures. Seeds and stones carried in a pouch were used to establish one-to-one correspondences with livestock. This functioned as a means of detecting missing livestock without requiring full knowledge of numerical values. Some villagers used stones independent of livestock to quantify increasing amounts (addition and multiplication in our terms) and decreasing amounts (subtraction and division in our terms) using different forms of counting. Finger counting was used across a wide variety of situations to quantify increasing and decreasing amounts as long as the amounts did not have to be grouped or regrouped into subquantities (as in multiplication and division). Finger counting was not useful for dealing with the larger quantities, though it was not limited to a quantity of 10 as the joints and tips of the fingers were usually counted rather than the fingers themselves. A tally system was used exclusively for monetary transactions and was based on various subdivisions of the 20 rupee currency note, the largest available at that time. For record purposes, one bisa (bis meaning twenty) received the longest tally, a half bisa tally (10 rupees) was half the length of the bisa tally, etc. down to a one rupee tally. Unlike stones and fingers, the written tallys provided a relatively durable record of quantity. Interviews with elders in Bherighat today suggest that many of the math calculations performed without the aid of these devices during this period followed mental procedures similar to the procedures used with the devices. We do not know whether other math procedures unique to mental calculation were used.

With the eradication of malaria, the villagers gradually shifted from the hillside to the valley, a location they had previously only visited during the day for farming. In 1960 the first primary school was established in the valley as part of the national system of education. This was followed by a lower secondary school in 1969 and an upper secondary school in 1974. Three additional primary schools were functioning in Bherighat by 1988.

During this time increasing percentages of village children attended primary school where arithmetic was taught using devnagri numerals and column algorithms for the four basic operations. Devnagri and their hindu-arabic equivalents are as follows:

(0) (1) (2) (3) (4) (5) (6) (7) (8) (9) (10).

By 1988 over 900 students were enrolled in the Bherighat schools. Math facts were learned by the collective chanting of math problems and answers from textbook tables. Finger counting was discouraged while teacher-student discourse on math followed the pattern of teacher asking question, student(s) answering question, and teacher evaluating answer (Cazden, 1984): a pattern of classroom discourse common to most of the subjects taught in the schools. Algebra and geometry were introduced at the secondary level in addition to arithmetic. Beginning with the lower secondary level, all math was carried out using Hindu-Arabic rather than devnagri numerals.

One or two chapters in each class's arithmetic textbook were devoted to learning metric measures. Only the earliest math textbooks made reference to the non-metric measures such as maana and dharni more commonly used in Bherighat. Next to English, mathematics was consider to be the most difficult subject by a majority of the secondary school students. Their test results bore this out. In 1987 roughly 40 percent of the village's 5th grade primary students did not continue their schooling. In the same year only 20 percent of the 10th grade students passed their school leaving exams. Most who did not pass were in the village workforce in 1988.

Shopkeeping followed the expansion of public education in Bherighat. This was not a coincidence. Paying children's school tuition and purchasing textbooks at the upper grades, purchasing school supplies, and removal of their children from the home workforce were often cited by farmers as creating an increased need for cash income. Agriculture held little cash-generating potential for most of the farmers whereas shopkeeping directly generated a cash income. A number of students from neighboring villages boarded in Bherighat while attending its schools. These students created an expanded market for many items not readily available from the villagers' homes such as soap, cigarettes, and biscuits. Given such ties with schooling, it is not surprising that the first two shops in Bherighat opened on the perimeter of the primary school compound in 1969, selling tea, sweets, notebooks, and pencils to the students. Since that time the number of general retail shops, tea shops, medical halls, and repair services in Bherighat has increased to over 40 in 1988.

Farming activity and associated arithmetic practices have remained relatively stable since the early 1900's when compared with school and shopkeeping activities and remains the principle work activity for most Bherighat villagers. While cattle drawn-plows rather than the hoe-like kodalo are used to till the soil, hybrid seeds along with fertilizer are used on occasion, and cash cropping has increased slightly, a majority of the farming activity in Bherighat remains at the subsistence level, using the techniques of previous generations.

Records of grain yields and household finances are kept using written numerals and school-based arithmetic calculations for the first time by a few Bherighat families. These families have had children who have attended school and generally are above average in the level and diversity of their economic resources. Metric units of measure began to be used in farming in the mid 1980's. In 1988 metric measures were used in calculating the cost of husking grain because of the introduction of several kerosene-powered mills into the village and in selling grain and meat beyond the village. A number of conflicts were observed in the process of converting from traditional grain measures which invoke volume to metric measures which invoke weight. For example, two farmers would bring their rice to be husked at the mill. Each of their quantities were equal by volume. When it came time to charge the farmers on the basis of number of kilograms husked, one farmer would be charged considerably more than the other because the water content and therefore the weight of the rice often varied even though the volumes were identical. With these exceptions, however, traditional forms of measurement continued to be used in farming practices, even by those who had attained some level of schooling.

The recent changes in shopkeeping and the increased accessibility of schooling have created a number of ties between schooling and shopkeeping activities and between shopkeeping and farming in Bherighat. Students and teachers rely on the shops for supplies and many of the newer shops are being opened by former students. Farmers have come to rely on the shops for kitchen utensils, spices, staples, and cloth rather than making annual or biannual trips to India or southern Nepal. All of the shopkeepers are also farmers or have farmed in the past. The shops also serve as a social gathering point for villagers.

Shopkeeping has come to be not so much a bridging activity between schooling and farming, but an activity that exists by virtue of it ability to serve the economic needs of both schooling and farming. These ties are reflected in the broad repertoire of math procedures used in most of the shops today. Conversions between non-metric measures used in farming and metric measures taught in school are common. Calculations often combine finger counting, written notation using column algorithms, and mental strategies which reflect both counting and column strategies. In addition, a number of mental strategies specific to shopkeeping have been developed.

At the same time, the relative stability of farming practices in the village and a view of schooling as a way out of farming as a livelihood has resulted in few direct ties being formed between farming and schooling. This is in spite of the fact that nearly all the teachers and students participate in some form of farming activity.

Generations of Bherighat Villagers Moving Between School and Work

Unlike shopkeeping and schooling, farming was at the very core of what constituted life in Bherighat and continues to occupy a central role in the lives of the villagers. Prior to the existence of schools and shops in Bherighat, children became adolescents who became adults continuous with the activity of farming. With the exception of the few Bherighat adolescents who were able to enlist in a military service, individual development across the lifespan and participation in farming were continuous.

When schools began to play a prominent role in village life, farming became what many students wanted to avoid as an occupation once they graduated from high school. Farming was participated in by all generations within the extended family. Therefore schools created the first village social groups defined within a narrow range of ages across families. Students who currently graduate from the upper secondary school retain their similar age group beyond the school through the establishment of local "clubs" for socializing, political activities, and village development work.

A majority of the students who either graduate from or drop out of primary, lower secondary, and upper secondary schools continue on in agriculture. This has been true since the inception of schooling in Bherighat. A small number of students enter the military, travel to India to work as day laborers and, among those who graduate from high school, go on to higher education. Most secondary school students do not graduate from the upper secondary school, however. Of those who do graduate few continue on to higher education due to economic constraints. Having spent a minimum of 10 years attending school, many of these students do not want to return to full time agriculture, something that they would be doing even if they had not attended school. The recent expansion of shopkeeping in Bherighat has provided alternative employment for a number former students and increasing numbers of secondary school students have chosen to become shopkeepers, either as their primary livelihood or as a supplement to farming.

Many of the Bherighat elders, born into a generation that experienced farming as its primary activity across the lifespan, recall that their estimation of crop yields, calculations with fingers, stones, and tallys, and measurements were once called "*hisaab*" or mathematics" before the introduction of schools to the village. In 1988 these same elders considered their estimations, calculations, and measurements to be "*andaaji*" or "guestimation" and *hisaab* to be something that one learns in school and something that is done with writing. Students often refer to the latter as "*lato hisaab*" or "dumb math." Not only the status, but the very definition of what constitutes "true" mathematics has shifted from farming to schooling practices over the time since schools were first introduced to Bherighat.

Many of the older Bherighat farmers rely on their sons and daughters who have attended school to keep family financial records, the records relatively recent innovation in family economics in Bherighat. Some have learned to read and write numerals and in some cases do paper and pencil arithmetic calculations from their sons and daughters. This generational reversal of traditional teacher-learner roles is something that often occurs during times of rapid societal change (Mead, 1978). In the last decade adult education classes in literacy and numeracy sponsored by the Ministry of Education and Culture and the district education office have been offered in Bherighat on five separate occasions with an estimated total attendance to completion of 40-50 farmers.

With the advent of shopkeeping in the village, shopkeepers' sons and brothers and occasionally their wives initially assisted in running the shops in Bherighat. These same relatives opened most of the new village shops during the 1970's. Most shopkeepers during this period had little or no formal schooling and viewed shopkeeping as a supplement to farming. Relying on tallys, fingers, and elaborate but rapid mental calculations they marked up prices, totaled items, calculated change, and made conversions between units of measure and price. Some of their math procedures were expansions of those they used in farming. Others were specific to shopkeeping. The size of most of these shops and the diversity of their stock was limited, however.

During the last decade a series of changes afforded the incorporation of written notation and column algorithms into the already broad repertoire of math procedures used by those who began shopkeeping in the previous two decades. The first change was that of the 100 rupee note becoming the common high value note in Bherighat, replacing the 20. This rendered the bisa system of quantifying price less wieldly than a 100 rupee-based system that was directly translatable into column values. Second, a roadhead to the Terai and India was opened within walking distance of Bherighat. This allowed a more diverse range of goods to be stocked by the shops. Some of these items, such as cloth, required new forms of calculation that lent themselves to column algorithms. Third, prices increased as did the size of the purchases made by villagers. The resulting general increase in the size and quantity of numbers used in calculations strained some shopkeepers' existing calculation techniques. Column algorithms could, in theory, be applied to any size and quantity of numbers. Last, His Majesty's Government ordered that all applicable shop items be priced in metric units. The metric system takes full advantage of the base 10 system with respect to defining its units. Therefore column algorithms are easily applied to calculations involving translations of metric quantities into price. The same is not true for many of the non-metric systems. For example gaj, a measure of length, is divided into 9 equal segments.

Some of the first generation shopkeepers learned to read and write numerals and perform calculations on paper using column algorithms from their sons and daughters who had attended school. Many openly expressed the belief that the calculations they could perform mentally, with their fingers, with stones, and with tallys were necessary but not sufficient if they wished to expand the size of their shops and the variety of items they carried. Because of this, what they learned from their sons and daughters was not “school arithmetic”, but rather that which was directly applicable to shopkeeping. For example, most learned to read and write numerals, some learned to use numerals as a mnemonic for their existing calculations, others learned to use numerals with standard column algorithms, and none learned to write or recognize the signs for the four operations. Addition, subtraction, multiplication, and division signs are superfluous when the arithmetic flows out of a non-arithmetic structure such as a customer purchase, something which is basically an economic exchange.

Over the last decade a number of these shopkeepers have taken advantage of the adult education classes in literacy and numeracy offered in Bherighat on five separate occasions with an estimated total attendance to completion of 10-15 shopkeepers.

Most Bherighat shops opened during the latter half of the 1980's were opened by former students who had not passed their school leaving exams or had never attempted them. Unlike new shopkeepers during previous decades, former students were usually the first member of their families to attempt shopkeeping. They initially approached math in the shops using column algorithms and written notation and gradually appeared to acquire a wider repertoire of mental calculation strategies, some specific to shopkeeping. This is approximately the reverse of the path of math acquisition followed by the previous two decades of Bherighat shopkeepers who have only recently acquired written notation and column algorithm procedures.

Figures 7 and 8 below depict the hetrochronicity of the histories of farming schooling and shopkeeping activities in Bherighat in relation to the heterochronicity of the lives of farmers, students, and shopkeepers participating in this study.

Figure 7

Heterochronicity of Activities in the Village

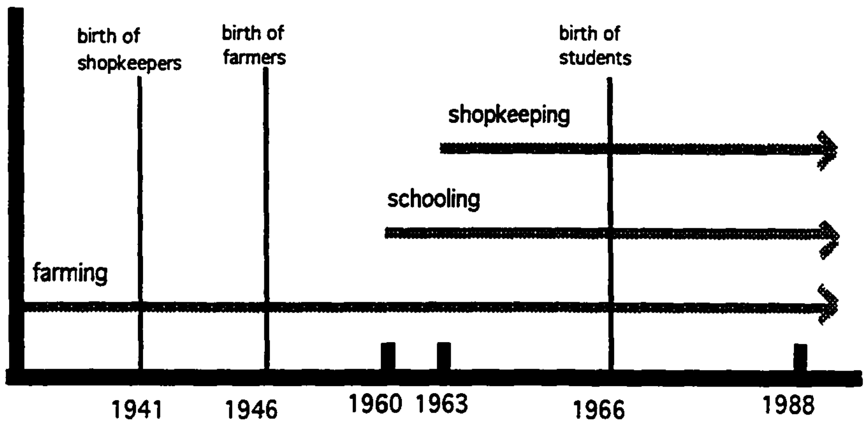
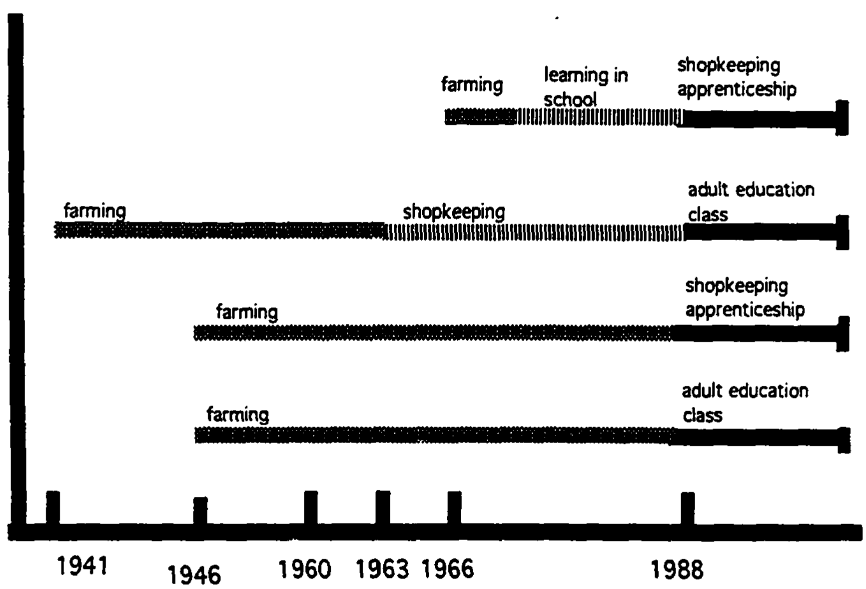


Figure 8

Heterochronicity of Students', Shopkeepers', and Farmers' Lives in Relation to Leading Activities and Interventions



Synchronic Descriptions

In this section I will provide a general description of current farming, schooling, and shopkeeping activities in Bherighat and the arithmetic practices embedded in them. Data from the demographic surveys will be used to compliment the ethnographic description.

Farming

In a very real sense, farming is life in Bherighat. Though it is considered work, or kaam, it permeates nearly every facet of the life of the Bherighat villager. The village shifted from the surrounding hills to the valley floor with the eradication of malaria so that the villagers could live beside and expand their fields. Approximately 75 percent of the valley floor is currently under cultivation. The schedule of classes in the schools and the shopkeepers' schedules are organized around the various planting seasons in the village, as are many of the Hindu festivals celebrated in the Bherighat. Virtually all villagers participate directly in farming activity or indirectly through the supervision of others. While most of Bherighat agriculture continues at the subsistence level, not very different from the way it has existed in rural Nepal for centuries, there has been a steady increase in the amount of rice, corn and wheat crop yield sold outside the village to various wholesale gain outlets. This is not cash cropping in the sense of commercial farming, but rather reflects the increasing surplus of grain produced by some families. Table 3 displays the basic demographic characteristics of the 73 farmers included in the demographic sample. All of the farmers included in the demographic sample are male, none have attended school, and none have worked in a shop.

Table 3

General Characteristics of Farmers: Demographic Samples

Informant Characteristics	Farmers n = 73	
	Mean	(SD)
Age (yrs.)	38.7	(12.5)
Farming Experience (yrs.)	29.4	(8.9)
Shopkeeping Experience (yrs.)	0	
Schooling Experience (yrs.)	0	
Size of Family	7.5	(3.0)
Size of School-Age Family	4.1	(2.4)
Education of School-Age Family Members (yrs.)	1.8	(2.2)
Education of Male School-Age Family Members (yrs.)	4.8	(3.1)
Education of Female School-Age Family Members (yrs.)	1.5	(2.3)

Table 4 displays the principal agricultural yields for farmers' (involved only in farming), shopkeepers' (involved in farming and shopkeeping), and high

Table 4

Agricultural Yields of Informants' Households: Demographic Samples

Agricultural Yields	Farmers n = 73	Shopkeepers n = 47	Students n = 84
Wheat (in pathi)			
mean (sd)	82.8 (62.4)	76.6 (60.8)	130.1 (82.4)
purchase %	27.4	38.3	16.7
sell %	8.2	0	4.8
sufficient %	64.4	61.7	88.5
Rice (in pathi)			
mean (sd)	325.1 (285.8)	219.6 (182.3)	498.6 (218.8)
purchase %	16.4	23.4	8.3
sell %	23.3	2.1	7.1
sufficient %	56.0	74.3	84.6
Corn (in pathi)			
mean (sd)	88.3 (62.1)	71.6 (60.4)	126.0 (71.9)
purchase %	15.1	25.5	9.5
sell %	15.1	4.3	7.1
sufficient %	69.8	70.2	83.4
Chickens			
mean (sd)	10.2 (15.8)	8.0 (9.0)	14.1 (16.6)
purchase %	8.2	23.4	7.1
sell %	4.1	2.1	0
sufficient %	87.7	72.3	92.9
Goats			
mean (sd)	2.1 (4.2)	1.9 (2.9)	2.2 (4.0)
purchase %	2.7	25.5	0
sell %	8.2	0	5.9
sufficient %	89.1	74.5	94.1
Pigs			
mean (sd)	1.2 (1.9)	1.5 (2.2)	2.6 (3.3)
purchase %	12.3	6.4	11.9
sell %	2.7	0	2.4
sufficient %	85.0	93.6	85.7

school students' (involved in farming and schooling) households included in the demographic survey. Students clearly reside in households in which the grain yields are higher, both overall and in terms of sufficiency for the household, than those of farmers and shopkeepers who have no students in high school. Shopkeepers' households have a somewhat lower overall agricultural yield than those of full time farmers, but are relatively equivalent in terms of the sufficiency of their yields for their households.

These figures suggest that there is a positive relationship between the agricultural wealth of a household and whether they have children attending secondary school. The lower overall agricultural yield for shopkeepers than for full time farmers fits with shopkeepers' reports of using cash income from their shops to supplement their agricultural income. Shopkeepers also tend to have smaller families than full time farmers (see Table 1 in chapter II) and they may have used their shop income in making their judgments of agricultural

Because of its permeation of village life, the boundaries of what constitutes farming activity are more difficult to define and are far more permeable than those of school-studying and shopkeeping activity. The following parameters are used to provide a set of "working boundaries" for farming activity in Bherighat and have the advantage of allowing comparison with the activity parameters of school-studying and shopkeeping.

Motive and Object. The primary motive for farming in Bherighat is to produce food that is at least sufficient for the nutritional needs of the extended family, with the object of the activity being nutritional sustenance. More recently, a secondary motive of producing food for sale with cash accumulation as its object has begun to appear and operate in conjunction with the primary motive. Rice, wheat, corn, and lentils are the predominant crops with mustard, vegetables, and soybeans being cultivated on occasion and in smaller quantities. Rice is the primary food staple in the village and therefore is considered to be the most important crop. Banana, lime, mango, and papaya are grown, though not by all households. Similarly, some, but not all households raise chickens, goats, cattle, pigs, and/or water buffalo.

Spatial Location. Most farming activity, such as rebuilding terraces, irrigating, plowing, planting, weeding, fertilizing, and harvesting takes places in the family's fields, some of which are usually adjacent to their house. Other fields owned by the family may be located as much as an hour's walk from the home. Additional aspects of farming activity, such as constructing plows, making rope, and storing grain take place in and around the family home and compound. Last, family members may work in the fields of neighbors' who have, in turn, helped them in their fields on a cooperative basis.

Temporal Location. The yearly work cycle for farmers is marked by the planting and harvesting of crops which is in turn set by the weather. The sequence that follows begins with the Nepali New Year (mid-March on our Greco-Roman calendar). The overall timing of the sequence can vary, as can the planting of secondary crops such as mustard. However, the sequence of corn followed by rice followed by wheat is invariant. Other farming practices are

interspersed around the planting-harvest cycle.

1. plant corn
2. plant dry and/or wet rice in nursery
3. harvest corn
4. transplant wet rice from nursery
5. plant lentils
6. plant mustard
7. harvest dry and/or wet rice
8. plant wheat
9. harvest mustard
10. harvest lentils
11. harvest wheat

The daily cycle of life for farmers during a planting or harvest period can be characterized as follows. Note that this is a characterization based on an average day in the life of a farmer and, as such, does not reflect the variance in their daily lives.

1. wake up
2. attend to toilet
3. do farming chores
4. eat morning meal
5. do farming work throughout the day with a break for snack
6. eat evening meal
7. talk with family and friends
8. go to sleep

Persons Involved. Farming is done in collaboration first, with other members of the household, followed by relatives in other households, and neighbors with whom there is a reciprocity agreement to work in their fields. Only a small minority of households in Bherighat currently hire outside workers for their fields. Literally all family members take part in farming, though the type of work is segregated by age and gender. For example, toddlers will usually be left to play around the area where the rice is being thrashed, and are occasionally told and shown by older family members how to collect bits of grain that have been thrown away for the central thrashing area. Men and not women will plow the fields. Women, and usually not men will transplant the wet rice from the nursery to the field.

The caste of the persons involved in farming varies widely as shown in Table 5 below in relation to those involved in shopkeeping and studying in school in addition to farming. The distribution generally reflects the overall distribution of caste group membership in Bherighat. The one exception to this is the over representation of *Bahaun* or Brahman members in shopkeeping and its under representation in farming.

Artifacts Involved. A large number of metal, wooden, and rope farming implements are either constructed by the family or are purchased from other families who specialize in making these implements. Those which are archetypal of farming are the wooden plow (with metal tip) or hulo pulled by cattle, the kadalo or hoe, the kok or rake, the hasia which is a curved scythe-like knife carried in a wooden holder, the doko which is a woven bamboo basket, and the naamlo which is the trump line used to carry the basket.

Practices Involved. The typical recurrent practices involved in farming are planting fields, harvesting fields, plowing fields, irrigating fields, tending fields, watering and feeding animals, and making and maintaining implements.

Table 5

Caste Characteristics of Informants: Demographic Samples

Caste Characteristics	Farmers n = 73		Shopkeepers n = 47		Students n = 84	
	f	%	f	%	f	%
Gurung	11	15.1	6	12.8	17	20.1
Magar	34	46.6	15	31.9	35	41.7
Bahaun	6	8.2	10	21.3	9	10.8
Chetri	13	17.8	6	12.8	11	13.2
Sunar	2	2.7	1	2.1	2	2.4
Sarki	0	0	1	2.1	1	1.1
Damai	2	2.7	1	2.1	1	1.1
Thakali	1	1.4	0	0	2	2.4
Thakuri	0	0	2	4.3	2	2.4
Newar	0	0	1	2.1	1	1.1
Kaami	3	4.1	3	6.4	1	1.1
Kumal	0	0	1	2.1	0	0
Giri	1	1.4	0	0	2	2.4

Knowledge and Skills Involved. The general categories of knowledge and skill most often cited by farmers are knowing when to plant and harvest, knowing how to prepare the fields for irrigation, knowing how to use the plow and hoe, and knowing how to get rid of various plant diseases and pests. The categories of knowledge are fairly isomorphic with types of practice.

Bherighat children's entrance to becoming farmers begins with their sitting in the fields while their older family members work. By two or three years of age boys are expected to "play" at farming by collecting errant bits of grain, pretending to pick vegetables, thrashing a few stalks of gain by walking on it, and the like. The children often do this spontaneously and are praised by the older family members. Occasionally a family member will direct them to play at farming as well. Four to six year old boys are frequently given small-scale farming tasks to do such as carrying water, cutting grass, planting seeds, carrying small baskets of grain, sheparding animals, and transplanting rice seedlings. These practices are critiqued and commented on by the older family members and are occasionally corrected through demonstration. Seven to eight year old boys continue these practices with more autonomy and begin practicing with a plow pulled by a pair of cattle. This is often accompanied by much laughter as well as direction, criticism and demonstration. A ten to twelve year old boy is expected to be able to plow and level fields with a fair degree of skill and by the time he reaches fifteen or sixteen is generally considered to be able to work as an adult farmer. This does not mean that his knowledge and skills at farming are considered equivalent to those of the elder family members. Rather, the adolescent can function as an adult male in farming activity while drawing on the knowledge of farming distributed among his family members (cf. Hutchins, in preparation).

Becoming a full participant in farming activity is generally accomplished through observation, demonstration, practice, and critique with more experienced members of the extend family. Written materials and hypothetical scenarios designed for instruction have little or no role to play in this process and eventual mastery of the practices are assumed.

Arithmetic embedded as a part of farming activity is rarely referred to as "math" or hisaab. More commonly it is called andaaji or "guesstimation", even if it involves precise calculations. All farming arithmetic that we were able to observe involved one or more forms of measurement.

Figure 9 displays the different forms of measures currently and/or previously in use in Bherighat. Many have their origins in farming while others have arisen from shopkeeping and school practices. Most forms of measurement with origins in farming historically predate those with origins in shopkeeping of schooling. However, a comparison of the "source" and "use now" categories reveals that a number of measurement forms with agricultural origins are currently used in shopkeeping and conversely, some forms that originated in shopkeeping and schooling are now used in farming.

The activity of farming is clearly permeable to forms of measurement

Figure 9

Measures Presently and/or Previously Used in Farming, Shopkeeping and Schooling in Bherighat

MEASURE	DIMENSION	CONTENTS	SUBUNITS	DEVICE	USE NOW	SOURCE	CONVERSIONS
muri paathi maanaa	dry volume	grains lentils flour vegetables	yes	metal container	farming shopkeeping	farming	kilo,muthi mato muri, ropani, quintal dalo
dalo	dry volume	grains lentils flour vegetables	no	basket	farming	farming	doko, paathi
doko	dry volume	grains flour vegetables	no	basket	farming	farming	dalo, muri
haate maanaa	dry volume	small seeds	no	small hollows between thumb and wrist	none	farming	none
kuruwa	wet and dry volume	all liquids peanuts	no	metal jug	farming shopkeeping	shopkeeping	liter, glass haap
liter	wet volume	all liquids	no	metal jug	schooling shopkeeping	schooling	kuruwa, haap
drum kantar chauthai haap	wet volume	oil, gas butter	yes	metal tin	farming shopkeeping	shopkeeping	liter, kuruwa
passo	wet volume	water, oil	no	cupped hand	none	farming	none
muthi	dry volume	grains, lentils, flour, sugar, salt, spices, tobacco	no	closed hand	farming shopkeeping	farming	maanaa, glass

Figure 9 (cont.)

Measures Presently and/or Previously Used in Farming, Shopkeeping and Schooling in Bherighat

MEASURE	DIMENSION	CONTENTS	SUBUNITS	DEVICE	USE NOW	SOURCE	CONVERSIONS
chimti	dry volume	salt sugar spices	no	between thub and two fingers	farming shopkeeping	farming	none
glass	dry and wet volume	tea peanuts sugar spices	no	glass	shopkeeping	shopkeeping	kuruwa, muthi
chamchha shopkeeping	dry volume	sugar	no	spoon	farming	shopkeeping	none
khal	dry volume	corn ears	no	suli (corn rack) divisions	farming	farming	doko, kattha
maan ser chhatak	weight	grains lentils flour vegetables	yes	two pan scale	none	farming	none
quintal number	weight	grains lentils potatoes sugar, salt cement	yes	metal container and two pan scale	shopkeeping farming	shopkeeping	kilo
gram kilo	weight	all dry items and butter	yes	two pan scale	shopkeeping schooling	schooling	paathi, quintal, dharni, tola
dharni bisoli ser pul paau	weight	raw meat and butter	yes	one and two pan scales	farming shopkeeping	farming	kilo

Figure 9 (cont.)

Measures Presently and/or Previously Used in Farming, Shopkeeping and Schooling in Bherighat

MEASURE	DIMENSION	CONTENTS	SUBUNITS	DEVICE	USE NOW	SOURCE	CONVERSIONS
tolaa aathanni chawanni lal	weight	precious metals, spices, hashish	yes	two pan scale	shopkeeping	shopkeeping	none
kattha bighaa dhur	area	land	yes	rope or chain	farming	farming	ropani, anna, muri
ropani anna paisa dam	area	land	yes	rope or chain	none	farming	kattha, bighaa, muri
hectare	area	land	no	survey transit	none	school	none
hula pata	area	land	no	takes one day to plow with two bulls	none	farming	none
hula kodala	area	land	no	takes one day for man to hoe	none	farming	none
mato muri	area	land	no	volume of dirt skimmed off surface and measured in muri container	none	farming	kattha bighaa
inch foot	length	wood	yes	rope ruler	farming	farming	haat, bittha
gaz gira	length	cloth	yes	ruler	none	shopkeeping	haat, bittha

Figure 9 (cont.)

Measures Presently and/or Previously Used in Farming, Shopkeeping and Schooling in Bherighat

MEASURE	DIMENSION	CONTENTS	SUBUNITS	DEVICE	USE NOW	SOURCE	CONVERSIONS
meter centimeter	length	cloth	yes	ruler	schooling shopkeeping	schooling	haat, bittha
pura haat (or haat)	length	cloth wood	yes	elbow to tips of fingers	farming shopkeeping	farming	foot, gaz, bittha, meter
muthi haat				elbow to end of closed fist			
bitta	length	wood cloth planting	no	thumb to little finger of spread hand	farming shopkeeping	farming	haat, aaunla, foot, gaz
kuret	length	wood cloth planting	no	thumb to index finger of spread hand	farming	farming	none
aaunla	length	wood cloth planting	no	width of finger	farming shopkeeping	farming	bittha
kadam	length	land	no	stride	farming	farming	kattha, janjir
paila	length	land	no	heel to toe	none	farming	kattha janjir
janjir	length	land	no	chain	none	farming	kattha, ropani, kadam, paila
chaak	amount	food	no	amount a person would normally eat	farming	farming	maana, muthi

Figure 9 (cont.)

Measures Presently and/or Previously Used in Farming, Shopkeeping and Schooling in Bherighat

MEASURE	DIMENSION	CONTENTS	SUBUNITS	DEVICE	USE NOW	SOURCE	CONVERSIONS
plate	amount	cooked food	no	amount on a small metal plate	shopkeeping	shopkeeping	rupees, dharni
kilometer	distance	travel	no	estimate	farming shopkeeping schooling	schooling	ghanta
kosh	distance	travel	no	estimate	none	farming	ghanta
chillum	distance	travel	no	time it takes to smoke one pipe load	none	farming	none
bisauna	distance	travel with load	no	distance carried until rest	none	farming	none
second minute ghanta din hapta mahina saal/barsa shatabdi	time	all time	yes	watch, calendar, patro, sun position	farming schooling shopkeeping	indeter.	kosh, kilometer ghardi pala
ghardi pala din	time	birth, marriage, planting	yes	bowel with small hole and water-filled basin	none	farming religious practice	ghanta, din
rupee mohar sukha paina anna (obsolete)	money	all capital	yes	bill coin	farming schooling shopkeeping	indeter.	most measures
paana tau deb kori jistha rim	quantity	paper	yes	none	shopkeeping	shopkeeping	rupees

Figure 9 (cont.)

Measures Presently and/or Previously Used in Farming, Shopkeeping, and Schooling in Bherighat

MEASURE	DIMENSION	CONTENTS	SUBUNITS	DEVICE	USE NOW	SOURCE	CONVERSIONS
kori	quantity	rope	no	number of loops	shopkeeping	shopkeeping	rupees

originating in other activities, as farming measures permeate shopkeeping. Schooling remain relatively impermeable to measurement forms from other activities.

The demographic data displayed in Table 6 describe individual farmers', shopkeepers', and students' reported use of different measurement forms during their participation in farming activity. It supports, with some modification, the previous discussion of the permeability of farming activity by forms of measurement from other activities. Farmers reported using metric measures with some degree of frequency for weight and for volume, but rarely for length, distance, or area. High school students and shopkeepers, however, reported using both the metric system of measures and the system of measures originating in farming with more than minimal frequency during agricultural activities: high school students perhaps because they are involved in both farming and schooling activities which originate two very different systems of measurements and shopkeepers perhaps because the activity of shopkeeping itself is a bridge activity between schooling- and farming-originated measures, involving conversion between the two forms.

Table 6

Types of Measures Used by Informants in Farming: Demographic Samples

	Percentage*		
Type of Measure Used	Farmers n = 73	Shopkeepers n = 47	Students n = 84
length			
meter	4.1	38.3	66.7
haat	100	95.7	45.2
paila	84.9	66.0	14.3
distance			
kilometer	0	0	6.0
kosh	13.7	4.3	0
area			
bighaa	100	100	100
hectare	0	8.5	29.8
weight			
dharni	100	91.5	77.4
kilo	31.5	74.5	92.5
tolaa	2.7	2.1	0
volume			
pathi	100	100	100
kuruwa	87.7	83.0	57.1
liter	12.3	74.5	90.5
kantar			
money			
rupee	94.5	100	100
time			
ghanta	100	100	100

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

In the case of students the metric forms permeate farming activity through individuals' participation in dual activities with dual forms of measurement. Note that this does not support arithmetic conversion between the two systems of measures, but only their parallel existence. In the case of the shopkeepers, however, metric forms of measurement permeate farming activity because of their participation in an activity that requires conversion between the two different forms of measurement. Shopkeeping itself is seen as supporting the permeation of metric measures into farming activity, not simply as parallel forms, but as forms integrated through conversion, e.g. a *dharni* weighs approximately 2 and a half kilos or half meter is the length of a *haat* (elbow to tip of middle finger) plus the distance from the tip of the middle finger to the first knuckle, second knuckle etc. depending on the length of the individual's arm.

The use of fingers, stones, and tallys in arithmetic have their origins in farming whereas the use of written numerals has its origin in schooling. Mental calculations without the use of external artifacts can have multiple origins, though their reported use is many time greater in farming by farmers than by high school students in school.

Fingers, seeds and stones, other persons, and mental calculations without the aid of external artifacts rather than written numerals are generally used by full time farmers doing arithmetic, as shown in Table 7. Tally marks are only used occasionally.

While several households reported keeping written financial records, this was unusual. These households were heavily involved in cash cropping and found written records of transactions and related arithmetic calculations useful as templates for future transactions. However, the other households involved in cash cropping did not keep written records. It is important to keep in mind that none of the full time farmers included in the demographic sample have attended school.

Shopkeepers again seem to negotiate both farming and school shopkeeping systems, this time in terms of arithmetic artifacts. The shopkeepers reported using fingers, written numerals, other persons, and mental calculations while doing arithmetic in farming. Stones were rarely used. Like the farmers, none of the shopkeepers included in the demographic sample had attended school. Most of the shopkeepers who reported using numerals reported having learned to do from younger household members attending school.

The students rarely reported using any arithmetic calculation artifacts with farming origins during their participation in farming activity, relying almost totally on written numerals and, to a lesser extent, mental calculations. Unlike students' reported use of dual measurement forms while farming, students' reported using only arithmetic artifacts in farming that they had acquired in school.

The social status of the various forms of calculation artifacts in Bherighat is important to understanding their use. Those shopkeepers and farmers who do arithmetic calculations using stones, and tallys would not

Table 7

Types of Math Mediational Devices Used by Informants: Demographic Samples

Activity and Type of Mediational Device	Percentages* Farmers n = 73	Shopkeepers n = 47	Students n = 84
In Farming			
fingers	61.6	53.2	3.6
stones	31.5	8.5	0
tallys	8.2	0	1.4
numerals	11.0	29.8	94.0
person	79.5	55.3	2.4
mental	80.8	100	48.8
In Shopkeeping			
finger		59.6	
stones		4.3	
tallys		2.1	
numerals		46.8	
person		10.6	
mental		87.2	
In Schooling			
fingers			1.2
stones			0
tallys			2.4
numerals			100
person			26.2
mental			22.6

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

normally do so in public, i.e. with strangers and it was generally acknowledged in Bherighat that this was the way calculations were done many years ago before the villages were *bhudi* or "smart." Finger calculations are higher in status than those done with stones and tallys. The reason given is that it is possible for some individuals could do complex calculations using large numbers using their fingers. The fact that the same is possible with stones or tallys did not enter into the distinction that was made. Nonetheless, several of our participants were found to be hiding their finger calculations during the later structured interview. This was done by holding a hand under the table we were sitting at while doing the calculation. Gentle questioning of those participants revealed that they were not aware that they were hiding their hand doing the calculation, but did so automatically, as if it was the proper thing to do.

Mental calculations are of a status between that of calculations using written numerals and calculations on fingers. Even though it is acknowledged that mental calculations without the use of external artifacts were used "before villagers were smart", the older Bherighat villagers who can do complex calculations "in their minds" are well known and admired for this. It is also generally acknowledged that while those who have been to school can do small calculations without the use of external artifacts, the advent of paper and pencil calculations in school has prevented them from becoming as good at mental calculations as some of the elderly villagers.

Calculation using written numerals clearly possesses the highest social status in Bherighat. As discussed previously, the primary reason for arithmetic originating in farming no longer being considered *hisaab* or true mathematics is the advent schooling and its use of written numerals in arithmetic calculations. Arithmetic calculations with written numerals is what is meant by villagers use of the term *hisaab* today. This sometimes results in students performing calculations with paper and pencil in farming when a more rapid mental calculation could have been carried out by the students.

An additional important distinction between calculations carried out with written numerals and calculations using other artifacts is that it provides a relatively durable record of the arithmetic. This sometimes interacts with its status in the following manner. A calculation will be carried out on paper by one party, the answer verbalized, and then the calculation on paper shown to the other party for approval, even though the first party is quite aware that the second party is unable to read the numerals. The display of a durable record signals that the calculating party can truly do *hisaab* and has nothing to hide.

If the various forms of artifacts and the arithmetic associated with them are ranked in terms of social status they would appear in order of decreasing social status as follows.

1. written numerals
2. mental calculations of any type
3. fingers
4. stones, tallys

While not a calculation artifact in the true sense of the term, other persons are sometimes called on to either furnish an answer to an arithmetic calculation, or provide a portion of the calculation in farming. No clear status differences are attached to this in farming, though in school it often falls under the category of cheating.

The reported use of arithmetic operations in farming varied depending on whether the participant was a full time farmer, a shopkeeper, or a student as can be seen in Table 8. While addition, subtraction, and counting were reported used by most of the farmers, shopkeepers and students during farming activity, multiplication and division were reported being used with considerable less frequency by full time farmers than by shopkeepers or students. Estimation, however, was reported used by most of the farmers and shopkeepers in farming, but by less than half of the students.

Table 8

Types of Math Used by Informants: Demographic Samples

Activity and Type of Math Used	Percentages* Farmers n = 73	Shopkeepers n = 47	Students n = 84
In Farming			
addition	95.9	100	98.8
subtraction	82.2	87.2	100
multiplication	64.4	87.2	91.7
division	43.8	85.1	98.8
counting	100	100	100
estimation	93.2	91.5	47.6
In Shopkeeping			
addition		100	
subtraction		93.6	
multiplication		82.9	
division		85.1	
counting		100	
estimation		93.6	
In Schooling			
addition			100
subtraction			100
multiplication			100
division			98.8
counting			41.7
estimation			19.1

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

A number of the full time farmers participating in the ethnography reported that while they understood what multiplication and division did (one increased numbers and the other decreased numbers was the most common explanation), they could use addition and subtraction for the same function. Two participants offered a possible partial explanation. A century or more ago a form of Hindu Sanskrit teaching furnished villagers with a hierarchical distinction between the four mathematical operations as diagramed in Figure 10.

Figure 10

Hierarchical Distinction Between the Four Mathematical Operations

```
jordne          bardaune
(to join)       (to make more)
  |                 |
  |---------|---------|
            |
     ubo garne
     (to increase)
            |
            |
     udho garne
     (to decrease)
            |
  |---------|---------|
  |                   |
gataune          banchne
(to take away)   (to break into pieces)
```

The superordinate categories are to increase and to decrease. Addition and multiplication are classified as operations that increase. Subtraction and division are classified as operations that decrease. The hierarchy supports farmers' statements that addition and subtraction serve the same function as multiplication and division. this is clearly the case at the superordinate level of the hierarchy as well.

The greater use of estimation in farming by full time farmers and shopkeepers than by students (though twice as many students reported using estimation in farming than in shopkeeping) indicates the importance and pervasiveness of estimation in the activity. The quantity of grain needed to sow a particular field must be estimated based on the type of seed, the quality of the earth, and the water available. The yield of different crops in various fields are similarly estimated. A starting point for these estimations is often the previous year's quantity of seeds sown and grain harvested in that field. There is also a sense of what each field should yield on the average, in many cases based on several generations of experience with particular crops in particular fields.

The calculation of length through proportion and relation also figures prominently in agriculture, both for the construction of buildings and the construction of implements. For example, the length of a beam for a shepard's hut can be a maximum of twice the normal height of a supporting post that is usually two *bitta* (length from thub to little finger of spread hand) higher than the top of the persons head. In order to place three holes evenly around the perimeter of a metal pan through which strings will be run to make a scale for weighing meat, a string is run around the circumference of the pan, cut to the circumference length, folded into three equal segments, cut at one of the folds, and that string segment is used to set the distance between the three holes to be made.

The mapping of farming calculation onto the standard arithmetic operations is imperfect, at best. The goal-directed organization of particular calculations and the procedures or means used to carry out the arithmetic as part of a larger agricultural practice are more adequate to describing arithmetic performances originating in farming. These will be taken up in some detail in Chapter VII.

Studying in School

Formal secular schooling began in Bherighat with the implementation of the first national system of education in the history of the Kingdom. By 1988 there are three primary schools and one comprehensive school with primary (grades 1 through 5), lower secondary (grades 6 and 7) and upper secondary school (grades 8 through 10) classes. Seven hundred and forty-six students are enrolled in the comprehensive school with approximately 200 additional students distributed between the additional three primary schools. While nearly all of the primary school students are from Bherighat, 15 percent of the lower secondary students and 36 percent of the upper secondary students are from villages surrounding Bherighat.

Primary school attendance is now mandatory in Nepal up through the 5th grade. Enforcement is lax, however. Textbooks and tuition are free at the primary level, though there is some cost to the student's family because of the student's decreased availability for agricultural work and the need to purchase notebooks, pencils, and the like.

In 1988, 79 percent of the primary school-age children in Bherighat were attending primary school classes. As a minimum, most families sent their sons and daughters to school for at least the first several primary grades. While there are no accurate figures on the number of families who never sent their children to school, we know of 9 families for which this is the case. In 6 of these instances the mother and/or father had died and the children needed to work in and around the home as a replacement for the absent parent.

Approximately 45 percent of the 1st grade students in the comprehensive school are female and 55 percent are male. Many of the parents and students express their belief in the value of education for education's sake, explaining that this is the only way one becomes a knowledgeable thinking person today. However, education as it relates to issues of a son's or daughter's status for marriage, status in the village at large, and access to jobs and further study outside of agriculture weigh more heavily in deciding how long a student's studies should continue.

A primary school education is currently seen as important for both boys and girls because it enables them to read, write, and do arithmetic. It is not seen as providing direct access to jobs that they would not otherwise have access to. At the same time, having a primary education is seen as benefitting those who become shopkeepers or remain in farming. The most often cited examples of benefits are being able to read the labels on products used in agriculture, write letters, and avoid being cheated when dealing with money. In many cases these examples appear to be on-the-spot constructions in response to the questioning rather than part of the collective consciousness of the village, however.

As a the majority of children in Bherighat have attained some level of primary education, for a child to not have done so stands out as unusual today. This is less true for secondary school attendance. The transition rate from primary to secondary school in 1988 was 28 percent, meaning that 72 percent of Bherighat's primary school students enter the work force after graduating or after having completed several years of primary education.

In 1988 only 9 percent of the secondary school population was female in marked contrast to the 45 percent enrollment rate at the primary level. A secondary education is viewed as providing increased access to non-agricultural jobs for males, but not for females. There is some reality to this view and therefore secondary education is currently seen as having less value for females than for males. A second principal cause of low female secondary school enrollment is parents' reluctance to send their daughters on to higher education, something secondary education is otherwise seen as providing access to. Attending an institution of higher education usually requires that the daughter leave Bherighat and live in a city, something that parents are willing to do with sons, but not with daughters. Last, women in Bherighat tend to marry at a younger age than men. This interrupts their further study in school as they are then expected to work in the husband's home.

Only 21.1 percent (n = 19) of the Bherighat students, male or female, taking the cumulative school leaving certificate (SLC) examination at the end of the 10th grade in 1988 passed the exam. While it is possible to take the exam again in following years, no more than 45 percent of the students in any class cohort has ever passed the exam over multiple attempts. Without the SLC certificate the years spent studying in school have no official value in terms of providing access to jobs.

Of the 19 students who passed the SLC examination in 1988, 8 have gone on to further study in higher education outside the village, effectively taking them out of the village workforce for a number of years and most likely permanently. All were male. Of the 11 students who did not go on, 2 were female and 9 were male. Two of the males obtained work as servants in district government offices. Seven of the males became involved in shopkeeping in some form in addition to agriculture, while the remaining 2 males and 2 females continued to work in agriculture.

Though the institution of schooling stands apart from many of the village activities in terms of the knowledge, skills, and practices it promotes, prominent social and economic ties do exist between the school and village activities at-large. The *puja* or worship of *Saraswati*, the Hindu goddess of learning has been integrated into the school from the village such that the actual ceremony is performed on the school grounds and is overseen by the school headmaster and teachers rather than a *pujari*, or priest. At home the children chant their arithmetic tables in order to memorize them in much the same way as Vedic scriptures were chanted by young disciples with a *guru* in the past. As previously mentioned, shops opened around the school cater to the students and the teachers by supplying tea, snacks, pens, pencils, and notebooks. The school schedule itself is an accommodation to the agricultural cycle. The school year begins in January and ends in mid-December with a monsoon vacation from June through August. The monsoon vacation occurs during the most labor-intensive period of farming, when the corn must be harvested, the fields and irrigation canals prepared, and the rice seedlings transplanted from their nursery beds. This vacation allows the students to work full time in their family's fields during this period.

Table 9 displays the general characteristics of the 9th grade student demographic sample. All were male and none had worked in a shop.

Table 9

General Characteristics of Students: Demographic Samples

Informant Characteristics	Students n = 84 Mean	(SD)
Age (yrs.)	19.7	(2.3)
Farming Experience (yrs.)	11.1	(4.5)
Shopkeeping Experience (yrs.)	0	
Schooling Experience (yrs.)	11.0	(10.4)
Size of Family	8.7	(3.7)
Size of School-Age Family	5.9	(2.4)
Education of School-Age Family Members (yrs.)	3.6	(1.5)
Education of Male School-Age Family Members (yrs.)	6.0	(2.0)
Education of Female School-Age Family Members (yrs.)	.6	(.9)

Most adults in Bherighat who can read and write numerals have either attended school themselves, or have learned from sons and/or daughters who are attending school. Few villagers described themselves as having learned to read and write numerals on their own. In this sense school is the direct or indirect source for learning to read and write numerals in the village, whether they be Devnagri or Hindu-Arabic. Table 10 displays the distribution of numeral reading and writing among the three demographic for farmers and shopkeepers who have never attended school and 9th grade students.

Table 10

Informants' Familiarity With Written Numerals: Demographic Samples

	Percentages		
Familiarity With Written Numerals	Farmers n = 73	Shopkeepers n = 47	Students n = 84
Can Neither Read Nor Write Numerals 1-9	57.5	8.5	0
Can Only Read Numerals 1 - 9	16.5	17.0	0
Can Read and Write Numerals 1 - 9	26.0	74.5	100

The parameters that follow are used to provide a set of "working boundaries" for school activity in Bherighat that can be compared with those of farming and of shopkeeping. These parameters are discussed in terms of male rather than female students because of the low percentage of female students in the upper grades.

Motive and Object. The primary motive of the activity of studying in school is learning. It is unique as an activity because its object and motive are one and the same (Engstrom, 1987). A strong secondary motive and object of studying in school is gaining salaried employment in an office and achieving SLC certification, respectively. At the level of the Bherighat schools, these may well be the primary motive and object. However the high degree of disengagement between the perceived desire for salaried work outside the village and the extremely low percentage that actually obtain such work with an SLC certificate lead us back to learning as a primary motive-object of studying in the Bherighat schools. Note that school studying activity is distinguished from other types of school activity such as teaching, administration, and accounting.

Tables 11, 12, and 13 display the beliefs of the 9th grade students in the demographic sample in terms of their passing the SLC examinations and what they will they will pursue if they pass the exams or do not pass the exams, respectively.

Spatial Location. Most school studying activity takes place in and around the school compound that includes a primary school building, a lower/upper secondary school building, a soccer/volleyball field, a student hostel for boarding students, a library building, a latrine, a water tap, and two tea shops. Students also study at home and in the hostel, usually after dinner by the light of a kerosene lantern and of a morning before school.

Temporal Location. The yearly school cycle begins in late August and ends in mid-June in Bherighat. As mentioned previously, the June to August break coincides with the corn harvesting and rice planting season. Tests are given at the end of each year to determine, in part, whether each student will

Table 11

Certainty of Passing the School Leaving Certificate Examinations Expressed by Students: Schooling Demographic Sample (n = 84)*

Certainty of Passing	Frequency	Percentage
0 percent	0	0
1 to 20 percent	0	0
21 to 40 percent	6	7.1
41 to 60 percent	40	47.6
61 to 80 percent	14	16.7
81 to 100 percent	24	28.6

* Students in the demographic sample expressed a mean percent certainty of 67.1 with a standard deviation of 56.7.

Table 12

What Students Believe They Will Pursue if They Pass the School Leaving Certificate Examinations: Schooling Demographic Sample (n = 84)

Pursuit	Frequency	Percentage
teaching	10	11.9
military	0	0
higher education	67	79.8
junior technical assistant	3	3.6
agriculture	0	0
shopkeeping	0	0
other	4	4.7

Table 13

What Students Believe They Will Pursue if They Fail the School Leaving Certificate Examinations: Schooling Demographic Sample (n = 84)

Pursuit	Frequency	Percentage
agriculture	15	17.9
shopkeeping	12	14.3
military	2	2.4
take the exam again	56	66.6

pass on to the next grade. The SLC examinations are administered after students have successfully graduated from the 10th class.

The daily life cycle for students during the time in which school is in session can be characterized as follows. Note that this is a characterization based on an average day in the life of a student and does not reflect the daily variance in their lives.

1. wake up
2. attend to toilet
3. study and/or do a few farming chores
4. eat morning meal
5. walk to school around 9:45 AM
6. school assembly at 10:00 AM
7. enter classroom around 10:10 AM
8. four classes in four 45 minute periods, e.g. mathematics, science, Nepali, English
9. break for 45 minutes and drink tea/play games
10. three classes in three 45 minute periods, e.g. social studies, agriculture, health
11. walk home at 4:00 PM
12. do farming chores around home
13. eat evening meal
14. study
15. sleep

Table 14 displays the farming chores that students who were part of the demographic sample reported performing on a regular basis before and/or after school.

Persons Involved. School studying is generally done with same age peers and adults who are not related to the students. This is the only activity in Bherighat is which interaction between large numbers of same age peers and unrelated adults occurs on a regular basis. In farming and in shopkeeping activities interaction occurs with family members of different ages and customers of different ages.

Table 14

Students' Chores Before and After School: Schooling Demographic Sample (n = 84)

Chores	Frequency	Percentage*
carrying water	6	7.1
planting	25	29.8
plowing	56	66.6
cutting fodder	9	10.7
grazing animals	22	26.2
cutting wood	3	3.6
studying	62	73.8
helping others study	7	8.3
watering animals	21	25.0
dumping garbage	16	19.0
carrying wood	9	10.7

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

The maintenance of same age peer groups after the completion of high school underlines the importance of this distinction. Peer group maintenance beyond school is a recent phenomenon in Bherighat and takes the form of various social and political "clubs." The membership of most of these clubs consists of members from two or three adjacent graduating high school classes.

Schooling in Bherighat also increases interaction between members of so-called *sudra* or "untouchable" groups and members of other castes. Caste discrimination is not permitted in the school and the students generally do not follow caste restrictions in their interactions with each other.

There is also greater interaction between males and females than would occur in other village activities. However, unlike caste restrictions which are largely ignored, males and females sit separately in the classroom. This is not mandated by the teachers, but is assumed and carried out by the students.

Artifacts Involved. The archetypal artifacts of school studying are the pen or pencil, the notebook, the textbook, and the blackboard. With the exception of the blackboard which is usually locally made, the other artifacts are all purchased or made available through the shops in

Bherighat.

Practices Involved. The typical recurrent practices involved in learning activity at school are taking examinations, doing homework, studying for examinations, taking notes, participating in sports, and attending class.

Knowledge and Skills Involved. Formally, the types of knowledge involved in attending the Bherighat high school are divided into the following disciplinary categories: mathematics, science, Nepali, English, health, social studies, moral development, agriculture, education. Note that the practices do not map on to these categories of knowledge and skills. Other formally unmarked knowledge and skills involve test-taking, classroom interaction with teachers, sports, and cheating.

A child instantly becomes a student when enrolled in school, unlike farming and shopkeeping where a person becomes a farmer or a shopkeeper after a period of what Lave and Wenger (1990) have termed legitimate peripheral participation. There is little sense that the first year student in high school is any less a student than the student completing his or her final year. It is interesting to note that this somewhat contrasts with the sanctioned and unsanctioned hazing of freshmen in high school and college in the United States, an activity that marks first year students as peripheral participants in the society of students.

Children generally enter primary school at 5 or 6 years of age and usually graduate when they are 17 to 20 years of age. Though high school only runs up to the 10th grade, most students fail one or more grades as indicated in Table 15 which displays the failure percentages for 9th class students in the demographic sample.

Table 15

Number of Years Failed by Students: Schooling Demographic Sample (n = 84)*

Number of Years Failed	Frequency	Percentage
none	23	27.4
one	49	58.3
two	8	9.5
three	4	4.8

* Students in the demographic sample failed a mean of .92 years of school with a standard deviation of .41 years

The subjects least favored by students, both in terms of doing poorly in them and in terms of personal dislike are English, followed by mathematics. These are the most frequently failed subjects at every grade level in the school and are also the most frequently failed on the SLC exams nationally. Table 16 displays the percentage of students in the 9th grade demographic sample for whom mathematics is their best and worst subject in terms of marks and favorite and least favorite subject in therm of preference.

Table 16

Characteristics of Mathematics as a Subject For Students: Schooling Demographic Sample (n = 84)

Mathematics	Frequency	Percentage*
student's best subject in terms of marks	0	0
student's worst subject in terms of marks	21	25.0
student's favorite subject	13	15.5
student's least favorite subject	33	39.3

* The mean annual math test score for a student is 27.4 out of a possible 100 with a standard deviation of 16.6. A score of 32 or above is generally considered a passing score by the school.

Arithmetic in school is largely impermeable to forms of measurement originating in farming. Forms of measurement originating in agriculture are not represented in the mathematics curriculum nor are they used in the classroom. At the outset of Nepal's national system of education, school arithmetic text books included a section on different forms of agricultural measures along with metric measures. However, a conscious policy decision was made in 1969 by the curriculum development unit of the Ministry of Education to include only metric forms of measures in the

Kingdom's textbooks. Table 17 illustrates the types of measures that the 9th grade students in the demographic sample reported using in school.

Table 17

Types of Measures Used by Informants in School: Demographic Sample

Activity and Type of Measure Used	Percentage*		
	Farmers n = 73	Shopkeepers n = 47	Students n = 84
length			
meter			89.3
haat			0
paila			0
distance			
kilometer			96.4
kosh			0
area			
bighaa			33.3
hectare			81.0
weight			
dharni			7.1
kilo			97.6
tolaa			
volume			
pathi			7.1
kuruwa			4.8
liter			92.9
kantar			9.5
money			
rupee			100
time			
ghanta			100

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

The mathematics curriculum and textbooks for grades one through five consist largely of lessons in arithmetic. Beginning with grade six, three separate mathematics textbooks are used: arithmetic, algebra, and geometry. The major topics covered in the 1st, 5th and 10th grade arithmetic textbooks are as follows.

Grade 1

- 1-5 whole numbers
- 1-5 written numbers
- 1-9 addition and subtraction
- ordinal numbers
- two-place addition and subtraction
- basic multiplication
- basic fractions
- metric measures, money, time
- general shapes

Grade 5

- large number notation and numeration
- number line with positive and negative numbers
- squares and cubes of numbers
- order of operation combined with the use of parentheses
- addition, subtraction, and multiplication of fractions
- decimal notation with addition and subtraction
- money, weight, volume, time and length, conversion between units

Grade 10

- area and volume of a cylinder and a sphere
- area and volume of a cube
- profit and loss calculation
- calculation of simple interest

The students are taught mathematics using Devnagri numerals through the fourth grade. Beginning in the fifth grade mathematics is taught only with Hindu-Arabic numerals.

The spoken language syntax for addition, subtraction, and division operations and fractions in Nepali mirrors that of current North American and European languages. However, the spoken syntax for multiplication taught in Nepali schools follows that used in Hindu religious texts written in Sanskrit. The multiplier in the operation and the denotation of the operation as multiplication are combined into a single word. In English, we might say "two times three equals six." In Nepali we would say " *dui* (two) *tiyaa* (times three equals) *chha* (six)." Combined multiplier-operation words are in common use up to ten and are only taught up to ten in the schools. Several of the Bherighat village elders indicate that such words exist up to a hunderd in some Sanskrit texts.

Classes consist primarily of teacher lectures based on the textbook, the demonstration of textbook examples worked through on the board by the teacher, and textbook exercises completed by students at their seats. Individual students will occasionally raise their hands and ask questions and will also work through a problem at the blackboard at the request of the teacher. The standard mode of teacher-student interaction during a mathematics lesson is question asked by teacher, response given by a single student or a choral response, followed by the teacher's out-loud evaluative comment. Rhetorical questioning is often used by the teacher working through a textbook example on the board, asking the students if they understand or asking them if what he did was correct.

An analysis of three days worth of 26 9th class student arithmetic notebooks revealed that 94 percent of what was written in the notebooks were direct copies of information provided in the textbook, excluding textbook exercises that were worked through by the teacher or the students. Note taking efforts duplicated the information contained in the textbook, including its format, either directly from the textbook or indirectly through the textbook as mediated by the teacher. There were almost no examples of reconstructions of textbook or teacher lessons into different representations

and there were no additional comments that might indicate students' attempts to add clarifying information beyond that which was given. demographic sample reported using in school.

The acquisition of math facts in addition, subtraction, multiplication, and division and the counting of textbook pictures of objects are encouraged in the primary grades in preparation for and in conjunction with the use of written numerals and equation formats. The only officially sanctioned form of calculation artifacts from the lower secondary level on through graduation are written numerals and equation formats. Many primary school students and under some circumstances even some upper secondary students use their fingers in calculating portions of larger arithmetic problems they are solving with column algorithms on paper.

As with calculation artifacts, officially sanctioned arithmetic strategies in school have a narrow range: encompassing the use of math facts, pre-determined formulae, and column-based calculation algorithms. Primary school students in the classroom were often observed to use strategies which were not officially sanctioned, such as decomposition, iteration, and the gaining of answers from neighbors. By the upper secondary grades, however, no students were observed using arithmetic strategies which were not sanctioned, other than gaining interim and final answers from neighbors.

It is possible that decomposition and iteration strategies were used, but were not directly observable in the upper secondary classrooms and were not logically derivable from our observations, perhaps because these strategies had become internally operational in the sense intended by Vygotskian theory (Elbers, Maier, Hoekstra, & Hoogsteder, 1992). However, situations encountered by upper secondary students in a later phase of the study, where the use of decomposition and iteration strategies were strongly encouraged, did not support the notion that the students were readily able to use such strategies given. It is important to note that it remains less clear whether these students had simply forgotten strategies that they may have used during the primary grades, or that the social sanctions against using them are so strong as to carry over into activities other than those which occur in mathematics class.

An important characteristic of arithmetic as it is taught in the secondary grades is the structure used to relate arithmetic operations to one another in the service of solving a problem. In most cases the structure is provided at the outset by the textbook and/or the teacher, rather than being derived by the students with the teacher. A partial exception to this are arithmetic word problems. They are best viewed as a particular genre of school math problem that often contradicts the non-arithmetic aspects of students' out-of-school experiences (Lave, 1988). The secondary students we observed had learned that "less" "take away", and "more than" mean subtract whereas "evenly among", "given evenly to", and "distributed to" means divide. However, the students were generally unable to solve a word problem when its structure did not clearly provide the sequence of the operations that they knew they must perform.

The pervasiveness of secondary students' inability to derive strategies to organize arithmetic operations in relations that afford adequate solutions will become important in our interpretation of findings from a later phase of this study.

Shopkeeping

Shopkeeping in Bherighat is an activity that currently mediates between the activities of learning in school and farming. Diachronically, it grew of both an increase in cash income from farming as an increased need for cash income for schooling, and increased access to goods. More recently it has come to serve as a source of work for former students who do not want to return to full time agriculture. Currently it also serves as a viable occupation for elderly villagers who can no longer work in the fields. Shopkeeping did not exist prior to the advent of formal schooling in Bherighat.

Fifty-one shops of various kinds existed in Bherighat at the time of the demographic survey run by 62 shopkeepers. Of the 62 shopkeepers, 47 had never attended school. A cluster of three tea and general items shops are located in the combined primary school and high school compound. An additional five shops are located at the Western end of the village along the edge of a cliff overlooking a river bed. A few of the smaller shops are located in individuals homes scattered throughout the village, but most are concentrated in two areas of the village, called *Shivanagar Bazaar* and *Krishnanagar Bazaar*. The names refer to temples dedicated to the Hindu deities *Shiva* and *Krishna* located in the two areas. Both areas were planned as bazaars for shops by the village government. Both areas were under cultivation prior to 1980. Table 18 displays the frequencies of the different types of shops in Bherighat.

Table 18

Types of Shops: Shopkeeping Demographic Sample (n = 47)

Type	Frequency	Percentage
general shop	27	57.4
general/tea shop	11	23.5
general/cloth shop	1	2.1
cloth shop	4	8.5
medical hall	2	4.3
repair shop	1	2.1
tea shop	1	2.1

Approximately 80 villagers are employed as shopkeepers or as principle assistants in the shops. Table 19 displays the relationships of the principal assistants to the shopkeepers. With the exception of three shops in which a shopkeepers employ students who are not members of their families, all others are relatives. This is partially a matter of convenience, as many of the shops are located in the first floor of homes in the bazaar areas. Of equal importance, however, is the need for shopkeepers to be able to trust their principle assistants with their money. While involving relatives in the running of their shop does not eliminate the problem of embezzlement, it does facilitates the recovery of funds in the few cases in which such incidents occurred.

Table 19

Shopkeepers' Relationships to Their Principal Assistants: Shopkeeping Demographic Sample (n = 47)

Relationship	Frequency	Percentage
none	18	38.3
wife	4	8.5
son	10	21.2
brother	3	6.4
brother-in-law	2	4.3
uncle	1	2.1
father	4	8.5
nephew	2	4.3
student (unrelated)	3	6.4

Table 20 displays the general characteristics of the shopkeepers included in the demographic sample. All were male and none had attended school. The parameters that follow provide a set of "working boundaries" for shopkeeping activity in Bherighat that can be compared with those of farming and studying in school.

Table 20

General Characteristics of Shopkeepers: Demographic Samples

Informant Characteristics	Shopkeepers n = 47	
	Mean	(SD)
Age (yrs.)	36.9	(11.0)
Farming Experience (yrs.)	28.4	(12.2)
Shopkeeping Experience (yrs.)	2.7	(2.7)
Schooling Experience (yrs.)	0	
Size of Family	5.4	(2.9)
Size of School-Age Family	3.5	(2.3)
Education of School-Age Family Members (yrs.)	3.2	(2.2)
Education of Male School-Age Family Members (yrs.)	4.8	(3.3)
Education of Female School-Age Family Members (yrs.)	1.5	(2.2)

Motive and Object. The primary motive for shopkeeping in Bherighat is to sell items for a profit, with the object being the generation of a cash income. A secondary motive may be being gainfully employed in an occupation other than agriculture, at least for those too old to work in agriculture and for former students who do not want to work in agriculture. Table 21 displays the range of cash income after costs for shopkeepers included in the demographic sample. The modal level of income from shopkeeping is less than 1000 rupees (approximately 38 US dollars) a year. Given that the per capita income in Nepal was approximately 4200 rupees at the time, cash income from these shops represents about one fifth of that yearly figure. Agriculture was still the primary income source, albeit usually not in cash, for these shopkeepers. Even those shopkeepers with shops showing a profit at or above the per capita income level were involved in farming, however. In many cases they would invest profits from their shops in additional farm land. The more wealthy shopkeepers hired outside labor to work their extensive landholdings during planting and harvest seasons, though they would usually work alongside the hired laborers in their fields.

The cash income afforded the shopkeepers with expanded opportunities to send many of their sons and, in some cases, their daughters to school past the primary level. Though this was reported by most of the shopkeepers interviewed, the average level of education of their school-age family members was no higher than for farmers' school-age family members. It is possible that shopkeeping is a recent enough development in Bherighat that its effects have not been seen in enrollment beyond the primary school grades and currently exists more as an intent.

Table 21

Shop Income Level: Shopkeeping Demographic Sample

(n = 47)

Income in Rupees*	Frequency	Percentage
less than 1000 rupees	16	34.0
1000 to 2000 rupees	11	23.5
2001 to 3000 rupees	9	19.1
3001 to 4000 rupees	3	6.4
4001 to 5000 rupees	0	0
5001 to 6000 rupees	2	4.3
6001 to 7000 rupees	1	2.1
7001 to 8000 rupees	1	2.1
8001 to 9000 rupees	0	0
9001 to 10,000 rupees	1	2.1
10,001 to 15,000 rupees	2	4.3
above 15,000 rupees	1	2.1

* Approximately 26 rupees equaled one US dollar at the time of the survey.

Spatial Location. Most shopkeeping activity, such as checking stock and selling items takes place within the physical confines of the shop which is generally located near a relatively well-traveled path. In the case of the shops in *Krishnanagar* and *Shivanagar Bazaars*, a path wide enough to eventually serve as a motor road was constructed separating a line of shops on either side. Many of the shops occupy part or all of the first floor the shopkeeper's house. In the case of shops located in the two main bazaars, the purpose of building a house in that particular location is usually to open a shop on the first floor or to rent the space to someone who wants it for a shop. The shops generally consist of a single room with stocked wooden shelves arrayed along the walls. The shopkeeper and the customers sit on the floor. If the shopkeeper also sells tea and hot snacks there is usually a thatched canopy attached to the shop under which wooden benches or chairs and a stone and mud stove are arrayed.

The buying of wholesale goods to stock a shop occurs outside the shop itself, as close as a neighboring shop or as far away as India or Kathmandu. Table 22 displays the locations of shopkeepers' wholesale sources in order of increasing distance.

Temporal Location. The yearly cycle for shopkeepers is marked by the rice planting and harvesting seasons, as are the yearly cycles for students and farmers. In addition the two week Dasain holiday, the one week Tihar holiday, and the one day Tij holiday are times during which Bherighat villagers make extensive purchases from the shops. Until 1986, shopkeepers found it difficult to obtain items for their shops during the monsoon. Footpaths were slippery for porters who consequently would charge more during

Table 21

Shop Income Level: Shopkeeping Demographic Sample

(n = 47)

Location	Frequency	Percentage*
Local	18	38.3
Lekh Pharsa (1 kilometer)	7	14.9
Chinchhu (8 kilometers)	40	85.1
Birendranagar (25 kilometers)	24	51.1
Nepalganj (30 kilometers)	28	59.6
India (31 kilometers)	5	10.6
Kathmandu (250 kilometers)	7	14.9

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

the monsoon and trucks and busses could not cross the Bheri River during this period, even when they could occasionally navigate mudholes and landslides on the roads leading up to the opposite side of the river. Consequently most of the shops minimally functioned during the monsoon period and a few actually closed. In 1988 trucks and busses reliably operated from Kathmandu and India up to the Bheri River, even during the height of the monsoon, due to road improvements. A new permanent bridge across the Bheri River allowed goods to be carried by truck and bus to within a two hour walk of the village. While it was still necessary to porter the goods into Bherighat, the yearly cycle for shopkeepers was no longer marked by decreased functioning during the monsoon.

Unlike farming and studying in school activity, shopkeeping does not have a particularly articulated yearly cycle.

1. rice planting season, low sales, shopkeeper involved in planting
2. rice harvest season, low sales, shopkeeper involved in harvest
3. Dasain holiday, high sales
4. Tihar holiday, high sales
5. Tij holiday, high sales

The daily cycle of life for shopkeepers other than during the rice planting and harvest seasons can be characterized as follows. Note that this is a characterization based on an average day in the life of a shopkeeper and, as such, does not reflect the variance in their daily lives.

1. wake up
2. attend to toilet
3. do farming chores around the home
4. open, sweep, and run shop

5. eat morning meal in shop or in home attached to shop
6. run shop
7. take money from cash box and close shop
8. eat evening meal at home
9. talk with family and friends
10. go to sleep

There is an important third temporal cycle between the yearly and daily cycles that exists for shopkeeping activity, but not for farming and schooling. It is the cycle of wholesale purchase and retail sales, depicted below. A single cycle can take anywhere between a week and two months to complete. Again, this represent an average and does not therefore reflect the within- and well as between-shop variance in the cycle.

1. negotiate rate with local porters
2. travel with porters to Chinchhu to purchase items wholesale
3. negotiate prices with shopkeepers in Chinchhu with whom you have an ongoing relation
4. renegotiate with porters based on actual loads
5. return with porters to shop
6. place items in stock and price based on wholesale cost and porterage

7. sell items

8. monitor stock and decide when to make the next trip for wholesale purchase

Persons Involved. As noted above, shopkeeping is generally participated in by the shopkeepers with the assistance of one of his family members, though a large percentage of the shopkeepers (38 percent) have no assistants. Customers range from relatives of the shopkeeper living in Bherighat, other Bherighat villagers, and individuals from other villagers who are visiting or are passing through Bherighat. Women and children in addition to adult males frequent the shops as customers. The cliental of a given shop tend to frequent that shop even when other shops offer identical items offer at identical or sometimes slightly reduced prices.

In addition to assistants, other shopkeepers, porters, and customers, there is a fifth category of person integral to the ambiance, if not the actual functioning of the shops: the socializer. Relatives, friends, and other Bherighat villagers will often stop by a shop and spend a couple of minutes or a couple of hours talking with the shopkeeper, the customers, or other socializers. Occasionally they will think of an item which they will then purchase from the shop, but this is not the initial purpose of their attendance.

Artifacts Involved. A tremendous variety of artifacts are used in shopkeeping, greater than are used in either farming or studying in school. Those which are archetypal are the cash box, the *traju* or two-pan scale, coins and paper money, and certain items for sale, such as cigarettes, matches, soap, and biscuits. These items are often depicted on shop signboards, almost as icons. Table 23 lists the most frequently sold items in the 47 Bherighat shops included in the demographic sample.

Table 23

Most Common Items* Found in Shops: Shopkeeping Demographic Sample (n = 47)

Item	Frequency	Percentage
Red Rose Tea	38	80.9
Matches	47	100
Yak Cigarettes	37	78.7
Gaida Cigarettes	44	93.6
Deaurali Cigarettes	45	95.7
Candy	44	93.6
Supari	38	80.9
Hair Ribbons	37	78.7
Mhaduri Soap	39	82.9
Myalu Soap	40	85.1
Myalu Biscuits	42	89.4
Glucose Biscuits	40	85.1
Pineapple Biscuits	36	76.6
Razor Blades	37	78.7
Chewing Tobacco	46	97.9
Notebooks	37	78.7
Pencils	38	80.9
Ballpoint Pens	41	87.2
Fountain Pens	36	76.6
Ink	38	80.9
Rara Noodles	43	91.5

* Only those items found in 75 percent or more of the shops in the demographic sample are included.

Other artifacts which play key roles in the construction, transmission, and preservation of information in many of the shops are organized packets of wholesale bills, a record book for items purchased on credit, cooking utensils, a meter ruler, item arrangement on shelves, and pens and scrap paper on which calculations are jotted.

Practices Involved. The typical recurrent practices involved in shopkeeping are buying items wholesale, pricing items for profit, stocking items on shelves, selling items for cash or on credit and making change, and socializing with customers and potential customers.

Knowledge and Skills Involved. The general categories of knowledge and skill most often cited by shopkeepers are skill at handling customers, knowing whom you should give credit to, knowledge of arithmetic, how to negotiate with porters and wholesale shopkeepers, how to measure, and how to price for profit.

Currently, approximately 28 percent of the shopkeepers in the demographic sample at one time served as assistants in a relative's shop. Twenty-one percent began shopkeeping at a time when there were few other shops, and the remaining 51 percent had never worked in a shop as an assistant, but had observed other beginning shops. Of the shopkeepers not included in the demographic sample because they had attended school, 93 percent were the first person in their families to open a shop. It is therefore necessary to describe two rather different learning situations, one resembling an apprenticeship and the other characterized by a drawing-on of experiences as a customer and using other shops and shopkeepers as resources.

The apprentice-like situation in almost all cases involves an immediate family member or a more distant relative who assists the shopkeeper during busy holiday times, acting as a second shopkeeper and keeps the shop open during times when the shopkeeper can not be present. The situation is apprentice like because the assistant does come to function as an auxiliary shopkeeper under the tulage of the shopkeeper. However, at no point is this situation viewed as a preparatory phase to becoming a shopkeeper. There is no expectation that the assistant will go on and open a shop of his or her own, either on the part of the shopkeeper or, at least initially, on the part of the assistant. This distinction is reinforced by the fact that four assistants in the Bherighat shops included in the demographic sample are women, while with one brief exception, all of the shopkeepers in Bherighat are men.

The assistant usually begins by having the shopkeeper point out where various items are located in the store, item locations that they believe their assistants are not familiar with. Much is often left out, to be discovered in the process of meeting customers' request. Most assistants are able to make change given their previous experience as customers. Doing conversions from traditional to metric forms of measurement for pricing presents a challenge for most of the assistants as this type of calculation is not engaged in by customers and most of the assistants are not familiar with metric forms of measurements. The strategy for doing various forms of conversion-pricing are taught orally by the shopkeepers. This generally occurs when the assistant encounters a purchase requiring a conversion-price calculation and is unable to do it rather than the shopkeeper producing hypothetical examples for instruction or using situations that occur with the customers he is attending to. The same occurs for totaling the prices of multiple items. The assistants are rarely involved in pricing for profit or negotiations with wholesale shopkeepers and porters.

Some assistants will eventually sell on credit, having gradually learned from the shopkeeper who is reliable and who is not and if they are capable of making a orthographic or graphic record of the transition. There was no evidence among shopkeepers that they ever taught their assistants how to read and write numbers or how to do calculation with their fingers. In three cases which we observed, the shopkeeper would make up special price weights which were item-specific for assistants who had difficulty doing measure-based price calculations, e.g. use this weight for 2 rupees worth of tobacco, or use this weight for 2 rupees of cumin. The shopkeeper would make the weights out of stones enclosed in small pieces of sheet plastic for commonly purchased amounts of certain items.

Usually after a week of participation in the shop, though occasionally earlier, the shopkeeper will begin to use his assistant as a replacement for himself when he cannot be present. When confronted with not being able to find an item the assistant will enlist the help of the customer in locating it. If he does not know a price he will ask a neighboring shopkeeper. If he is unable to total item prices or do a conversion-pricing calculation he will request the assistance of a neighboring shopkeeper or the customer. All else failing, he will tell the customer to come back later when the shopkeeper is present.

In starting his own shop, the assistant generally begins with items which are known to sell well, such as soap, biscuits, cigarettes, matches, flashlight batteries, and biscuits. These items are available from other local shopkeepers who often sell them at wholesale rates to assist the new shopkeeper. Measuring instruments are either made locally by a member of the *Kaami* group, historically blacksmiths, or are purchased ready-made outside the village. The new shopkeeper will continue to rely on other shopkeepers for information and occasionally for arithmetic calculations. Over time, many new shopkeepers will develop particularly close ties with one of the four or five largest stores, making collective wholesale purchases outside of Bherighat with the larger shops. Ties to the initial shop in which they worked as an assistant are usually maintained.

The person who begins his shop without having had the benefit of working as a shopkeeper's assistant initially creates a shop from his perspective as a customer. Often these new shopkeepers offer a free cigarette or a free cup of tea to customers, as do many of the better established shopkeepers, but do so to the extent that the store operates at a loss rather than a profit. In a similar vein, some of these new shopkeepers keep their extended family members well stocked with "free" soap, biscuits, tea, cigarettes, and the like--again resulting in the shop operating at a loss. Many of these stores fail in their first year. Those that do succeed generally make frequent use of other shopkeepers as resource persons.

When shopkeepers of either type expand the size of their shops to include new items, new forms of arithmetic calculation and measurement may accompany the sale of those items. Examples of such items are cloth, kerosene, sugar, and various spices. Selling cloth places particularly heavy demands on arithmetic calculation. The cloth is generally ordered by the customer using traditional measures of length which the shopkeeper must then convert to metric units and price based on the number of meters and centimeters. Five of the shopkeepers in the demographic sample reported that they did not sell cloth because of the difficulty of doing the calculation. Several shopkeepers who sold cloth reported having to ask other shopkeepers to calculate the price of particular pieces of cloth. Several others stated that they only sell cloth in predetermined price units, such as by the meter, in order to avoid doing the calculations. As with the price weights previously discussed, selling cloth by predetermined price units instantiates the measure to money conversion in the object itself rather than requiring its calculation.

Four of the shopkeepers who participated as informants in the ethnography stated that their ability to do arithmetic calculations limited the nature and variety of the items they could sell in their shop, and therefore their income. This was independently confirmed regarding the four shopkeepers by other participating shopkeepers.

Shopkeeping is the only activity of the three under study that involves the use of traditional and metric measures in approximately equal proportions. This reflects the role of shopkeeping as an activity with relations to both farming and schooling, and also its translation of community measurement forms into official units of measure sanctioned by the state. Table 24 displays the different types of measures employed by shopkeepers in the activity of shopkeeping.

Table 24

Types of Measures Used by Informants In Shopkeeping:

Demographic Samples

Activity and Type of Measure Used	Percentage*		
	Farmers n = 73	Shopkeepers n = 47	Students n = 84
length			
meter		76.6	
haat		59.6	
paila		0	
distance			
kilometer		12.8	
kosh		0	
area			
bighaa		0	
hectare		0	
weight			
dharni		51.1	
kilo		91.5	
tolaa		80.9	
volume			
pathi		89.4	
kuruwa		80.9	
liter		72.3	
kantar		38.3	
money			
rupee		100	
time			
ghanta		97.9	

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

The use of fingers, written numerals, other persons, and mental calculations predominate in doing arithmetic in shopkeeping. Stones and tallys are used as calculation artifacts by only a small percentage of the shopkeepers when participating in the activity. Almost three quarters of the shopkeepers in the demographic sample can read and write numerals from 0 to 9. Most shopkeepers who could do so reported learning to read and write numerals from younger family members who had attended school and that their primary motivation for doing so was to assist them in doing arithmetic in their shops.

Written records are used to record purchases made on credit and generally consist of the date, the customer's name, and the amount of credit. Some of the larger shops kept more detailed records including a running total of the person's outstanding credit and a categorization of individuals by location in the village. Interestingly, none of the shops included in the demographic sample kept a record balancing sales against purchases for calculating profit. The shopkeeper who owned the largest shop in Bherighat and is a former lower secondary school teacher reported constructing such a record for part of a year, two years after having left his teaching position and having opened his first shop. He found it to be too much work and ceased keeping such a record, feeling that he could formulate a sufficiently accurate yearly estimate of his profit with greater ease. As Bherighat shopkeepers did not pay taxes on most of their profits, or more accurately avoided doing so, there was actually a disincentive to keep such records. Most arithmetic calculations using written numerals were carried out on scrap sheets of paper and cardboard laying around the shop and did not become part of a permanent record.

The shopkeepers displayed a flexible use of strategies with and without the various calculation artifacts and various forms of traditional and metric measures. Traditional measures and estimation were used in cases where relatively small quantities of inexpensive items were sold, such as tobacco or salt. In sales that involved the totaling of prices for a large number of items multi-step calculations in measurement conversion, shopkeepers who could write would write numerals on paper where they would function as a mnemonic cue, but the actual calculations would be carried out mentally. In some cases a column algorithms and paper and pencil would be used to determine the total amount to be paid by the customer. In other cases calculations would be carried out mentally, but with the shopkeeper using his fingers to do secondary calculations that entered into the overall calculation.

The customer could enter into the arithmetic of the purchase in a number of ways. One method frequently occurred with multiple purchases. The customer would tell the shopkeeper two or three items that he would like to purchase and to please total their prices. The customer would then pay for those items and once the shopkeeper returned his change make a decision as to what else he or she would buy. This process could be repeated four or five times until the customer had only small change remaining or even that had been spent on the purchase of several cigarettes, boxes of matches, or candy. If the customer did not want to start with a set amount of money to spend and make midpoint decisions as to what to purchase based on the amount of money remaining, the shopkeeper would use cumulative pair-wise addition of the prices to calculate the final total as a single event.

Another way for the customer to enter into the purchase arithmetic would be to question the total price and/or the amount of change returned. In cases such as this the shopkeeper would often resort to doing mental calculations out loud or, if feasible, do algorithmic calculations on paper. This was done more to show the customer that the shopkeeper had nothing to hide and to double check his calculations than to communicate the actual procedure to the customer. The status of written numbers was often invoked as part of this process as well. In many such situations, both the customer and the shopkeeper knew that the customer could not read written numbers or follow the mental calculations.

Finally, some customers would assist the shopkeeper in making the calculations, calculate along with the shopkeeper, shadowing his calculations, or check the shopkeeper's calculations after the fact.

The customer purchase episode represented the most frequently occurring instance of arithmetic use in shopkeeping. Much of the arithmetic in farming involved single arithmetic operations and sophisticated forms of estimation. In high school arithmetic was generally taught and learned as arrangements of operations in a fixed linear sequence based on formulae. Unlike practices involving arithmetic observed in farming and in studying at school, customer purchases in shopkeeping provide an overarching organization through which multiple arithmetic operations can be sequenced using multiple measures and multiple calculation artifacts in order to arrive at a solution. Many, but not all of the shopkeepers could flexibly adapt a broad repertoire of strategies, procedures, and calculation artifacts to each set of customer purchases.

The customer purchase episode described in Figure 11 below was selected as one which clearly depicted many of the facets of a customer purchase mentioned above.

Figure 11

Customer Purchase Episode

Customer : [Customer has been sitting in shop for 12 minutes chatting with other customers and the shopkeeper before this] How much is your tobacco? I want 5 rupees worth and...

Shopkeeper: You will get two *muti* [handfuls] for that.

Customer : What, what...?

Other : Two of them, but he has small hands and...

Customer : Alright, and I need a pair of those *chapel* [plastic sandles] over there. [While the customer is asking for the *chapel*, the shopkeeper is taking two handfuls out of the tobacco bin and placing it on a piece of scrap paper. He adds a small additional amount, folds up the paper into a packet and hands it to the customer]

Shopkeeper: What did you, you said you wanted *chapel*? [The shopkeeper looks at the customer's bare feet and throws a pair of *chapel* at him.] Try these on.

Customer : [Customer tries one on and it appears too big] Let me try that one. [Customer points to one in another color that is a size larger.]

Shopkeeper: That is an 8 and what you tried was a 7 and that was too large. Try this one. [throws him another pair in the same color, but a size 6]

Other : [Customer tries on both *chapel*] That pair is too small, I think the other was...

Customer : This is alright. How much?

Shopkeeper: 22 rupees so that makes 27 [shopkeeper counted silently on fingers from 23, incrementing 5 times for the 5 rupees of tobacco and writes 27 on a scrap piece of cardboard]

Customer : [Customer thumbs through his money] Let me have 15 rupees of nails that are about 3 *anula* [3 finger widths long].

Shopkeeper: [The shopkeeper picks up a 200 gram weight and places on one pan of his two-pan scale and places a 50 gram weight on the other pan. Then he adds nails that are approximately the length requested by the customer to the pan with the 50 gram weight until the scale balances. Note that the nails cost 5 rupees per

100 grams. he pours the 150 grams of nails on to some scrap paper, wraps up the nails and hands them to the customer] That is a total of 39 rupees. [He crosses out the 27 on the scrap of paper and writes 39 next to it. The sum is calculated mentally without any apparent external calculation artifact. The procedure by which it was calculated is unknown]

Customer : [Customer again thumbs through his money] What is that cloth blue and red cloth like up there? I need some for my oldest daughter's blouse. [He points to a bolt of cotton cloth on the shelf]

Shopkeeper: [The shopkeeper drags down the bolt requested by the customer and several others of similar price and style. He rolls part of each bolt on the floor of the shop] All of these would be nice for your oldest daughter.

Customer : How much is each of these? [pointing]

Shopkeeper: This is 23 rupees, this is 25, this is also 25, this 22. [pointing to each]

Customer : [Customer takes time fingering the different pieces of cloth] I'll take this one. [a blue and green cotton at 25 rupees a meter]. I think I need about 2 and a quarter *haat.* [length from tip of elbow to tip of middle finger]

Shopkeeper: [The shopkeeper measures off a little more than 2 and a quarter *haat* of cloth from the bolt using his own arm and cuts it with the scissors. Then he measures the piece of cloth with a meter ruler, finding that it is 1 meter and 21 centimeters in length. On a piece of scrap paper he writes 25 rupees, the price of a single meter. Then he pauses and writes 25 paisa which is the price of a single centimeter, pauses again and writes 2 rupees 50 paisa twice, then writes 5 rupees, then writes 5 rupees 25 paisa.] Thirty rupees and one *suka* [25 paisa] for this piece. [He crosses out the 39 rupees on the other sheet of scrap of paper] Thirty and thirty, sixty, nine and.. 25 paisa...sixty-nine rupees and twenty-five paisa. [The shopkeepers writes 69/25 next to the crossed out 39 on the paper] Anything else?

Customer : [The customer hands the shopkeeper a fifty rupee note and three ten rupee notes]

Shopkeeper: [The shopkeeper returns one of the ten rupee notes, digs in his cash box and pulls out a suka (25 paisa) and a mohar (50 paisa) coin and hands them to the customer] This is left.

Customer : Give me some candy for this. [He throws the 75 paisa change on the floor in front of the shopkeeper]

Shopkeeper: [The shopkeeper hands three candies at 25 paisa each to the customer.]

VII. STRUCTURED INTERVIEW, NARRATIVES ON LEARNING: ANALYSES AND FINDINGS

This chapter and chapter VII contains analyses and findings from the experimental subsamples: farmers (n = 26), farmer/ shopkeepers (n = 13), farmer/students (n = 13). Appendix A contains tables displaying the demographic characteristics of the experimental subsamples. The subsamples do not consistently differ from the demographic samples on most characteristics.

The exceptions are that the experimental subsamples tend to be slightly older and slightly more experienced in farming and shopkeeping than the demographic samples, on the average. An examination of the mean age and years of experience of the pools of volunteers from which the subsamples were randomly drawn indicate that the volunteer pool for the shopkeepers is slightly older and more experienced on the average than the shopkeeper demographic sample. We have no potential explanation other than some age- and experience- related characteristics may also have been associated with shopkeepers' willingness to volunteer. The volunteer pools from which the student and farmer subsamples were constructed were equivalent in age and experience to the demographic samples, suggesting that the somewhat greater average age and experience of the later were a product of random selection from the volunteer pools.

Analyses and results from the structured interviews are divided into two sections. The first provides a summary of the participants' narrative descriptions of why they became farmers, students, and shopkeepers and the arithmetic they acquired in the process. Appendix B contains a list of the narrative questions used in the interview. The second section, covered in Chapter 8, provides a summary of their current knowledge and use of calculation artifacts, math facts, calculation, and measurement.

It is important to keep in mind in interpreting the participants' narratives of past learning experiences that they are constructions based in part on the way they perceive their lives now and not simply how they experienced them then. Therefore a reported influence of school arithmetic on arithmetic in farming, for example, may be a function of the student reflecting back through his current student experience on his earlier farming experience rather than or in addition to school arithmetic actually having influenced calculations done while participating in farming activity.

A majority of the farmers and students in the experimental subsamples stated that they would have become shopkeepers if they had the opportunity. The principle reason given for a lack of opportunity by both students and farmers was insufficient capital for establishing a shop.

Interestingly, twice as many farmers as students indicated that they would not have opened a shop even if they had the opportunity. A variety of reasons were given and are displayed in Table 25. Attending college was the only reason cited by the students for not choosing to become shopkeepers, given the opportunity.

A majority of the farmers and shopkeepers in the experimental subsample stated that they would have attended school if they had the opportunity. The most frequently cited reason for a lack of opportunity was that there were no schools in Bherighat at the time they were of school age. Of those who would not have attended school even if they would have had the opportunity, only the farmers offered a lack of intelligence as a reason.

Clearly there were a series of extra-individual factors such as sufficient entry capital, need to support family, and existence of an institution at a particular point in time that afforded and constrained whether they participated in farming and schooling or shopkeeping activity. Other factors, though clearly framed by Bherighat society, were more individual in nature, such as a preference for farming, not being smart enough, wanting to go onto college, or having no knowledge of the activity. Both sets of factors had a lot to do with what and how the participants learned and developed during their life spans.

Table 25

Whether Informants Would Have Participated in Schooling and/or Shopkeeping Activities if They Had the Opportunity and Their Reasons for Not Having Participated: Experimental Samples Interview

Activity, Choice of Participation, Reasons	Percentage		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Shopkeeping			
Would not participate given chance because:	34.6		15.4
- prefer farming	22.2		0
- want to attend college	0		100
- too risky	33.4		0
- too many hassles	22.2		0
- no knowledge of shopkeeping	22.2		0
Would participate but can not because:	65.4		84.6
- no capital to begin shop	52.9		72.7
- had\have to farm to support family	29.4		27.3
- limited demand for shops	17.7		0
Schooling			
Would not have participated given chance because:	23.1	15.	
- no interest	50.0	100	
- not smart enough	50.0	0	
Would have participated but could not because:	76.9	84.5	
- no schools at the time	65.0	72.7	
- no money for tuition/books	10.0	0	
- had to farm to support family	25.0	27.3	

Table 26 summarizes the participants' views on whether and how their

Table 26 summarizes the participants' views on whether and how their understanding of arithmetic affects how well they are able to participate in an activity. Surprisingly, students far more than farmers or shopkeepers felt that arithmetic was important to how one performed as a farmer. It may be that the farmers' and shopkeepers' generally poor self estimate of their arithmetic abilities, with arithmetic acquired in school as their point of reference, coupled with their confidence in their abilities as farmers resulted in their expression of this view. There is anecdotal support for this speculation.

All of the students and shopkeepers were of the view that arithmetic was important for their participation in schooling and shopkeeping, respectively. The shopkeeping group, however, presented a unique case. They clearly distinguished between the two activities in which they participated, farming and shopkeeping, with respect to the importance of arithmetic. This is reinforced with information from the focused ethnographic phase of the study. Most of the shopkeepers who had not been to school whom we spoke with indicated by concrete example that their ability to do arithmetic was quite directly related to the variety of items they could sell in their shops.

Table 26

Whether and How Participants Feel Their Arithmetic Knowledge Affects How Well They Do at an Activity: Experimental Samples Interview

Activities	Percentages of Participants		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Farming			
No effect on activity performance	69.2	76.9	38.5
Effect on activity performance	30.8	23.1	61.5
plant/harvest at wrong time	7.7	7.7	15.4
incorrect measure of harvest	7.7	0	23.1
fertilizer quantity wrong	3.8	7.7	23.1
cannot give example	11.5	7.7	0
Shopkeeping			
No effect on activity performance		0	
Effect on activity performance		100	
loose profit		53.8	
anger customer		7.7	
can be cheated		15.4	
cannot sell cloth		7.7	
give wrong change		15.4	
Schooling			
No effect on activity performance			0
Effect on activity performance			100
fail math tests			69.2
look stupid in class			7.7
have to retake math class			15.4
can not graduate			7.7

All of the shopkeepers and students in the experimental subsamples agreed that they did far more arithmetic when shopkeeping or studying in school than they did while farming.

Table 27 summarizes what the participants reported they would do if they could not solve a problem that involved arithmetic. Events in which the participants must deal with large numbers constituted the most frequently occurring situation in which this occurred across all three groups of participants. Other events in which this occurred were relatively specific to the activities of shopkeeping and/or schooling.

It is striking to note that asking another person for the answer and estimation were viewed as alternative strategies for resolving a problem for farmers and for shopkeepers, but not for students. Unfortunately that the question was not asked in such a way that it was possible to clearly distinguish whether the participants were commenting in general as individual, or with respect to their participation in a particular activity. However, the response patterns of the groups' match that which we would expect if they were responding to farming, shopkeeping, and schooling activities in particular, based on the focused ethnographies. Compared to the farmer and the shopkeeper groups, the student group displayed far fewer alternatives to resolving a problem in which arithmetic was initially involved.

The participants were asked to remember back to when they first began to learn things about numbers, and to reconstruct the sequence in which they learned about their different aspects and uses. Farmer's, shopkeeper's and student's grouped recollections were highly consistent with one another in terms of the sequence of acquisition, as indicated in Table 28.

Table 27

What Do Participants Do When They Cannot Solve a Problem Involving Arithmetic: Experimental Samples Interview

	Percentage*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
In what types of situations does this happen?			
dealing with large numbers	100	100	84.6
dealing with written numbers	30.8	69.2	0
measure to price conversion	0	23.1	0
forgetting numbers	92.3	100	0
factorization	0	0	53.8
algebra	0	0	100
simplification	0	0	46.2
What do you do when this happens?			
ask someone for answer	100	76.9	7.7
try again	69.2	100	100
give up	3.8	0	15.4
estimate	100	76.9	0

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

The categories used in the table are derived from the participants' narration, hence their apparent lack of inclusiveness and inconsistency reflects their terminology in describing how they learned about numbers. For exampledistinctions between addition and subtraction were not made when discussing calculation with objects, but were made when describing calculation "in the head."

Most of the participants reported having learned counting with objects

Table 28

Early Learning About Numbers: Experimental Samples Interview

Sequence and Characteristics of Early Number Learning	Percentage		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Learned First			
How to name words	15.4	15.4	7.7
How to count objects	34.6	38.5	46.2
How to count w\out objects	15.4	7.7	15.4
How to measure	15.4	30.8	23.1
How to count higher w\out objects	0	0	0
How to calculate w\ objects	0	0	0
How to calculate with fingers	0	0	0
How to add	0	0	0
How to subtract	0	0	0
How to read numbers	0	0	7.7
How to write numbers	0	0	0
Learned Second			
How to name words	0	0	0
How to count objects	26.1	0	7.7
How to count w\out objects	0.8	38.5	23.1
How to count with fingers	7.7	15.4	7.7
How to count higher w\out objects	7.7	7.7	23.1
How to measure	7.7	15.4	7.7
How to calculate w\objects	19.2	15.4	0
How to calculate with fingers	0	7.7	15.4
How to add w/out objects	3.8	0	7.7
How to subtract w/out	0	0	0
How to read numbers	0	0	0
How to write numbers	0	0	7.7

Table 28 (cont).

Early Learning About Numbers: Experimental Samples Interview

Sequence and Characteristics of Early Number Learning	Percentage		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Learned Third			
How to name words	0	0	0
How to count objects	0	0	0
How to count w\out objects	0	0	0
How to count with fingers	15.4	7.7	0
How to count higher w\out objects	0	7.7	0
How to measure	46.2	38.5	15.4
How to calculate w\objects	3.8	15.4	7.7
How to calculate with fingers	7.7	7.7	0
How to add w/out objects	23.1	23.1	38.5
How to subtract w/out objects	3.8	7.7	7.7
How to read numbers	0	0	15.4
How to write numbers	0	0	15.4

in its various forms, followed by counting with out objects and some calculation with objects, followed by measurement and calculation without objects, specifically addition and subtraction. All reported being initially shown how to count with stones or seeds by a parent or older sibling, but had no recollection of calculation ever being taught. Rather, most had a recollection of learning to add and later subtract through games played with other children and through keeping track of livestock with an older family members.

This provides some evidence that farmers, shopkeepers, and students had a similar introduction to numbers and calculation in the early years of their lives and that they did not have unique experiences with numbers and arithmetic that predisposed them to one activity or another. This may follow from the fact that all three groups essentially spent their early childhood years around family agricultural activity rather than school- or shop-based activity.

The only potential exception to this is that two of the student participants were taught to read and write numbers by their parents. None of the participants in the other two groups were taught to read and write numbers, at least as encompassed by the first three aspects they reported as having learned. Both of these students had parents who had attended primary school. Though students more than farmers or shopkeepers tended to come from families in which siblings and/or parents had also attended school, four other student participants, three farmer participants, and one shopkeeping participant also had parents with a primary education, but the participants were not taught to read and write numbers at such an early age. Thus it appears that having formally educated parents or siblings is a necessary but not sufficient condition for learning to read and write numbers early on in life.

Forms of measurement are central to the use of numbers outside of school activity. The participants generally recollected first learning traditional dry volume measures, followed by traditional length measures, traditional weight measures, and time measures. Like learning about numbers, this learning sequence appears to be common across the three groups of participants as illustrated in Table 29. The exception to this is s

Table 29

Early Learning About Measurement: Experimental Samples Interview

Sequence and Characteristics of Early Measurement Learning	Percentage		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Learned First			
maana, pathi (dry volume)	100	84.6	92.3
haat, bittha, aaunla (length)	0	15.4	7.7
dharni, bisoli (weight)	0	0	0
ghanta, minute (time)	0	0	0
kilogram, gram (weight)	0	0	0
Learned Second			
maana, pathi (dry volume)	0	15.4	7.7
haat, bittha, aaunla (length)	11.5	30.8	7.7
ghanta, minute (time)	3.8	7.7	0
kilogram, gram (weight)	0	0	7.7
Learned Third			
maana, pathi (weight)	0	0	0
haat, bittha, aaunla (length)	0	38.5	15.4
dharni, bisoli (weight)	57.6	46.2	30.8
ghanta, minute (time)	38.5	15.4	7.7
kilogram, gram (weight)	3.8	0	46.2

learning about metric weight measures. Metric weight measures appear to have been the third measurement form many of the students learned at an early age, in most cases in advance of learning traditional length measures.

It is possible that their later school experience with metric measures affected their recollection of earlier learning. However, fully three quarters of the students who listed metric weight measures as the third form of measure learned had parents who had attended primary school, wherea approximately three quarters of the students who did not list metric weight measures as the third form of measure learned had parents who had not attended primary school. This suggests a relation between the student participants' sequence of learning particular forms of measurement and whether their parents had attended school. It also suggests that in so far as the student participants had a greater percentage of parents who had attended school than the other participants, early experiences with metric measures were related to later participation in school, albeit indirectly.

Tables 30 through 33 summarize participants' discussions of whether, where, from whom, and how they learned to use various types of artifacts in arithmetic calculations. While all participants reported that they could use stones/seeds, tallys, and fingers, few shopkeepers and students reported actually using stones/seeds and tallys in their calculations and few students reported using their fingers. This is summarized in Table 30.

Few farmers, slightly more than half of the shopkeepers, and all of the students reported being able to use written numerals in calculation. Unlike with the reported use of other calculation artifacts, however, the percentage of participants who could use written numerals for calculation matched the percentage who actually used them. This may reflect the

Table 30

Use of Arithmetic Artifacts: Experimental Samples Interview

	Percentage*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
STONES/SEEDS			
Can use these	100	100	100
Do use these	69.2	15.4	0
TALLYS			
Can use these	100	100	100
Do use these	30.8	7.7	0
FINGERS			
Can use these	100	100	100
Do use these	92.3	61.5	15.4
WRITTEN NUMERALS			
Can use these	15.4	69.2	100
Do use these	15.4	69.2	100
"MENTAL" CALCULATION			
Can do this	100	100	100
Does do this	88.5	100	53.8

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

previously discussed higher status of written forms of arithmetic over forms that involve fingers, tallys, and seeds/stones. It may also reflect the less-than-total permeation of written numerals into Bherighat society in the following manner. The learning of written numerals and associated calculation was not a part of standard childrearing practices in Bherighat in the way that the learning of other calculation artifacts were, at least when the participants were children. Therefore a villager would not learn to use written numerals in calculations unless there was an intent and opportunity to use them.

All of the participants reported being able to do calculations without the use of external artifacts and the majority of farmers and shopkeepers reported actually doing such calculations. Interestingly, almost half of the student participants reported not actually doing calculations "in their head." Though many such calculations had their initial origins in the use of external artifacts and students did perform secondary calculations "in their heads" when using written numerals and algorithms, many of the student participants did not feel that the sakale (real) calculation was taking place other than that tied directly to the representation written on paper.

As indicated by Table 31, stones/seeds and tallys were reported to be used by the shopkeepers during their participation in both farming and shopkeeping, or not at all. The students reported never having used stones/seeds or tallys in either activity.

When fingers were reported as used by the shopkeepers in shopkeeping, those same shopkeepers always reported using them in farming as well. However, not all shopkeepers who reported using their fingers for calculation in farming reported using them in shopkeeping. The relation reverses when examining shopkeepers' reported use of written numerals: all those who reported using written numerals in farming used them in

Table 31

Activities in Which the Arithmetic Artifacts are Used: Experimental Samples Interview

	Percentage*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
STONES/SEEDS			
farming	69.2	15.4	0
shopkeeping	-	15.4	-
schooling	-	-	0
both activities	-	15.4	0
TALLYS			
farming	30.8	7.7	0
shopkeeping	-	7.7	-
schooling	-	-	0
both activities	-	7.7	0
FINGERS			
farming	92.3	61.5	15.4
shopkeeping	-	38.5	-
schooling	-	-	0
both activities	-	38.5	0
WRITTEN NUMERALS			
farming	15.4	15.4	30.8
shopkeeping	-	69.2	-
schooling	-	-	100
both activities	-	15.4	30.8
"MENTAL" CALCULATION			
farming	100	92.3	76.9
shopkeeping	-	100	-
schooling	-	-	46.2
both activities	-	92.3	38.5

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

shopkeeping, but all who used them in shopkeeping did not report using them in farming. This supports the notion that the sequencing of activities in Bherighat society for this particular cohort, e.g. farming followed by shopkeeping/farming, does not in and of itself determine the direction of "transfer." Rather, the particular activity in conjunction with the particular type of calculation artifact that is in learned by the shopkeepers participating in that activity determines the direction of transfer. The data on students using written numerals in farming and/or schooling support this interpretation as well.

The origins of calculations without the use of external artifacts can be multiple and were not specifiable with the information that was obtained from the narratives. Therefore this data could not be used to support or refute.

The farmers and participants generally reported having learned to use all forms of calculation artifacts as well as mental calculations from a combination of older siblings, parents, and/or on their own, as indicated in Table 32. However, all of the student participants indicated that they learned to use written numerals from their teachers and only a small percentage from older siblings as well. This contrasts with the large percentages of shopkeepers who learned written numerals from a combination of both older and younger siblings as well as their own children, all of whom had attended school. For this generation of shopkeepers, unlike the students, learning to use written numerals is not

Table 32

From Whom Did They Learn to Use the Arithmetic Artifacts: Experimental Samples Interview

	Percentage*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
STONES/SEEDS			
parents	61.5	15.4	84.6
older siblings	46.2	84.6	53.8
on own	7.7	100	15.4
TALLYS			
parents	76.9	100	92.3
older siblings	23.1	23.1	30.8
on own	15.4	0	0
FINGERS			
parents	76.9	84.6	46.2
older siblings	61.5	92.3	30.8
on own	11.5	0	30.8
WRITTEN NUMERALS			
parents	0	0	7.7
younger siblings	0	15.4	0
own children	3.8	30.8	0
older siblings	15.4	46.2	23.1
on own	0	30.8	0
teachers	0	0	100
"MENTAL" CALCULATION			
parents	19.2	30.8	0
older siblings	0	7.7	0
on own	80.8	84.6	100

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

Table 33

How Did They Learn to Use the Arithmetic Artifacts: Experimental Samples Interview

	Percentage*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
STONES/SEEDS			
observation	76.9	76.9	46.2
taught	34.6	61.5	69.2
TALLYS			
observation	88.5	69.2	84.6
taught	30.8	38.5	38.5
FINGERS			
observation	100	92.3	100
taught	57.6	15.4	15.4
WRITTEN NUMERALS			
observation	0	7.7	0
taught	15.4	61.5	100
"MENTAL" CALCULATION			
observation	23.1	23.1	7.7
taught	19.2	38.5	0
do not know	65.4	46.2	92.3

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

seen as a school-based activity.

All of the students reported that they had learned to do calculations without the use of external artifacts strictly on their own. This is an apparently puzzling finding. Anecdotal evidence from one participant's narrative suggests that as "mental" calculation is not something that is sanctioned in school, the default belief may be that it is learned on one's own.

Most shopkeepers and farmers reported learning how to use stones/seeds, tallys, and fingers via observation which would include occasional correction by others, as indicated in Table 33. However, most shopkeepers and farmers also reported being taught written numerals rather than having learned them through observation despite the fact that they had not attended school. The majority of student participants reported being taught to calculate with stones/seeds and with numerals, though the teachers were family members and school instructors, respectively. Most reported having learned to use tallys and fingers through observation. A majority of the participants in all three activities reported not knowing how they learned to do calculations without the use of external artifacts.

VIII. STRUCTURED INTERVIEW, CURRENT KNOWLEDGE OF CALCULATION, ARTIFACTS, AND MEASUREMENT: ANALYSES AND FINDINGS

This chapter describes the participants' current knowledge of and facility with calculation artifacts, calculation strategies, and measurement. Data and analyses in this section seem to assume a particular Cartesian view of knowledge, i.e. knowledge is represented as mental structures or meaning associations that reside "in the head." The Cartesian framework appears to be embraced through constructing and analyzing the data as if the questions and the "artificial" interview setting in which they were asked permit the participants to "bring with them" and display arithmetic knowledge and skill from farming, schooling, or shopkeeping. However, the other extreme would suggest that we can understand nothing about arithmetic in farming, schooling, and shopkeeping in this particular research context. This supports a dualistic view of the world as well. It proposes that individuals learn and develop discretely within discrete practices, that it is the practices that are the sole determinate of learning and development, and the individual experiences no sense of wholeness and continuity across practices.

Cartesian dualism is opposed by the various dialectical (Ilyenkov, 1977) and constructivist (Cobb, 1992) perspectives which take the construction and representation of knowledge to occur between persons participating in different forms of activity (Tolman, 1991) and social practices (Walkerdine, 1990). Neither version of dualism is consonant with the reconceptualization of transfer proposed in this research.

The findings therefore need to be interpreted as a reflection of the participants' continuing transformation of their arithmetic developed as part of becoming farmers, shopkeepers, and students through what is clearly an evaluative interview practice. The participants' behaviors can not be interpreted as if they are solely a product of their prior school and work experience, nor can they be assumed to be purely a product of the particular interview procedure.

Knowledge of Calculation Artifacts

The participating farmers', students', and shopkeepers' knowledge of finger-based and numeral-based calculation artifacts was examined using a series of recognition, writing, and calculation tasks. Details of these tasks were described in Chapter V. Participants' knowledge of stones and tallys as calculation artifacts was not examined. It was believed that the direct one-to-one correspondence between quantities of these artifacts and the quantities being calculated afforded equivalent and universal knowledge of these artifacts as calculation devices. Evidence from the focused ethnographies supported this belief. In retrospect, however, there appear to be ways of using stones as calculating artifacts that break away from simple one-to-one correspondence. This only became apparent when some of the participants were later given the opportunity to do calculations with stones that they would not normally encounter in their everyday lives and appeared to innovate.

All but one of the participants (a farmer) were able to recognize all single digit numerals whereas slightly less than half of the farmers were able to do so. As the number of digits in the numerals increased, the frequency of recognition decreased for farmers and shopkeepers, but not for students. Students demonstrated a high level of recognition for arithmetic signs and arithmetic equations whereas farmers and shopkeepers recognized almost none of them. Table 34 displays the mean number of items recognized correctly by each group of participants.

A similar pattern holds for farmers', students' and shopkeepers' knowledge of how to write numerals, arithmetic signs, and equations as indicated in Table 35. Numeral writing generally lags behind numeral recognition for farmers and shopkeepers, indicating that some of these participants are able to read some numerals without being able to write them.

While knowledge of arithmetic operation signs and equations is quite specific to students, knowledge of one and two digit numerals occurs more

Table 34

Reading Numeral, Sign, and Equation Artifacts by Group: Structured Interview

	Means and (Standard Deviations) of Items Read Correctly		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
single digit(12)	7.4 (3.1)	12.0 (0.0)	12.0 (0.0)
double digit(4)	1.7 (2.2)	3.1 (1.8)	4.0 (0.0)
3-4 digits(8)	.6 (0.8)	4.3 (1.3)	8.0 (0.0)
5-8 digits(21)	.8 (1.5)	0.2 (0.3)	17.9 (4.2)
addition sign(1)	.1 (0.1)	.1 (0.1)	1.0 (0.0)
subtraction sign(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)
multiplication sign(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)
division sign(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)
equal sign(1)	0.0 (0.0)	.2 (0.1)	1.0 (0.0)
vert. addition equation(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)
vert. subtraction equation(1)	.1 (0.1)	.2 (0.1)	.9 (0.1)
vert. multiplication equation(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)
vert. division equation(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)
hor. addition equation(1)	.1 (0.1)	.1 (0.0)	1.0 (0.0)
hor. subtraction equation(1)	.1 (0.1)	.1 (0.1)	1.0 (0.0)
hor. multiplication equation(1)	0.0 (0.0)	0.0 (0.0)	.9 (0.1)
hor. division equation(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)

widely, among farmers and shopkeepers in addition to students. It is important to note, however, that though these artifacts can be used in farming and in shopkeeping, it is possible to fully participate in farming and participate in some forms of shopkeeping without knowledge of written numerals.

Table 35

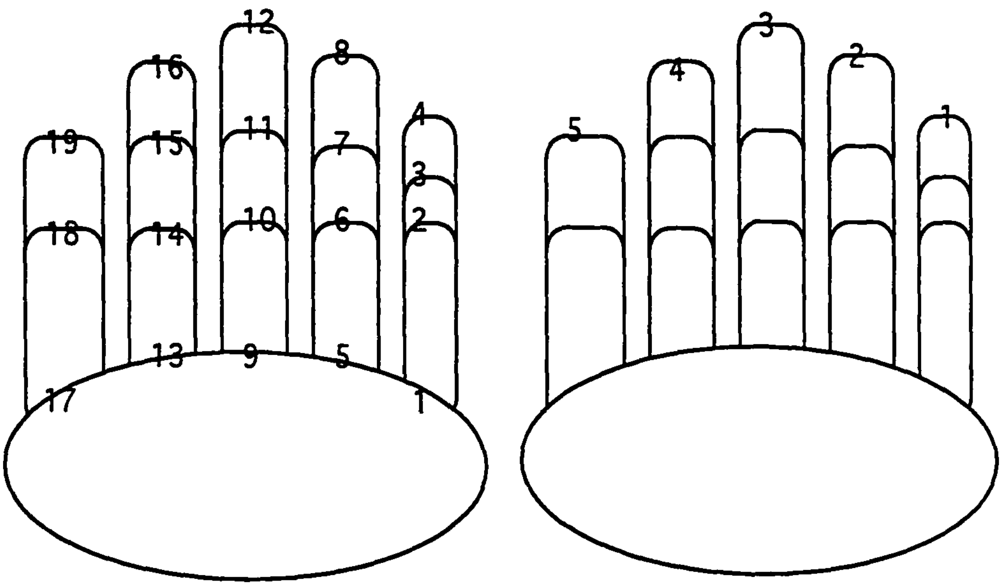
Writing Numeral, Sign, and Equation Artifacts by Group: Structured Interview

	Means and (Standard Deviations) of Items Written Correctly		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
single digit(12)	5.2 (4.4)	10.4 (3.0)	12.0 (0.0)
double digit(4)	1.2 (1.2)	3.1 (1.8)	4.0 (0.0)
3-4 digits(8)	2.0 (1.2)	5.1 (0.9)	8.0 (0.0)
5-8 digits(21)	0.0 (0.0)	0.2 (0.3)	19.5 (6.0)
addition sign(1)	.1 (0.1)	.1 (0.1)	1.0 (0.0)
subtraction sign(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)
multiplication sign(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)
division sign(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)
equal sign(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)
addition equation(1)	0.0 (0.0)	.1 (0.1)	1.0 (0.0)
subtraction equation(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)
multiplication equation(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)
division equation(1)	0.0 (0.0)	0.0 (0.0)	1.0 (0.0)

The picture is quite different with respect to participants' knowledge of fingers as calculation artifacts. It is possible to use each finger to increment by one and count fingers. It is also possible to use the joints and tips of one's fingers rather than the fingers themselves , thereby increasing the segmentation of the artifact from 10 to 38. The thumb is considered to have one less joint than the fingers, thus each hand has 19 segments. Figure 12 illustrates the two forms of segmentation.

Figure 12

Finger Segmentation



A second distinction among the participants in using fingers as calculation artifacts is whether specific fingers/segments are used to represent certain specific numeric values in an invariant manner, or whether any numeric value can be associated with any finger/segment. For example, 15 minus 9 can be solved by counting forward to 15, then backward by nine and then reading off the value of that segment or counting upward to that segment from the first segment. Alternatively, it be solved by designating the first segment as 10, counting forward to 15, and then counting "backward" with a different value-segment correspondence to reach 6 when one runs out of segments.

The participants were orally presented with addition, subtraction, multiplication, and division problems to solve using finger-based calculation. The problems afforded the use of both finger and joint segment counting, both fixed and floating value location. Note that the way the operations were envisioned and presented by the researchers did not necessarily determine the operations carried out in action by the participants, e.g. multiplication could be achieved through repeated addition.

A greater percentage of the farmers and shopkeepers used joint and floating value location in solving both the addition and subtraction problems than did students, as indicated in Table 36. The percentage of the farmers and shopkeepers who used joints and floating value location in solving multiplication and division problems was considerably lower than when solving the addition and subtraction problems, whereas the percentage of students who used joints and floating value location was approximately the same for all for operations. This had the effect of approximately the same percentage of students as shopkeepers using joint and floating value location in solving the multiplication and division problems and far smaller percentages of farmers.

Developmentally, most children in Bherighat first learn to count with the finger as the unit and value locations fixed. Most farmers and

Table 36

Knowledge of Fingers as Calculation Artifacts by Group: Structured Interview

	Percentage of Participants*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Addition			
- Unit is finger	3.8	0.0	61.5
- Value-Location Fixed	15.4	7.7	23.1
- Unit is joint	96.2	100.0	38.5
- Value-Location Floating	84.6	92.3	76.9
Subtraction			
- Unit is finger	0.0	0.0	53.8
- Value-Location Fixed	15.4	0.0	38.5
- Unit is joint	100.0	100.0	46.2
- Value-Location Floating	84.6	100.0	61.5
Multiplication			
- Unit is finger	7.7	46.2	61.5
- Value-Location Fixed	3.8	15.4	15.4
- Unit is joint	26.9	46.2	30.8
- Value-Location Floating	30.8	76.9	76.9
Division			
- Unit is finger	3.8	46.2	46.2
- Value-Location is Fixed	3.8	23.1	38.5
- Unit is joint	19.2	30.8	15.4
- Value-Location is Floating	19.2	53.8	61.5

* Percentages do not total 100 where one or more participants were unable to complete the task

shopkeepers have progressed toward using joints as units and floating locations for values, though this does not mean that they cannot revert to earlier means as the shopkeepers clearly do when confronted with multiplication and division problems. Five of the students, however, consistently attempted to use finger units and fixed values for all calculations. When interviewed afterward, these students suggested that they had not learned the other methods because they could do calculations on paper. Schooling therefore appears to truncate the development of more advanced finger counting strategies among some students, but not others.

The student participants displayed a decided preference for constructing written equations on paper for solving single and two digit arithmetic problems. Tables 37A and 37B indicate that this was the preferred calculation artifact among students for all arithmetic operations and was consistently preferred by more students than farmers or shopkeepers. This is in spite of the students' decided advantage over farmers and, to a lesser extent, shopkeepers in their knowledge of math facts. Student participants solving multiplication and division problems preferred written artifacts over others as well, though more shopkeepers constructed written artifacts in solving multiplication and division problems than on addition and subtraction problems. Students used the written equations as a calculation device in the case of the double digit problems and as a mnemonic device on the single digit problems, problems which were generally solved by the students with a math fact.

Table 37A

Artifacts Used in Arithmetic Problem Solving by Group: Structured Interview

	Percentage of Participants Who Used an Artifact or Used No Tool for One or More Problems Within a Category*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Addition			
Single Digits (4)			
no tool	100.0	92.3	53.8
tally	0.0	0.0	0.0
seeds/stones	0.0	0.0	0.0
fingers	26.9	7.7	0.0
paper & pencil	0.0	0.0	61.5
Double Digits (4)			
no tool	76.9	84.6	23.1
tally	3.8	0.0	0.0
seeds/stones	15.4	0.0	0.0
fingers	38.5	15.4	0.0
paper & pencil	3.8	30.8	100.0
Subtraction			
Single Digits (2)			
no tool	80.8	92.3	30.8
tally	7.7	0.0	0.0
seeds/stones	3.8	0.0	0.0
fingers	30.8	23.1	0.0
paper & pencil	0.0	7.7	100.0
Double Digits (4)			
no tool	46.2	61.5	30.8
tally	15.4	0.0	0.0
seeds/stones	34.6	0.0	0.0
fingers	34.6	53.8	15.4
paper & pencil	7.7	7.7	100.0

* Percentages do not total 100 because participants could use more than one strategy within a given set of problems.

Table 37B

Artifacts Used in Math Problem Solving by Group: Structured Interview

	Percentage of Participants Who Used an Artifact or Used No Tool for One or More Problems Within a Category*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Multiplication			
Single Digits (4)			
no tool	30.8	69.2	53.0
tally	7.7	15.4	0.0
seeds/stones	11.5	7.7	0.0
fingers	19.2	15.4	0.0
paper & pencil	0.0	7.7	69.2
Double Digits (3)			
no tool	3.8	23.1	38.5
tally	11.5	7.7	0.0
seeds/stones	19.2	15.4	0.0
fingers	11.5	7.7	0.0
paper & pencil	0.0	23.1	100.0
Division			
Single Digits (2)			
no tool	3.8	69.2	69.2
tally	7.7	7.7	0.0
seeds/stones	19.2	7.7	0.0
fingers	11.5	7.7	0.0
paper & pencil	0.0	7.7	84.6
Double Digits (4)			
no tool	0.0	7.7	7.7
tally	3.8	15.4	0.0
seeds/stones	23.1	15.4	7.7
fingers	0.0	7.7	0.0
paper & pencil	0.0	23.1	100.0

* Percentages do not total 100 because participants could use more than one strategy within a given set of problems.

An additional function of written calculation artifacts for the students was the fulfillment of a calculation "script" which only became apparent in a comparison with the shopkeepers. Farming participants rarely used written artifacts and consequently did not provide an adequate comparison. The students always wrote out the solutions to their written calculations and the appropriate operation sign when using written artifacts. The shopkeepers never wrote the operation sign when doing written calculations and in only 5 percent of the cases wrote out the answer in addition to stating it orally. More often then not, the shopkeepers would construct written numerals as a mnemonic for "mental" calculations rather than decomposing the numbers into place values and carrying portions of those values. The importance of students fulfilling a written calculation script is indicative of the close coupling of particular forms of artifacts with particular content and strategies characteristic of learning arithmetic in school. It also seems to be part and parcel of the high social status accorded written arithmetic in Bherighat that is acquired in school.

The percentage use of mental calculations and the use of math facts, classified as "no tool" in Tables 37A and B, were consistently greater in solving single digit problems than double digit problems and in addition and subtraction problems than multiplication and division problems for all three groups of participants. This roughly mirrors the distribution of the participants' knowledge of math facts displayed in Table 38 below. The

Table 38

Knowledge of Math Facts by Group: Structured Interview

	Means and Standard Deviations		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Addition (34)			
Correct 0-2 seconds	8.5 (2.7)	19.4 (3.1)	21.3 (2.6)
Subtraction (36)			
Correct 0-2 seconds	8.5 (2.2)	19.0 (3.9)	21.3 (2.1)
Multiplication (34)			
Correct 0-2 seconds	2.3 (3.0)	6.9 (5.2)	21.2 (2.0)
Division (16)			
Correct 0-2 seconds	.7 (.9)	3.2 (2.9)	10.4 (1.0)
Total (120)			
Correct 0-2 seconds	20.0 (7.5)	48.5 (10.6)	74.2 (4.7)
Correct 2-5 seconds	3.9 (1.9)	5.2 (3.2)	4.5 (1.8)
Incorrect 0-5 seconds	8.5 (4.0)	10.4 (8.7)	11.3 (5.3)
No Answer	86.0 (9.1)	55.7 (14.9)	30.3 (6.0)

category "no tool" includes only those solutions generated without the use of any external artifacts.

Student participants, as a group, used math facts and mental calculation with consistently less frequently than the shopkeeping and the farming participants. Though this would seem to stand in contradiction to the students' greater fund of math facts, it actually reflects the fact that the students would rarely solve a problem without use some form of external artifact, usually written numerals, in addition to involving math facts or mental calculations.

Unlike the students, the shopkeeping and farming participants solved addition and subtraction problems without using any form of external artifacts in a majority of cases. The shopkeeping and farming participants were roughly equal in their percentage of use of "no tool" strategies in solving addition and subtraction problems. However, the shopkeeping group used "no tool" strategies with at least double the frequency of the farming group on multiplication and division problems. This reflected the farming participants' general difficulty in solving the multiplication and division problems as they were presented rather than the use of an alternative set of calculation artifacts.

This raises an important issue, that of arithmetic problem presentation vs arithmetic calculation and the fact that the two were often not isomorphic. Those farming participants who were able to successfully solve some of the problems presented as multiplication and division problems did so by redefining the problems as something other than multiplication or division. This was generally accomplished with the use of artifacts which could be arrayed in one-to-one correspondence with the numbers: tally marks on paper, fingers/finger joints, seeds/stones. Shopkeeping participants also did so with multiplication and division arithmetic problems, though with less frequency because of their use of written numerals in calculation and calculation not involving external artifacts in addition to tallys, fingers/finger joints, and seeds/stones. The student participants never used seeds/stones or tallys as calculation artifacts and only occasionally used their fingers as calculation artifacts.

Certain calculation artifacts are generally associated with certain types of calculation strategies. Furthermore, many of the calculation strategies which the participants performed without the use of external artifacts may have developed through their use of external calculation artifacts, mirroring Hatano, Amaiwa, & Shimizu's (1987) findings that Japanese students come to perform mental calculations in a manner reflecting their experience with using the Japanese "abacus" or *soroban*.

Knowledge of Arithmetic Facts Calculation Strategies

Participants' knowledge of math facts varied widely with the activities in which they regularly participated. The farmers consistently displayed knowledge of fewer precalculated arithmetic solutions than the shopkeepers or the students as indicated in Table 38. The focused ethnography suggested that many of the numerical facts used by Bherighat farmers are measurement facts such as field yields and those that specify relations between different units of measure, rather than precalculated arithmetic solutions. This should not be taken as evidence of lack of math fact knowledge so much as a partial lack of precalculated arithmetic solutions beyond single digit addition and subtraction. This makes functional sense given the forms of numerical reasoning engaged in as part of farming activity.

The shopkeepers closely mirrored the students in their display of addition and subtraction math facts, but were well below students in their knowledge of multiplication and division facts. The students had spent much time during their primary grades learning addition, subtraction, multiplication, and division tables and continued to utilize math facts in place of subsidiary calculations in later grades. Math facts are formally marked as a mathematical achievement in the classroom. The shopkeepers, however, participated in a variety of practices from wholesale purchases to pricing to retail sales that involved addition and subtraction out of which they acquired math facts, though the memorization of math facts in not marked as an achievement in shopkeeping. Many of the shopkeeping events in which the shopkeepers could have invoked multiplication and division strategies were instead resolved through addition and subtraction. This may in part explain the relative paucity of precalculated multiplication and division solutions available to shopkeepers in comparison to students.

Overall, the number of math facts (correct solution in 0-2 seconds) displayed by the shopkeepers was more than twice that of the farmers and approximately two-thirds that of the students. These differences were mirrored in the number of arithmetic problems not responded to. However, the number of presumably calculated solutions (correct solution in 2-5 seconds) and incorrect solutions were roughly the same for all three groups of participants. This suggests that the participants took equivalent advantage of the 3 second period after the initial two second period and responded incorrectly with equivalent frequency across the three groups. This in turn suggests that differences between the groups of participants reflect differences in math fact knowledge rather than a differential preference for rapid calculations or rapid but incorrect answering.

Only fifteen percent of the farming participants reported being able to count beyond 1000, as shown in Table 39, whereas sixty-nine percent of the shopkeepers reported being able to count beyond 10,000. Most of the students reported being able to count indefinitely. When a participant stated that he could count no further than a certain number, he was asked whether he could count that number plus one, then was asked if he could count to the next largest value shown in Table 39. This procedure was repeated until the participant said that he could not count to the next largest value.

These results therefore represent more than the participants' first opinions on how high they can count. Discussions with the participants after their final response to this line of questioning suggest that the results

Table 39

The Highest Number Participants Reported Being Able to Count To: Experimental Samples Interview

	Percentage		
Highest Number	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
100	15.4	7.7	0
1000	69.2	15.4	0
10,000	0	7.7	0
100,000	3.8	30.8	0
1,000,000	0	15.4	0
10,000,000	3.8	15.4	15.4
indefinitely	7.7	7.7	84.6

also do not represent conceptual limits to the farmers' and shopkeepers' counting so much as a recognition that it is possible to conceive of actually counting by ones from 100 to 1000, but not from 1,000,000 to 10,000,000. If the counting process is reflected on in this manner this is probably the case for most readers of the dissertation as well.

This can not explain the relative difference between the farmers, shopkeepers, and students, however. We are left with explanations that make some structural sense when drawing on earlier focused ethnographies, but are none the less post hoc in nature. The average shopkeeper encounters larger numbers than the average farmer, particularly when purchasing stock from wholesalers whose prices are tied to quantity of purchase, e.g. 100 soap bars for 510 rupees or 500 soap bars for 2400 rupees. However, the shopkeeper would never directly count items such as single soap bar, but rather would count the boxed units and add or multiply.

A number of the student participants reported learning in school that "numbers never end" and every teacher of secondary mathematics in the Bherighat schools reported mentioning this at one point or another in their instruction. Explicit instruction in place value and column algorithms which only repeat themselves with larger and larger numbers may contribute to this conception as well. Thus for most of the student participants, how high they could count was an instance of a mathematical fact, numbers never end, rather than an assessment of the actual processing of counting.

Calculation artifacts and strategies do not exist in simple causal relation to each other. As shown in Tables 40A through 40D below, the variety of strategies use by the participants is much greater than the variety of artifacts, suggesting that while certain artifacts may afford some strategies and not others, particular strategies are not determined or caused by the artifacts.

A typology of strategies was developed from the participants' in-process oral descriptions, the participants' after-the-fact oral explanations, and written records of their use of artifacts, both participant- and researcher-produced. In some cases the existing research literature provided definitions adequate to characterizing participants' strategies. In other cases the existing literature was inadequate and characterizations were derived from the researcher's solo attempt to characterize the data. None of the strategies were necessarily exclusive of other strategies used on a given arithmetic problem. In some cases two or more strategies would be used in conjunction with one another to solve a problem.

Some of the strategies used by the participants were used for more than one operation problem type, e.g. for problems presented as addition and subtraction problems. In other cases the strategy was specific to a single operation problem type. Tables 40A through 40D display the strategies used by the participants to solve the arithmetic problems presented as addition, subtraction, multiplication, and division problems. Brief descriptions of the strategies follow each table.

Table 40A

Strategies Used in Addition Problem Solving by Group: Structured Interview

	Percentage of Participants Who Used a Strategy for One or More Problems Within a Category*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Single Digits (4)			
- min strategy	34.6	15.4	15.4
- max strategy	7.7	0.0	0.0
- decomposition	26.9	0.0	0.0
- math fact	19.2	100.0	92.3
- column algorithm	0.0	0.0	15.4
- counting forward	46.2	0.0	0.0
Double Digits (4)			
- min strategy	34.6	45.8	7.7
- max strategy	7.7	0.0	0.0
- decomposition	45.9	53.9	0.0
- math fact	26.9	30.8	23.1
- column algorithm	0.0	30.8	92.3
- counting forward	42.3	0.0	0.0

* Percentages do not generally total 100 because participants could use more than one strategy within a given set of problems.

Min Strategy. This is a counting-on strategy in which the participant begins with the larger of the two addends and counts up by 1's or some other regular interval as far as is specified by the smaller addend. For example, 5 + 8 is solved as "9, 10, 11, 12, 13." (Petitto, 1979)

Max Strategy. This is a counting-on strategy in which the participant begins with a the larger of the two addends and counts up by 1's or some other regular interval as far as is specified by the smaller addend. For example, 5 + 8 is solved as "6, 7, 8, 9, 10, 11, 12, 13." (Petitto, 1979)

> **Decomposition Strategy.** This is a flexible strategy that involves breaking the numbers presented as part of the problem down into smaller units in various ways and reassembling them into a solution through calculation. For example, 28 + 35 is solved as "if it were twenty, then twenty and thirty is fifty, and eight is fifty-eight, and five, the result would be sixty-three." (Carraher, Carraher, & Schliemann, 1987)
>
> **Math Fact Strategy.** This involves the retrieval of facts about number relations that do not need to be calculated. For example, 15 + 5 would be solved as "twenty."
>
> **Column Algorithm Strategy.** This strategy follows a set of rules for getting from a specific input to a specific output and involves splitting the initial numbers into their respective place values, performing calculations on those separated values, translating number values between places when necessary, and through this process composing a series of partial solutions into a whole (Knuth, 1977). For example, 18 + 9 would be solved as "eight plus nine is seventeen, write the seven, carry the one, so one and one is two, so twenty-seven."
>
> **Counting Forward Strategy.** This strategy involves combining the two numbers through counting both forward. For example, 6 + 5 would be solved as "one, two, three, four, five, six, seven, eight, nine, ten, eleven."

Shopkeepers and students relied primarily on math facts to solve the single digit addition problems whereas farmers utilized a much wider variety of strategies. It appears that the relative paucity of farmers' available math facts compared to that of shopkeepers' and students' is associated with the use of a wider variety of strategies, at least on the single digit problems. While farmers, as a group, also used a diverse set of strategies on the double digit addition problems, shopkeepers used fewer math facts as direct solutions and increased in their use of a variety of other strategies. Students shifted from using math facts as direct solutions to using column algorithms as the principle means of solving the addition problems. Only the farmers used a counting forward strategy which consisted of counting both numbers. Note that this strategy was most often associated with using seeds as a calculation artifact.

By not relying primarily on math facts, the farmers seem to use a wide variety of strategies that are independent of whether the numbers involved are single or double digit. Both the shopkeepers and the students rely primarily on math facts in solving single digit addition problems, but adapt quite differently to the larger digit size, with the shopkeepers using a variety of strategies including column algorithms and the students using only the column algorithmic strategy in most cases. It should be noted that while these patterns appear in the group data, they hold true for the majority of the individual participants as well.

Table 40B

Strategies Used in Subtraction Problem Solving by Group: Structured Interview

	Percentage of Participants Who Used a Strategy for One or More Problems Within a Category*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Single Digits (2)			
- min strategy	73.1	15.4	7.7
- math fact	26.9	92.3	92.3
- column algorithm	0.0	0.0	15.4
- counting backward	3.8	7.7	0.0
Double Digits (4)			
- min strategy	53.8	84.6	7.7
- max strategy	3.8	0.0	0.0
- decomposition	34.6	46.2	0.0
- math fact	15.4	53.8	15.4
- column algorithm	0.0	15.4	100.0
- counting backward	3.8	0.0	0.0

* Percentages do not generally total 100 because participants could use more than one strategy within a given set of problems.

Min Strategy. This is a counting-off strategy in which the participant begins with the minuend and counts down by 1's or some other regular interval as far as is specified by the subtrahend. For example, 9 - 2 is solved as "9, 8, 7." (Petitto, 1979)

Math Fact Strategy. This involves the retrieval of facts about number relations that do not need to be calculated. For example, 15 - 5 would be solved as "ten."

Column Algorithm Strategy. This strategy follows a set of rules for getting from a specific input to a specific output and involves splitting the initial numbers into their respective place values, performing calculations on those separated values, translating number values between places when necessary, and through this process composing a series of partial solutions into a whole (Knuth, 1977). For example, 18 - 12 would be solved as "eight take away two is six, write the six, and one minus one is zero, so the answer is just six."

Counting Backward Strategy. This strategy involves counting forward to establish the minuend, then backward incrementing by the subtrahend. For example, 9 - 5 would be solved as "one, two, three, four, five, six, seven, eight, nine...eight, seven, six, five, four."

Max Strategy. This is a counting-on strategy in which the participant begins with the subtrahend and counts up by 1's or some other regular interval as far as is specified by the minuend. For example, 9 -2 is solved as " three, four, five, six, seven, eight, nine... one, two, three, four, five, six, seven."

Decomposition Strategy. This is a flexible strategy that involves breaking the numbers presented as part of the problem down into smaller units in various ways and reassembling them into a solution through calculation. For example, 35-28 is solved as "if it were thirty, then thirty take away twenty-eight is two, and five is seven." (Carraher, Carraher, & Schliemann, 1987)

The same patterns of strategy usage between the groups on the single and double digit addition problems existed on the subtraction problems as well. The only clear difference between strategies used on the addition and on the subtraction problems was that on the subtraction problems a counting forward strategy could not used to solve the problems. However, one farmer and several shopkeepers used a counting backward strategy that necessarily included a counting forward strategy. It was not used with the frequency that the counting forward strategy was on the addition problems.

Though these patterns appear in the group data, they hold true for the majority of the individual participants in each group as well.

Table 40C

Strategies Used in Multiplication Problem Solving by Group: Structured Interview

	Percentage of Participants Who Used a Strategy for One or More Problems Within a Category*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Single Digits (4)			
- iteration	19.2	15.4	0.0
- math fact	15.4	69.2	53.8
- column algorithm	0.0	0.0	26.9
- duna series	0.0	26.9	100.0
- halving/doubling	3.8	15.4	0.0
- multiple counting	42.3	38.5	0.0
Double Digits (3)			
- iteration	7.6	7.7	7.7
- math fact	0.0	0.0	7.7
- column algorithm	0.0	23.1	92.3
- duna series	3.8	0.0	0.0
- halving/doubling	0.0	7.7	0.0
- multiple counting	34.6	30.8	0.0

* Percentages do not generally total 100 because participants could use more than one strategy within a given set of problems.

Iteration Strategy. This is a flexible strategy that involves working toward the solution in a stepwise fashion by means of successive subtractions or additions. (Carraher, Carraher, & Schliemann, 1987) For example, 8 X 50 is solved as "fifty, one hundred, one fifty, two hundred, four hundred."

Math Fact Strategy. This involves the retrieval of facts about number relations that do not need to be calculated. For example, 15 X 2 would be solved as "thirty."

Column Algorithm Strategy. This strategy follows a set of rules for getting from a specific input to a specific output and involves splitting the initial numbers into their respective place values, performing calculations on those separated values, translating number values between places when necessary, and through this process composing a series of partial solutions into a whole (Knuth, 1977). For example, 34 X 6 would be solved as "six times four is twenty-four, write the four and carry the two, six threes is eighteen, twenty, so the answer is two hundred and four."

***Duna* Series Strategy.** The duna series, described in more detail in chapter 6, combines the multiplier and the multiplication designation into a single term, e.g. *tin* [three] *duna* [times two equals] *chaa* [six]. The strategy involves orally progressing through the *duna* sequence up through the multiplier with the multiplicand held constant. For example, 3 X 4 would be solved as "*char* [four] *ika* [times one equals] *char* [four], *char* [four] *duna* [time two equals] *aath* [eight], *char* [four] *tiya* [times three equals] *bara* [twelve]."

Halving/Doubling Strategy. The halving/doubling strategy involves halving either the multiplier or the multiplicand so that a math fact can be used as the solution and then doubling the product for the solution. For example, 12 X 6 is solved as "six times six is 36, so double that is seventy-two.

Multiple Counting Strategy. This strategy involves defining a counting cycle by either the multiplier or the multiplicand and performing the counting cycle a number of times defined by the opposing number while incrementing by one. For example, 3 X 5 would be solved by "one, two, three...four, five, six...seven, eight, nine...ten, eleven, twelve...thirteen, fourteen, fifteen."

There was little difference in strategy usage among farmers between the single and double digit multiplication problems, similar to their addition and subtraction problem performances. The most frequently used strategy was a multiple counting strategy, a strategy afforded by the multiplication problems, but not by the addition and subtraction problems. Less than half of the farmers generated a solution to one or more multiplication problems whereas all of the farmers generated solutions to all of the addition and subtraction problems. Both the shopkeepers and the students relied on a variety of strategies in solving the single digit multiplication problems. Shopkeepers predominantly used math facts and multiple counting while the students used math facts, column algorithms, and the *duna* series.

On the double digit problems, math facts were rarely used as an independent strategy by either the shopkeepers or the students. Both groups of participants used a greater percentage of column algorithm strategies on the double digit problems, though these strategies represented a far greater percentage of the cases for the student group than for the shopkeepers.

In not relying primarily on math facts, the farmers again seem to use a wide variety of strategies that are independent of whether the numbers involved are single or double digit. Many of the farmers were unable to solve many one or two digit multiplication problems, however, suggesting that multiplication, at least as formally defined by multiplication problems, is not central to farming activity in the same way that addition and subtraction seem to be.

The shopkeepers and students often use different strategies for single and double digit multiplication, though the shopkeepers overall use a more diverse repertoire of strategies than do the students. This is similar to their strategy use pattern on the addition and subtraction problems.

The *duna* series strategy currently has its origins in school activity, though it is used by some shopkeepers who acquired the strategy outside of school activity. The *duna* series is generally only mastered for single digit multipliers and therefore is rarely used for double digit multiplication problems.

Though these patterns appear in the group data, they hold true for the majority of the individual participants in the student and shopkeeping groups and the majority of the farmers on the single digit problems. Individual participants in the farming group on the double digit problems varied from the aforementioned patterns. This may be a result of the small number of participants attempting the problems struggling to develop and/or use strategies with which they are less familiar.

Table 40D

Strategies Used in Division Problem Solving by Group: Structured Interview

	Percentage of Participants Who Used a Strategy for One or More Problems Within a Category*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Single Digits (2)			
- iteration	7.6	23.1	0.0
- math fact	19.2	38.5	23.1
- column algorithm	0.0	0.0	30.8
- duna series	3.8	23.1	76.0
- successive halving	7.7	30.8	0.0
- grouping	15.4	0.0	0.0
- estimating quotient/grouping	11.5	0.0	0.0
Double Digits (4)			
- math fact	0.0	0.0	15.4
- column algorithm	0.0	15.4	100.0
- duna series	0.0	7.7	0.0
- successive halving	7.7	15.4	0.0
- grouping	7.7	15.4	0.0
- estimating quotient/grouping	15.4	7.7	0.0

* Percentages do not generally total 100 because participants could use more than one strategy within a given set of problems.

Iteration Strategy. This is a flexible strategy that involves working toward the solution in a stepwise fashion by means of successive subtractions or additions. (Carraher, Carraher, & Schliemann, 1987) For example, 75 / 5 is solved as "ten times five is fifty, twenty-five is left over, goes 5 more times to five, so five and ten are fifteen."

Math Fact Strategy. This involves the retrieval of facts about number relations that do not need to be calculated. For example, 15 / 5 would be solved as "three."

Column Algorithm Strategy. This strategy follows a set of rules for getting from a specific input to a specific output and involves splitting the initial numbers into their respective place values, performing calculations on those separated values, translating number values between places when necessary, and through this process composing a series of partial solutions into a whole (Knuth, 1977). For example, 67 / 6 would be solved as "six goes into six once, nothing to carry. And six goes into seven once with one left over, so it's eleven with a remainder of one."

***Duna* Series Strategy.** The duna series, described in more detail in chapter 6, combines the multiplier and the multiplication designation into a single term, e.g. *tin* [three] *duna* [times two equals] *chaa* [six]. The strategy involves orally progressing through the *duna* sequence up through the multiplier with the multiplicand held constant. It involves solving division problems as a multiplication problems. For example, 12 / 4 would be solved as "*char* [four] *ika* [times one equals] *char* [four], *char* [four] *duna* [time two equals] *aath* [eight], *char* [four] *tiya* [times three equals] *bara* [twelve]."

Successive Halving Strategy. The successive halving strategy uses the relation between the dividend and the divisor as a ratio and successively halving both until a the quotient over one is achieved. For example, 48 / 8 would be solved as " twenty-four to four, twelve to two, so six to one or six."

Grouping Strategy. This strategy involves using the divisor or the dividend to set the number of groups and distributing the other number evenly across the groups. The final group quantity becomes the quotient. For example, 12 / 4 would be solved by making four groups and then placing twelve evenly in the four groups, placing one in each group on a rotating basis until 12 is distributed, creating a final group size of 3.

Estimating Quotient/Grouping Strategy. This strategy is similar to the grouping strategy, but involves first estimating the quotient and then checking the estimation

> through the formation of equal size groups. For example 15 / 3 might be solved as "one, two, three, four, five groups...then putting three in each...should give me...one, two three, four , five, six, seven, eight, nine, ten, eleven, twelve, thirteen, fourteen, fifteen."

The differences in farmers' strategy usage between the single and double digit division problems appeared to be due more to their infrequent attempts to solve the double digit division problems than to a change in strategy use patterns.

Both the shopkeepers and the students relied on a variety of strategies in solving the single digit multiplication problems. Shopkeepers used math facts, iteration, the *duna* series, and successive halving to solve the single digit problems while the students used math facts, column algorithms, and the *duna* series. Again, shopkeepers displayed a greater variety of strategy usage as a group than did students.

On the double digit division problems the students used column algorithms almost exclusively. While the shopkeepers did not use math facts as they had on the some of the single digit problems, a grouping strategy and a column algorithm strategy were used on several occasions. Most of the shopkeepers did not attempt to solve the double digit division problems, however.

Division, at least as formally defined by division problems, may not be central to farming activity in the same way that addition and subtraction seem to be. In a similar manner, double digit divisions problems that can not be solved using the duna series or math facts may not be as central to shopkeeping activity as addition, subtraction, and to a lesser extent, multiplication seem to be.

Though these patterns appear in the group data, they hold true for the majority of the individual participants in the student group and the majority of the shopkeepers on the single digit problems. Individual participants in the farming group on both single and double digit problems and the shopkeeping group on the double digit problems varied from the aforementioned patterns. This may be a result of the small number of participants attempting the problems struggling to develop and/or use strategies with which they are less familiar.

Summarizing the findings from Tables 40A through 40D, the farmers did not change their pattern of strategy use from single to double digit problems. While they generally used a wide variety of strategies, they did not rely as heavily on math facts as did the shopkeepers or the students. Many of the farmers did not attempt to solve the double digit multiplication problems and single or double digit division problems.

The students changed their pattern of strategy use from single to double digit problems, generally from using math facts (and the *duna* series in the case of multiplication) to using column algorithms. They did not use a broad repertoire of strategies compared with either the farmers or the shopkeepers. With one or two exceptions, the students attempted all of the problems with which they were presented.

The shopkeepers changed their pattern of strategy use from single to double digit problems, generally from using math facts to using a wide variety of strategies including reorganization strategies (e.g. decomposition and iteration), counting strategies (min and multiple counting) and column algorithms. With few exceptions the shopkeepers attempted all of the single and double digit addition and subtraction problems and all of the single digit multiplication and division problems. Many of the shopkeepers did not attempt to solve the double digit multiplication and division problems.

The participants' strategies can be classified into four meaningful categories based on the aforementioned findings. The categories are meaningful in that they reduce the complexity of the data while retaining and clarifying the pattern of findings. The four categories are as follows.

- **math facts strategies** - strategies which exclusively involve the use of precalculated and memorized solutions (math facts, *duna* series).

- **column algorithm strategies** - strategies which follows rules for getting from a specific input to a specific output involving splitting the initial numbers into their respective place values, performing calculations on those separated values, translating number values between places when necessary, and composing a series of partial solutions into a whole (column algorithms).

- **counting strategies** - strategies that involve increasing or decreasing numbers by increments of one (min, max, counting forward, counting backward, multiple counting).

- **reorganization strategies** - strategies that involve reorganizing initial numbers into other numbers to facilitate the use of other specific strategies (decomposition, iteration, halving/doubling, grouping, estimating quotient/grouping, successive halving).

Table 41 provides a summary of strategy usage based on these four categories.

Table 41

Categories of Strategies Used by Group and Number of Digits: Structured Interview

	Percentage of Participants Who Used a Strategy Set for One or More Problems Within a Category*					
	Farmers (n = 26)		Shopkeepers (n = 13)		Students (n = 13)	
	single	double	single	double	single	double
Addition						
math fact strategies	19.2	26.9	100	30.8	92.3	23.1
column algorithm strategy	0	0	0	30.8	15.4	92.3
reorganization strategies	26.9	45.9	0	53.9	0	0
counting strategies	69.2	61.5	15.4	45.8	15.4	7.7
Subtraction						
math fact strategies	26.9	15.4	92.3	53.8	92.3	15.4
column algorithm strategy	0	0	0	15.4	15.4	100
reorganization strategies	0	34.6	0	46.0	0	0
counting strategies	73.1	53.8	23.1	84.6	7.7	7.7
Multiplication						
math fact strategies	15.4	3.8	69.2	0	100	7.7
column algorithm strategy	0	0	0	23.1	26.9	92.3
reorganization strategies	23.0	7.6	30.8	15.4	0	7.7
counting strategies	42.3	34.6	38.5	30.8	0	0
Division						
math fact strategies	23.0	0	53.9	7.7	100	15.4
column algorithm strategy	0	0	0	15.4	30.8	100
reorganization strategies	34.6	23.1	38.5	30.8	0	0
counting strategies	0	0	0	0	0	0

* Percentages do not generally total 100 because participants could use more than one strategy within a given set of problems.

The average number of arithmetically correct solutions constructed and the average number of solutions attempted by the participants are displayed in Table 42 below.

Table 42

Arithmetic Problems Attempted and Solved Correctly by Group: Structured Interview

	Mean and (Standard Deviation) of Number of Problems Solved Correctly and Number of Problems Attempted*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Addition			
Single Digits (4)			
correct	3.6 (.6)	4.0 (0.0)	3.9 (.3)
attempted	4.0 (0.0)	4.0 (0.0)	4.0 (0.0)
Double Digits (4)			
correct	3.1 (1.0)	3.7 (.6)	3.8 (.4)
attempted	3.3 (.4)	4.0 (0.0)	4.0 (0.0)
Subtraction			
Single Digits (2)			
correct	1.6 (.6)	2.0 (0.0)	1.9 (.3)
attempted	2.0 (0.0)	2.0 (0.0)	2.0 (0.0)
Double Digits (4)			
correct	2.7 (1.1)	3.9 (.3)	3.8 (.4)
attempted	3.2 (.9)	4.0 (0.0)	4.0 (0.0)
Multiplication			
Single Digits (4)			
correct	2.0 (1.7)	3.1 (1.5)	3.9 (.3)
attempted	2.3 (1.2)	3.7 (1.1)	4.0 (0.0)
Double Digits (3)			
correct	.7 (1.1)	1.2 (1.3)	2.5 (.7)
attempted	1.0 (.6)	1.6 (1.1)	3.0 (.7)
Division			
Single Digits (2)			
correct	1.0 (.9)	1.5 (.9)	1.8 (.4)
attempted	1.0 (.9)	1.8 (.6)	2.0 (0.0)
Double Digits (4)			
correct	.4 (.9)	1.5 (1.5)	3.5 (.8)
attempted	.4 (.9)	2.0 (1.2)	3.8 (.8)

* Mean and standard deviation are based on number of problems attempted rather than number of problems presented.

Problems which were not attempted by the participants during the structured interview most likely would have been solved during their participation in their respective activities by asking another person for assistance or would not have been encountered as part of the activity. For this reason, when a problem on the structured interview was attempted, but an arithmetically incorrect solution was produced, the solution most likely represents a strategic mistake rather than a conceptual inability to solve the particular type of problem. The mean number of problems solved correctly represents the average number of problems that the participants could solve independently without making a strategic error.

The overall pattern of correct solutions is what the reader would expect. Addition and subtraction problems are more frequently solved correctly than multiplication and division problems by the farmer and the shopkeepers. Students achieve a high degree of solution accuracy across all four problem types. Single and double digit problems are solved with relatively equivalent accuracy by students and shopkeepers whereas farmers solve single digit problems with greater accuracy than double digit problems.

Interestingly, the mean numbers of problems attempted were generally within three tenths of the mean number of problems solved correctly for farmers, shopkeepers, and students. This, coupled with individual data suggests that most of the participants were fair judges of which problems they could solve independently and which they could not.

Knowledge of Measures

Measurement plays a role in all arithmetic as part of farming and shopkeeping activities and a limited role in arithmetic at school in math class. In so far as all of the participants engage in farming, however, measurement does play a central role in the arithmetic of all the participants.

Measure words are similar to cardinal number words in that they describe the numerosity of a set (Fuson & Hall, 1983). They have the additional characteristic of possessing a semantic history of objects-to-be-measured, measurement instruments, and economic practices as measurement systems and units (Menninger, 1958/69).

Tables 43A through 43H below display how the participants performed conversions between different units of measure, different measurement systems, and different dimensions of measurement. Four interrelated categories are used to characterize the different measurement conversion relations.

> **Close Conversion\Far Conversion** - whether the conversion is between neighboring units (millimeters and centimeters) or non neighboring units (millimeters and meters).
>
> **Traditional-Traditional\Metric-Metric\Traditional-Metric** - whether the conversion is between traditional

systems of measurement (*muri and maana*), metric systems of measurement (millimeters and centimeters), or between traditional and metric systems of measurement (*haat* and meter).

Within System\Between Systems - whether the conversion is within a single system of measurement (foot and inch) or between systems of measurement (foot and meter).

Within Dimension\Between Dimensions - whether the conversion is within the same dimension (pound and ounce) or between dimensions (yard and acre).

Table 43A indicates that all close conversions between units of time, by definition within the same measurement system and the same dimension, are solved through the use of measurement facts by all of the participants. Far conversions within the same system of time measurement were generally solved by using arithmetic calculation or, in the case of farmers, estimation. All of the far conversions were attempted by the students where as less than half were attempted by the farmers and shopkeepers.

It appears that all of the participants were able to draw on precalculated conversion solutions (e.g. there are 60 minutes in a *ghanta*, or hour) that existed as part of the shared knowledge of the village for the near conversions, but had to construct their own conversion solutions through estimation or arithmetic calculation if they were not a part of that shared base of knowledge.

Table 43A

Modes of Time Measure Conversion by Group: Structured Interview

Conversion Parameters and Modes	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
	Percentage of Participants Who Used Mode One or More Times*		
Same System, Close Conversion (2)			
- measure fact	100	100	100
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation	0	0	0
Same System, Far Conversion (2)			
- measure fact	0	0	7.6
- arithmetic conversion	7.7	23.0	92.4
- physical conversion	0	0	0
- estimation	23.0	15.4	0

* Percentages do not generally total 100 because participants could use more than one strategy within a given set of problems.

It is difficult to envision an activity which would require far time conversion (e.g. from seconds to *ghanta*) other than perhaps a word problem in a math class, hence far conversions may rarely be instantiated as measurement facts within a society or a given activity. Arithmetic calculation and estimation are used by many of the participants, particularly the students, to construct answers where none existed before as part of the shared knowledge of a given activity.

The pattern appears somewhat different for length measurement conversion as shown in Table 43B. The farmers and the shopkeepers generally have access to measurement facts for close conversions within the same traditional system of length measurement, whereas the students rely more on estimation. Note that arithmetic calculation is not particularly feasible with traditional systems and units of length measure which are not standardized, e.g. between *aula* (fingers) and *haat* (forearm and hand length). What is feasible is physical conversion by counting the number of *aula* that equal one's *haat*. A number of farmers, shopkeepers, and students used this mode of measurement conversion.

A number of the farmers and shopkeepers used measurement facts for far length conversions as well, suggesting that farming and shopkeeping activity, but not schooling involve the use of such conversions, though students do have some farming experience. It therefore appears that the activity of origin rather than the adjacency of the measurement units alone is associated with whether or not a measurement fact exists for a particular participant to construct the conversion through physical conversion or estimation. As we shall see, this is not necessarily the case across different systems of measures on other dimensions. While most of the farmers and shopkeepers attempted the conversions through physical conversion and estimation, most of the students were unwilling to attempt such conversions.

Table 43B

Modes of Length Measure Conversion by Group: Structured Interview

Conversion Parameters and Modes	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
	Percentage of Participants Who Used Mode One or More Times*		
Trad.-Trad., Same System, Close Conversion (4)			
- measure fact	84.6	76.9	15.4
- arithmetic conversion	0	0	0
- physical conversion	15.4	23.0	23.0
- estimation	0	0	61.5
Trad.-Trad., Same System, Far Conversion (2)			
- measure fact	30.8	46.2	0
- arithmetic conversion	7.7	23.0	15.4
- physical conversion	23.0	46.2	7.6
- estimation	53.8	11.5	11.5
Trad.-Trad., Diff. System, Close Conversion (3)			
- measure fact	0	0	7.6
- arithmetic conversion	0	0	15.4
- physical conversion	50.0	69.2	15.4
- estimation	80.8	61.5	15.4
Metric-Metric, Same System, Close Conversion (1)			
- measure fact	7.7	76.2	92.3
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation	11.5	7.6	0
Metric-Trad., Diff. System, Close Conversion (3)			
- measure fact	15.4	69.2	0
- arithmetic conversion	0	0	0
- physical conversion	30.8	30.8	15.4
- estimation	19.2	23.0	38.5

* Percentages do not generally total 100 because participants could use more than one strategy within a given set of problems.

Measurement facts do not appear to exist for conversion across different systems of traditional length measures, requiring nearly all of the conversion.

Few of the farmers, but most of the shopkeepers and students used measurement facts for close conversions within the metric system. Through an oversight, far conversions within the metric system were not included in the final version of the structured interview. Performances on the near conversions reflect most of the farming participants' lack of familiarity with the metric system, at least in terms of length, and shopkeepers' and students' relatively familiarity. Shopkeepers who sell cloth measure and price the cloth using the metric system. The only system of measurement taught in school is metric. Again, it appears to be the particular activities in which the participants engage in addition to the characteristics of the conversions themselves that give meaning to and determine whether and how the conversions are attempted.

Interestingly, several of the farmers and a number of the shopkeepers used measurement facts to convert from traditional to metric systems of length. This reflects the fact that these participants have "standardized" their traditional length measures in relation to the metric system, e.g "a piece of cloth starting at my elbow and wrapping over the ends of my fingers to the second knuckle is half a meter."

Table 43C

Modes of Weight Measure Conversion by Group:Structured Interview

Conversion Parameters and Modes	Percentage of Participants Who Used Mode One or More Times*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Trad.-Trad., Same System, Close Conversion (5)			
- measure fact	100	100	100
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation	0	0	0
Trad.-Trad., Same System, Far Conversion (2)			
- measure fact	26.9	46.2	15.4
- arithmetic conversion	42.3	76.9	76.9
- physical conversion	0	0	0
- estimation	7.7	15.4	15.4
Trad.-Trad., Diff. System, Close Conversion (1)			
- measure fact	0	53.8	0
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation	26.9	30.8	11.5
Metric-Metric, Same System, Close Conversion (1)			
- measure fact	0	76.2	92.3
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation	11.5	7.6	0
Metric-Trad., Diff. System, Close Conversion (3)			
- measure fact	69.2	92.3	61.5
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation	19.2	38.5	30.8

* Percentages do not generally total 100 because participants could use more than one strategy within a given set of problems.

None of the students used such a mode of conversion, relying more on physical conversion and estimation.

Table 43C above displays the different modes used by the participants in converting measures of weight. The pattern of the participants' modes of converting between different measures of weight were similar to their conversions of length, with two exception.

First, all of the participants used measurement facts as the sole mode of close conversion between traditional measures in the same system. Unlike with traditional units of length, traditional units of weight have a fixed relation to one another, eg. two *bisoli* always equals exactly one *dharni*. This fixed relation appears to support the development of measurement facts more than the variable relation between finger width and arm length, for example.

Second, most of the participants had access to measurement facts which allowed them to convert between traditional and metric systems of weight, whereas students and farmers generally did not possess such measurement facts for length. This reflects the general importance of traditional to metric weight conversions in rural Nepali society today, particularly in farming which all of the participants are involved with.

Dry volume measures are prototypic measures in farming activity, in large part because they are used to measure grain yields which are central to the motive of farming activity. Table 42D indicates that close conversions were solved by all of the participants by using measurement facts, e.g. eight *maana* equal one *pathi*. However, few of the participants possessed a measurement fact for far conversions in dry volume. Arithmetic conversion was the preferred mode for a majority of the participants doing the far conversion, though a number of the farmers did not attempt the conversion. All of the shopkeepers and students who did not have access to a measurement fact for the conversion were able to construct the solution using some form of calculation.

Table 43D

Modes of Dry Volume Measure Conversion by Group: Structured Interview

	Percentage of Participants Who Used Mode One or More Times*		
Conversion Parameters and Modes	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Trad.-Trad., Same System, Close Conversion (2)			
- measure fact	100	100	100
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation			
Trad.-Trad., Same System, Far Conversion (1)			
- measure fact	19.2	23.0	7.6
- arithmetic conversion	38.4	76.9	92.2
- physical conversion	0	0	0
- estimation	11.5	0	0

* Percentages do not generally total 100 because participants could use more than one strategy within a given set of problems.

Table 42E displays the modes of conversion used by the participants among units and systems of wet volume measure. A majority of the farmers and the shopkeepers had access to measurement facts that they used

Table 43E

Modes of Wet Volume Measure Conversion by Group: Structured Interview

Conversion Parameters and Mode	Percentage of Participants Who Used Mode One or More Times*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Trad.-Trad., Same System, Close Conversion (2)			
- measure fact	84.6	84.6	38.5
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation	11.5	7.6	61.5
Trad.-Trad, Same System, Far Conversion (1)			
- measure fact	7.7	53.8	0
- arithmetic conversion	19.2	46.1	100
- physical conversion	0	0	0
- estimation	73.1	0	0
Metric-Metric, Same System, Close Conversion (1)			
- measure fact	11.5	76.9	100
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation	11.5	23.1	0
Metric-Trad., Diff. System, Close Conversion (3)			
- measure fact	7.7	84.6	0
- arithmetic conversion	0	0	30.8
- physical conversion	0	0	0
- estimation	30.8	46.1	46.2

* Percentages do not generally total 100 because participants could use more than one strategy within a given set of problems.

in the conversion between traditional units of dry volume measure. Most. but not all of the students relied on estimation for the same conversions. This difference reflects the fact that metric measures of liquid volume (particularly liter and half a liter) have come to replace the traditional measures throughout much of the village. As most of the student participants are younger than the shopkeepers and farmers and most villages activities that currently involve wet volume measurement use a metric rather than a traditional system of measure, many of the students did not have access to these measurement facts.

Most of the shopkeepers used measurement facts for far conversions within the traditional system of wet volume measure and for close conversions between traditional and metric systems. The farmers and the students rarely used measurement facts for these conversions, resorting to the use of arithmetic conversion and estimation instead. Far conversions between traditional wet volume units and conversions between traditional and metric systems of wet volume measure are frequently used as part of shopkeeping activity and not generally seen as part of farming or school activities. The activity-specific nature of conversions such as these are directly reflected in the availability of measurement facts for the different groups of participants.

Most of the students and shopkeepers used measurement facts for close conversions within the metric system of wet volume measure whereas the farmers, generally less familiar with metric forms of wet volume measure other than a single liter, did not have access to such measurement facts and in most cases did not attempt the conversion.

Table 42F displays the modes of conversion used by the participants among units and systems of area measure. Traditional area measures are prototypic measures in farming activity, in large part because they are used to measure wealth and potential grain yields which are central to the motive of farming activity. Close conversions within the traditional systems of measure is so central to farming activity that all of the participants did the conversion with a measurement fact. This should not be taken as a given in so far as using a measurement system does not always require knowledge of one or more measurement facts. For example, many farmers could estimate or even measure a meter length without knowing how many centimeters are in a meter.

While some of the participants in each group were able to do the far conversions within the same system of measurement using measurement facts, most had to rely on arithmetic conversion, indicating that while the relations between the units were easily specifiable, the conversion solutions needed to be constructed. Conversions between two traditional systems of area measurement involved estimation on the part of all of the participants,

Table 43F

Modes of Area Measure Conversion by Group: Structured Interview

Conversion Parameters and Modes	Percentage of Participants Who Used Mode One or More Times*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Trad.-Trad., Same System, Close Conversion (4)			
- measure fact	100	100	100
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation	0	0	0
Trad.-Trad., Same System, Far Conversion (3)			
- measure fact	38.5	30.8	23.0
- arithmetic conversion	65.4	69.2	77.0
- physical conversion	0	0	0
- estimation	15.4	15.4	0
Trad.-Trad., Diff. System, Close Conversion (3)			
- measure fact	15.4	7.7	0
- arithmetic conversion	0	0	15.4
- physical conversion	0	0	0
- estimation	100	100	100

* Percentages do not generally total 100 because participants could use more than one strategy within a given set of problems.

however, reflecting not only the need to construct a conversion solution, but also the lack of easily specifiable relations between the units across the two systems, e.g. one *ropani* of land is equivalent to 10.346 *dhur*.

Metric measures are not used to measure land area except by government officials and most villagers were not familiar with them. For this reason metric area measures were not included as part of the interview.

Table 43G displays the mode of conversion used by the participants among units of monetary measure. All participants used measurement facts alone for both the close and far conversions. This is indicative of the widespread use of money by the villagers across farming, shopkeeping and, to a lesser extent, schooling activities.

Table 43G

Modes of Money Measure Conversion by Group: Structured Interview

Conversion Parameters and Modes	Percentage of Participants Who Used Mode One or More Times*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Trad.-Trad., Same System, Close Conversion (2)			
- measure fact	100	100	100
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation	0	0	0
Trad.-Trad., Same System, Far Conversion (2)			
- measure fact	100	100	100
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation	0	0	0

* Percentages do not generally total 100 because participants could use more than one strategy within a given set of problems.

Table 43H indicates the modes of conversion across dimensions:

conversions which are necessarily across different systems of measurement as well. The conversion between weight and dry volume was generally carried out by the farmers and shopkeepers using measurement facts. Farming and shopkeeping are activities in which grain, generally measured

Table 43H

Modes of Measure Conversion Across Dimensions by Group: Structured Interview

Conversion Parameters and Modes	Percentage of Participants Who Used Mode One or More Times*		
	Farmers (n = 26)	Shopkeepers (n = 13)	Students (n = 13)
Weight-Dry Volume, Trad.-Metric (2)			
- measure fact	53.8	100	23.0
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation	19.2	0	69.2
Area-Dry Volume, Trad.-Trad. (2)			
- measure fact	73.8	69.2	23.0
- arithmetic conversion	0	0	0
- physical conversion	0	0	0
- estimation	100	100	100.0

* Percentages do not generally total 100 because participants could use more than one strategy within a given set of problems.

in traditional dry volume units, is sold or husked/ground at a mill using metric measures of weight. Schooling, however, does not involve cross-dimensional measurement of this sort. Though the students had some farming experience, they used estimation more frequently than measurement facts to do the conversion.

The conversion between area and dry volume is one that is commonly done in estimating the yield of one's fields. All of the participants used estimation and in some cases measurement facts to do the conversion. The participants used measurement facts after specifying what the weather and field conditions should be like, basing it on their family's fields. When the unit of area did not match that used in their family's fields the participants used estimation. Again, farmers and shopkeepers used measurement facts for the conversion in a greater percentage of cases than did the students.

A general pattern emerges from the participants' measure conversions. Measurement facts were generally used by a participant when the conversion to which it was a solution occurred frequently and/or was important to the activity or activities in which the participant engaged. This was independent of whether the measurement fact was for a near or far conversion, across systems different of measurement, or even across different dimensions.

If, however, the activities in which they participated did not embody the measurement fact and/or the participant was a relatively peripheral participant in the activity, as in the case of students farming, it often became necessary for the participant to construct a solution to the conversion during the interview. When this was accomplished it was generally done through estimation, arithmetic calculation, or physical conversion. These modes of conversion were sensitive to whether the units were multiples of each other, whether the units were relative or standardized, and whether a physical conversion was possible. In short, the nature of the measures themselves, not their use in a particular activity, affected the mode of conversion used by the participants along with the participants' knowledge of strategies and calculation artifacts.

From these analyses it becomes clear that strategies for manipulating numbers, the affordances and constraints of different forms of artifacts, and meanings in the form of measures embody arithmetic as part of social practices and activities in Bherighat. These analyses examined strategies, artifacts, as separate entities. The chapter which follows examines them together, organized as problems derived from farming, shopkeeping, and schooling activities.

IX. INITIAL TASKS: ANALYSES AND FINDINGS

The initial tasks were simulations of events derived from farming, shopkeeping, and schooling activities. Each of the three sets of tasks were presented to each of the 52 participants. This was done not only to examine how each participant group did arithmetic as part of the tasks derived from their primary activity, but also how they did arithmetic on tasks from activities that they did not participate in or were peripheral to. The later was important given the participants participation in multiple activities, e.g. shopkeepers farm and students buy things from Bherighat shops.

It was determined that the principal research questions introduced in Chapter 4 could be satisfactorily addressed through analyses of the shopkeeping and schooling groups alone. The farming group (no schooling and no shopkeeping), while important in its own right, does not allow the separating of the effects of participating in farming activity from schooling or shopkeeping, as was explained in Chapter 5. Therefore the initial problem solving data and tracking task data for the farmers will not be included in the analyses that follow. The analyses will be based on data from the shopkeeping and schooling groups alone.

Strategies and artifacts were the primary units of behavior coded from the structured interviews in Chapter 8. Both of these units and a third, that of goal-directed organization (GDO), are coded for in conjunction with one another on the initial tasks. These units and the coding categories the contain are described in detail below. They have been refined on the basis of the interview analyses.

Strategies

Strategies are the means by which a particular task is accomplished under certain objective circumstances, or conditions, within a particular goal-directed organization. In this case of this study, the strategies are those used in arithmetic calculation, though the goal-directed organization may or may not be mathematical in nature. They were coded from the video tapes using verbalizations, physical actions, and artifacts in conjunction with the nature of the task to distinguish between the strategies.

> **math fact strategies.** All arithmetic strategies can involve the use of math facts at some point. However, for the purposes of coding a math fact strategy involves the exclusive use of precalculated arithmetic solutions to construct a solution.
>
> **counting strategies.** Both column algorithm and reorganization strategies can involve the use of counting. However, a counting strategy involves the exclusive use of incrementing or decrementing the initial numbers by a consistent amount to construct a solution.
>
> **column algorithm strategies.** Strategies which involve the separation of initial numbers into column values, performance of arithmetic operations on those values, and recomposition of the

results to construct a solution. These strategies could be a special case of a reorganization strategy if it were not for their algorithmic nature, i.e. their generalizability and inflexibility with respect to the characteristics of the numbers involved.

reorganization strategies. Strategies which involve the reorganization of initial numbers into numbers and operations that possess characteristics that specifically facilitate the construction of a solution.

Math facts and counting strategies are first order strategies, i.e. they can not subsume other strategies, whereas column algorithm and reorganization strategies are second order strategies because they always encompass math fact and/or counting strategies.

Artifacts

Artifacts are the symbols, texts, signs, and technologies that function to coordinate humans with the physical world and each other, possessing histories-in-practice which often extend across activities and generations of individuals (Wartofsky, 1979). All artifacts have both an ideal (conceptual) and material (physical) aspect (Cole, 1990). Which aspect is consciously attended to at a particular moment depends on the particular social practice in which one is engaged. Coding of the artifacts was relatively straightforward as their use was apparent from the video tapes. In this case of this study, the artifacts examined are those used in arithmetic calculation.

paper and pencil artifacts. Written numerals and/or written equation formats used in arithmetic calculation.

object artifacts. Fingers, seeds, tallys, pictures, and actual target objects, e.g. candies used in arithmetic calculation.

no artifacts. Arithmetic calculations are performed without the use of artifacts at the time the calculations are performed, though the strategies used may have developmental origins in the use of particular form of an artifacts.

Goal-Directed Organizations

A goal-directed organization (GDO) is the overall coherence of a task event associated with the formation and achievement of goals and related actions associated with those goals as part of an activity. The GDO coordinates artifacts and strategies through a specific set of conditions and an anticipated future which are properties of the person-activity relation. GDO's are not superordinate to artifacts and strategies, but rather are the "glue" that holds them together in a particular organization as a part of a particular practice. They are not purely mental phenomena, but rather represent the person's perception of future through participation in an activity. For example a goal-directed organization for participating in schooling activity such as math instruction may not only include obtaining the correct solution, but also how one should obtain the solution, e.g using column algorithms, but not math facts or counting which are first order strategies. For shopkeeping activity the goal-directed organization could involve achieving the correct pricing and making it clear to the customer that it is a fair price, allowing strategies and artifacts, including column algorithm strategies, free to vary and adapt to the particular characteristics of the numbers and the shopkeepers's knowledge. Goal-directed organizations are associated with the particular task event as well as the person and the activity. For this reason they cannot be specified by a general set of coding categories across tasks and activities.

GDO's were distinguished and coded using the apparent goal of the task-in-isolation, determining whether the participant's strategies, artifacts, and verbalizations reflected that goal or not, and if not, then what the alternative GDO might be that would match those strategies, artifacts, and verbalizations. In some cases alternative GDOs could only be disambiguated on the level of the group through the observation of patterns and not on the level of the individual. Clearly, this method of coding would not afford claims of GDO's causing changes in strategies and artifacts because the determination of GDO's is partially dependent on the strategies and artifacts which it embodies. As discussed above, GDOs are not part of a hierarchy that subordinates strategies and artifacts, but rather are part of a tripartate organization in which they provide organization by giving directionality to the practice.

These definitions of strategies and goal-directed organization are related to Leont'ev's (1981) tripartite system of structural-functional relations: activity-motive, action-goal, operation-condition (See Beach, 1992 for a more detailed discussion). Like Leont'ev's operations-conditions pairing, the "content" of strategies can become goal-directed organizations. The "content" of goal-directed organizations, like Leont'ev's goal-action pairing, have the potential of developing into strategies. However, they differ from Leont'ev's conception in two ways.

First, actions-goals and operations-conditions can only occur in conjunction with one another. While it is possible for different actions to be associated with the same goal and different operations to function under the same conditions, changes in these associations for an individual are necessarily a byproduct of shifts in content between action and operation functions and between goal and condition functions. Analyzing goals independent of actions and operations independent of conditions contributes no additional information, at least for the purposes of this study.

Second, artifacts did not play an explicit role in Leont'ev's structural-functional system of activity, whereas they play a prominent role in this study. It is difficult to conceive of how there can be "content" that changes through Leont'ev's structural-functional relations without the use of artifacts of one form or another at some point in the developmental process. A similar point has been made by Wertsch (1989) among others, suggesting that artifacts and the process of semiosis provide an empirical bridge between activity and Vygotskian theories.

The reliability of the coding schemes was a concern. For this reason a procedure was established by which interrater relibility could be established on a five percent sample of the video data. Working in the U.S. with two Nepali raters, the researcher found that they had difficulty understanding the villager's arithmetic and some of the language. Both raters had been born and raised in Kathmandu, and had little or no contact with rural Nepal. The researcher then established what amounted to instructional sessions in which he taught the Nepali raters the villagers' forms of arithmetic and explained words in the rural dialect that were unclear. It became clear that the process was one of establishing intersubjective agreement, much as one become a functioning member of a culture. This in turn suggested that achieving reliability reflected the degree to which the raters became aculturated to the data, and the researcher's instruction, rather than the reality of the data. A decision was made to not obtain interrater reliability for this reason. Reliability as aculturation to data, and the problem it raises for scientific assumptions of truth is worth further exploration.

Farm Tasks

Five categories of problem solving tasks were derived from farming activity in Bherighat: estimating and measuring the volume of rice, estimating field planting/yield, weighing and dividing meat, word problems, correcting the measurements of a plow. All five categories of tasks could routinely occur as part of farming practices highlighted as typical of farming activity. Each task category was analyzed separately: describing the participants' uses of artifacts, strategies, goal-directed organization, and the correctness of their solutions.

Measures and their "content", e.g. unhusked rice, were generally taken to be non-negotiable by the participants, whereas goal-directed organizations, artifacts, and strategies were underspecified by the task presentation and varied in the solution process.

Estimating and measuring the volume of rice

Table 44A indicates that nearly 69.3 percent of the shopkeepers estimated the volume of unhusked rice within less than a *pathi* of the actual volume whereas only 7.7 percent of the students did so. This reflects the shopkeepers' willingness and or ability to make finer distinctions than a *pathi* in their estimation. All but one of the students made whole pathi estimates whereas only 4 of the shopkeepers did so.

Table 44A

Accuracy of Unhusked Rice Estimation (14.5 kilograms): Initial Farming Tasks

	Percentage of Participants	
	Shopkeepers (n = 13)	Students (n = 13)
8 *pathi*	0	23.1
7 pathi	15.4	30.8
6 pathi, 3 maana	38.5	7.7
6 *pathi*, 2 *maana*, 3 *muthi*[1]	----	----
6 pathi, 1 maana	30.8	0
6 *pathi*	15.3	30.8
5 *pathi*	0	7.7

[1] Most accurate estimate based on modal measurement of unhusked rice by farming participants. Note that 1 *pathi* contains 8 *maana* and 1 *maana* contains 6 *muthi*.

Table 44B displays the accuracy of participants' actual measurement of the unhusked rice volume. Over half of the shopkeepers obtained our most accurate measure of the rice volume whereas only 15.4 percent of the students did so. Most of the students who did not obtain the most accurate measurement over-measured rather than under-measured the volume of the unhusked rice. Unlike the students, those shopkeepers who did not obtain the most accurate measurement constructed measurements which were relatively evenly distributed

Table 44B

Accuracy of Unhusked Rice Measurement (14.5 kilograms): Initial Farming Tasks

	Percentage of Participants	
	Shopkeepers (n = 13)	Students (n = 13)
more than 6 *pathi*, 3 *maana*	0	7.7
6 *pathi*, 3 *maana*	0	15.4
6 *pathi*, 2 *maana*, 5 *muthi*	7.7	15.4
6 *pathi*, 2 *maana*, 4 *muthi*	15.4	38.5
6 *pathi*, 2 *maana*, 3 *muthi*[1]	61.5	15.4
6 *pathi*, 2 *maana*, 2 *muthi*	15.4	7.7
6 *pathi*, 2 *maana*, 1 *muthi*	15.4	7.7
6 *pathi*, 1 *maana*	0	0
less than 6 *pathi*, 1 *maana*	0	0

[1] Most accurate measurement based on modal measurement of unhusked rice by farming participants. Note that 1 *pathi* contains 8 *maana* and 1 *maana* contains 6 *muthi*.

around the accurate measurement. The reason for this becomes apparent when we examine Table 44C.

Table 44C displays different strategies, artifacts, and goal-directed organizations for measuring the volume of the unhusked rice. One goal-directed organization maximizes accuracy and the other maximizes speed.

The goal-directed organization that maximizes accuracy involves first checking the copper *pathi* container against the copper maana container to make sure that the *pathi* contains eight *maana*. After measuring out the number of full pathi, the participant measures out the number of *maana* of the remaining grain, followed by the number of *muthi*, or handfuls. The *pathi* and *maana* are

Table 44C

Strategies and Artifacts in Unhusked Rice Measurement (14.5 kilograms): Initial Farming Tasks

	Percentage of Participants	
	Shopkeepers (n = 13)	Students (n = 13)
With Careful Heaping		
Checked *Pathi*		
used *muthi*[1]	61.5	0
didn't use *muthi*	0	0
Didn't Check *Pathi*		
used *muthi*	38.5	7.7
didn't use *muthi*	0	0
Without Careful Heaping		
Checked *Pathi*		
used *muthi*	0	7.7
didn't use *muthi*	0	0
Didn't Check *Pathi*		
used *muthi*	0	30.8
didn't use *muthi*[2]	0	53.8

[1] Denotes combination of strategies and artifacts in a goal-directed organization (GDO) that maximizes accuracy of measurement, but minimizes speed.
[2] Denotes combination of strategies and artifacts in a goal-directed organization (GDO)that maximizes speed of measurement, but minimizes accuracy.

filled initially by scooping up the rice with the container and then gently and repeatedly heaping additional rice on top until it flows down the sides of the mound and out of the container several times. This constitutes a full and accurate measure.

The goal-directed organization that maximizes speed does not involve an initial checking of pathi container, involves a single addition to the container with rice scooped into it rather than repeated gentle heapings, and any unhusked rice remaining after the number of full *maana* has been counted is rounded up to another full *maana* or rounded down and discounted. A *muthi* measure is not used.

Several intermediate versions exist of these goal-directed organizations exist as well, achieving more of balance between accuracy and speed.

A majority of the shopkeepers used the accuracy goal-directed organization, reporting that this is how they would usually measure their grain with measuring instruments that were not their own. A majority of the students used the speed goal-directed organization, reporting that this was how they would do it with their family's crops. While this would explain their not checking the capacity of the *pathi* artifact for accuracy, it does not offer an explanation for their not carefully heaping the grain and not using the *muthi* measure. They may have viewed the task as one to complete quickly because it was not a part of real framing activity, or they may not measure grain as accurately as the shopkeepers in farming activity. Corroborating evidence for the latter came from several of the parents who indicated that their children were often careless in measuring crop yields and could not be trusted to be accurate.

Most of the students who did not obtain the most accurate measurement over-measured rather than under-measured the volume of the unhusked rice, as indicated in Table 44B. The over measure is explained by the fact that all but one of the students who over measured did not carefully heap the rice, resulting in more rice being leftover to measure a greater number of *maana* being included in the solution.

Estimating field planting/yield

Table 45 displays the shopkeeping and schooling participants' estimations of planting and harvest yields of an irrigated field for corn, wheat, and rice. Irrigation is used only for the rice crop. They were also asked to estimate planting and harvest yields for the three crops if the field was located by the riverside, making the land more valuable than it was in its actual location.

The participants were on the average quite accurate in their estimates of the seed to be sown and the harvest yields for corn, rice, and wheat crops from the actual field. The students and the shopkeepers were approximately equivalent in the accuracy of their estimations. Over three quarters of the students and shopkeepers reported taking water availability and soil quality into account in making their estimation. All but one of the

Table 45

Accuracy of Field Planting/Yield Estimates in *Maana*[1]: Initial Farming Tasks

	Shopkeepers (n = 13)		Students (n = 13)	
	Mean	(SD)	Mean	(SD)
Corn				
Sow				
actual field	1.0	(0)	0.9	(0.2)
riverside field	1.3	(0.4)	1.2	(0.8)
Harvest				
actual field	125.6	(1.4)	137.1	(1.8)
riverside field	72.3	(1.0)	129.0	(2.3)
Wheat				
Sow				
actual field	6.1	(0.2)	5.8	(0.3)
riverside field	5.8	(0.5)	5.0	(0.6)
Harvest				
actual field	158.5	(0.8)	168.6	(1.7)
riverside field	240.0	(1.2)	171.5	(2.0)
Rice				
Sow				
actual field	5.3	(0.2)	5.4	(0.4)
riverside field	5.2	(0.6)	4.8	(0.6)
Harvest				
actual field	318.8	(0.9)	334.8	(1.6)
riverside field	412.4	(1.4)	344.4	(2.5)

[1] Field area was 1 *dhur* or approximately 220 sq meters. Actual amounts of seed sown in the previous year for corn was 1 *maana*, 6 *maana* for wheat, and 5.5 *maana* for rice. Actual yields from the previous year for corn was 123 *maana*, 163 *maana* for wheat, and 316 *maana* for rice.

participants (a student) reported making their judgment using their own family's fields as a base.

A distinction appears between the shopkeepers and the students when we compare their estimation of harvest yields for the actual and the hypothetical riverside fields. The shopkeepers correctly decreased their harvest estimates for the riverside field for corn and increased their estimates for wheat and for rice. Corn prefers a dryer field whereas wheat and particularly rice thrive in wetter fields such as those found by the riverside. The students generally did not make such adjustments. In explaining their estimates eight of the ten shopkeepers commented on the riverside field harvest relative to the actual field harvest whereas only one of the students did so. In this case the difference between the students and the shopkeepers is probably not due to a differential interpretation of the task so much as a difference in the shopkeepers' and the students' knowledge of farming as a basis for estimation.

The amount of seed sown should not differ for the two fields and on the average did not differ in the participants' estimates.

Weighing and dividing meat

Tables 46A and 46B display the artifacts and goal-directed organizations used by participants in two tasks events in which they were asked to use a *tulo* or single-pan scale to divide a number of weighted sacks simulating meat evenly among people who had "bought into" the animal slaughtered.

Goal-directed organizations were distinguished on the basis of the combination of strategies and artifacts used. This process was inferential, tying combinations of artifacts and strategies to goal-directed organizations inherent in farming and schooling activity. These tasks would not have occurred as a part of shopkeeping activity. Where possible, post-solution descriptions of the event were used to corroborate the inferences. In no case did they contradict the inference. Strategies did not vary within the goal-directed organizations for this particular set of tasks and therefore were not analyzed separately.

All but one of the shopkeepers in the first task event (Table 46A) displayed a goal-directed organization in which they would weigh a "piece of meat" and place it on a straw mat in a location that stood for a particular participant, weigh another piece and place it in a new location for yet another participant if it is the same weight, or if it is a different weight, place it on the previous participant's pile. This was continued until all five participants had equivalent weights of meat. Two of the farmers also checked the final weights by placing the combined pieces for each participant on the *thulo*, making sure they were equivalent. This goal-directed organization and strategy does not appear to involve any arithmetic calculation beyond counting and in fact may have involved

Table 46A

Weighing and Dividing Meat, Goal-Directed Organization by Percent Correct:

Initial Farming Tasks

	Shopkeepers (n = 13)					Students (n = 13)				
	f	percent correct	pp[1]	ob	na	f	percent correct	pp	ob	na
Ten pieces of meat of two different weights to be divided evenly between five people (1)										
Obtain total weight of meat, then divide by number of recepients[2]	0	0.0	0	0	0	8	25.0	7	0	1
Determine equal weights of meat and divvy them between the participants[3]	12	100	0	12	0	2	100	0	2	0
Switched from total weight GDO to divvying GDO	1	100	1	1	0	3	66.6	3	3	0

[1] Number of participants who used a particular artifact one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers), na=no external artifact. Because participants can use more than one type of artifact to solve a problem, the total may be greater than the number of participants.
[2] This goal-directed organization (GDO) is directly associated with giving an equal portion of meat to each participant and does not involve arithmetic calculation. As such it is most directly associated with farming activity.
[3] This goal-directed organization (GDO) is directed associated with achieving an arithmetic solution and only through that solution, giving an equal portion of meat to each participant. As such it is most directly associated with schooling activity.

subitization rather than counting in some cases. Two of students did similarly. However, eight used what can best be described as an arithmetic goal-directed organization, converting the task event into one that could be

Table 46B

Weighing and Dividing Meat, Goal-Directed Organization by Percent Correct: Initial Farming Tasks

	Shopkeepers (n = 13)					Students (n = 13)				
	f	percent correct	pp[1]	ob	na	f	percent correct	pp	ob	na
Sixteen pieces of meat of two different weights to be divided evenly between six people (1)										
Obtain total weight of meat, then divide by number of recepients[2]	0	0.0	0	0	0	7	14.3	7	0	0
Determine equal weights of meat and divvy them between the participants[3]	13	100	0	13	0	2	50.0	0	2	0
Switched from total weight GDO to divvying GDO	0	0.0	0	0	0	4	100	4	4	0

[1] Number of participants who used a particular artifact one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers), na=no external artifact. Because participants can use more than one type of artifact to solve a problem, the total may be greater than the number of participants.

[2] This goal-directed organization (GDO) is directly associated with giving an equal portion of meat to each participant and does not involve arithmetic calculation. As such it is most directly associated with farming activity.

[3] This goal-directed organization (GDO) is directed associated with achieving an arithmetic solution and only through that solution, giving an equal portion of meat to each participant. As such it is most directly associated with schooling activity.

solved with a single division equation. This was accomplished by finding the total weight of the pieces using the *tulo* and dividing by five to arrive at the correct weight for each person. All but one of the eight students cumulatively added the weights of the pieces using paper and pencil and do the division using a written division algorithm. Two of these students actually ended the event by stating the correct weight without actually distributing the pieces to five locations. One of the shopkeepers and three of the students began with the arithmetically-based organization, but backtracked and switched to the distribution-based organization once they tried using paper and pencil notation.

All participants using the distribution-based organization used the simulated meat pieces as counting artifacts. With the exception of one student, all participants used a paper and pencil along with a column algorithm strategy when working with an arithmetic-directed organization.

Table 46B displays a similar pattern of performance for the second task event involving six people and sixteen simulated pieces of meat.

On all but one occasion the participants who initially used the distribution-based organization, shopkeepers and students alike, correctly completed the task, but less than one quarter of the participants (all students) produced a correct solution using the arithmetic-based organization. The correctness of solutions appears to affect on learning of participants as all those who switched goal-directed organizations shifted from arithmetic- to distribution-based organizations, and not the reverse.

However, the three students who switched goal-directed organizations on the first task event approached the second by again using the arithmetic-based organization and again switched to the distribution-based organization. Two of these three students achieved a correct solution on the first task, yet persisted in beginning with a arithmetic- directed organization on the second.

The distribution goal-directed organization is more strongly associated with achieving a correct distribution of meat than is the arithmetic-directed organization. It is also more strongly associated with the use of simulated meat pieces as counting objects whereas the arithmetic-directed organization is associated with the use of written artifacts and column algorithm strategies. However, the realization of a correct solution by a participant, a goal-directed organization, and the particular artifacts and strategies used are not inexorably linked to one another as illustrated by the individual exceptions to the group associations.

Word problems

Table 47 displays the artifacts and strategies used by participants on eight word problems that simulate actual occasions for arithmetic calculation in farming activity. Because of the nature of these task events, i.e. they could be interpreted as tied to farming or schooling activities with equal ease and could be solved equally well as math word problems or as a events encountered in farming, it was difficult to establish clear distinctions between goal-directed organizations. These tasks would not occur in shopkeeping. For similar reasons, post-solution descriptions of the event could generally not be used to disambiguate any inferences we might make regarding goal-directed organizations. However, strategies and artifacts did vary together in several systematic ways, ways that allow some tentative inferences as to how the task events might relate to farming and schooling activities.

The first clear pattern emerges in the two sets of tasks that involve addition or subtraction operations unless reorganization occurred: finding the total grain yield and finding the difference in grain yields. None of the shopkeepers used written artifacts and column algorithm strategies in solving the tasks, though four used a counting strategy with fingers or seeds and one a counting strategy without any external artifacts at least once. Those shopkeepers who used reorganization strategies did so without the use of external artifacts. A majority of the shopkeepers used a math fact strategy to solve these tasks. By definition, math facts do not involve the use of any external artifacts, though they may originate in their use.

Roughly equal numbers of students used math fact strategies without external artifacts and column algorithm strategies with written artifacts one

Table 47

Word Problems, Strategy by Mean Number Correct, by Artifacts Used: Initial Farming Tasks

	Shopkeepers (n = 13)				Students (n = 13)			
	mean(sd) correct[1]	pp[2]	ob	na	mean(sd) correct	pp	ob	na
Find grain yield total (2)	1.8(.5)				1.8(.4)			
math fact str.		0	0	13		0	0	10
col. algo. str.		0	0	0		8	0	3
reorgan. str.		0	0	3		0	0	0
counting str.		0	4	5		0	3	1
Find grain yield difference (2)	2.0(0)				1.8(.4)			
math fact str.		0	0	9		0	0	10
col. algo. str.		0	0	0		13	0	2
reorgan. str.		0	0	6		0	0	0
counting str.		0	4	3		0	0	0
Find total pay for multiple fieldworkers (2)	1.8(.2)				1.8(.1)			
math fact str.		0	0	12		0	0	10
col. algo. str.		2	0	0		13	0	0
reorgan. str.		0	2	3		0	0	0
counting str.		0	2	3		0	0	0
Find pay for each fieldworker given a fixed overall amount (2)	1.5(.2)				1.7(.1)			
math fact str.		0	0	13		0	0	10
col. algo. str.		2	0	1		13	0	0
reorgan. str.		0	1	5		0	0	0
counting str.		1	2	2		0	0	0

[1] Mean and standard deviation of problems solved correctly using a given strategy, maximum of 2.0.

[2] Number of participants who used a particular artifact and a particular strategy together one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers), na=no external artifact. Because participants can use more than one type of artifact together with more than one strategy to solve a problem, the total may be greater than the number of participants.

or more times to solve the first two sets of tasks. The frequent use of column algorithms coupled with written artifacts is somewhat surprising given the greater number of math facts available to students as compared to the shopkeepers and the small numbers involved in the tasks, but could be explained by a goal-directed organization that defines the means of solving the task as part of the goal for the students. Several students also used a column algorithm strategy at least once without the use of written artifacts, though the use of written artifacts such as equation formats on paper may very well be the origin of those strategies. While several students did use counting strategies with and without object artifacts, math facts without the use of artifacts and column algorithms with the use of written artifacts were clearly dominant for the students.

A slightly different pattern emerged in the two sets of tasks that involve multiplication and division operations unless reorganization occurred: finding the total pay for multiple field workers and finding the pay for each fieldworkers given a fixed overall amount.

Several of the shopkeepers used written artifacts and column algorithm strategies at least once in solving the tasks, several shopkeepers used a counting strategy with fingers or seeds at least once, and several shopkeepers used a counting strategy without any external artifacts at least once. Those shopkeepers who used reorganization strategies generally did so without the use of external artifacts. However, all of the shopkeepers used a math fact strategy to solve these tasks one or more times. The students used math facts without external artifacts or column algorithm strategies with written artifacts in all cases to solve these tasks.

Several interesting patterns emerged from the participants' completion of the word problem tasks derived from farming activity. First, shopkeepers used a greater variety of strategies and artifacts to complete the tasks than did students. Second, artifacts seemed to be more closely tied to particular strategies for the students than for the shopkeepers. While several of the students did use column algorithms without any external artifacts one or more times, a majority linked column algorithms with written artifacts in completing the tasks. In contrast, the shopkeepers used a variety of strategy-artifact linkages in completing the tasks, e.g. counting strategies with written artifacts, object artifacts and no external artifacts. Last, students' greater knowledge of math facts did not differentiate between the students and the shopkeepers in terms of their use of math facts in completing the tasks. This suggests that while students may generally have access to a larger number of math facts than do shopkeepers, their knowledge of math facts may be relatively equivalent with respect to use in farming activities, at least as represented in these tasks.

Correcting the measurements of a plow

Table 48 displays the percentage of participants who found and corrected measurement errors in the construction of a plow.

Table 48

Finding and Correcting Measurement Errors on the Plow: Initial Farming Tasks

	Percentage of Participants			
	Shopkeepers (n = 13)		Students (n = 13)	
	correct[1] correction	incorrect correction	correct correction	incorrect correction
dharo length				
finds error on own	61.5	15.4	7.7	15.4
finds error after probe	23.1	0	15.4	7.7
doesn't find error	0		53.8	
phari to dharo length				
finds error on own	100	0	61.5	23.1
finds error after probe	0	0	0	0
doesn't find error	0		15.4	
halo length				
finds error on own	84.6	15.4	23.1	23.1
finds error after probe	0		0	7.7
doesn't find error	0		46.1	
hatso position				
finds error on own	53.8	7.7	0	7.7
finds error after probe	30.8	0	15.5	30.8
doesn't find error		7.7	46.1	
phari position				
finds error on own	69.2	15.4	0	0
finds error after probe	7.7	0	30.8	23.1
doesn't find error		7.7	46.1	

1 The correct correction was defined by the modal solution constructed by the farming participants, plus or minus one measurement unit

A greater percentage of shopkeepers than students identified each of the five errors in the plow. Furthermore, proportionally more of the students who identified the error did so only after they were specifically probed for it compared to the shopkeepers. Last, of those who corrected the errors, more students than shopkeepers incorrectly corrected the measurement errors across all five types of errors .

Both groups of participants had extensive experiences in using plows in their family's, neighbors', and relatives fields, though the shopkeepers had had more years of experience doing so. For of the thirteen shopkeepers had actually built a plow whereas one of the students had done so.

Taken collectively, this evidence suggests that despite both the students and the shopkeepers having extensive farming experience, the students cannot be assumed to possess knowledge of farming and associated arithmetic identical to that of the shopkeepers'. This may be a result of students having to spend extended periods of time in school and on homework. Overall time of participation may also be a factor, with the shopkeepers having spent a greater number of years participating in farming activity than the students. Four of the students participated in farming activity during peak periods such as rice planting and many of the harvests, but did not participate in farming activity at other times, suggesting that at least some of the students's relations to the various farming practices were more peripheral than those of the shopkeepers.

Shop Tasks

Six categories of problem solving tasks were derived from shopkeeping activity in Bherighat: item price knowledge, weighing sugar, cloth measure conversion, profit/loss, purchase total/change, unit/subunit pricing. All six categories of tasks could routinely occur as part of shopkeeping practices highlighted as typical of shopkeeping activity. Each task category was analyzed separately: describing the participants' uses of artifacts, strategies, goal-directed organization, and the correctness of their solutions.

Measures and their "content", e.g. sugar, were generally taken to be non-negotiable by the participants, whereas artifacts, goal-directed organizations, and strategies were underspecified by the task presentation and varied in the solution process.

Item price knowledge

Table 49 displays the number of participants who correctly stated the price of items commonly available in Bherighat shops. The items are divided into those with a price that does not vary from shop to shop and those items that do. For those items with a variable price, the three most frequently occurring prices in the Bherighat shops were counted as correct.

An equal or greater number of shopkeepers than students accurately stated the price for each of the 16 items. However, while shopkeepers' accuracy was at or above 90 percent for both the fixed and variable price items, students' accuracy dropped from 78 percent on the fixed price items to 45 percent on the variable price items. This suggests that students do have knowledge of the prices of many of the items as customers, but they are not as familiar with limits of what constitutes a reasonable price for the variable price items in Bherighat.

Table 49

Pricing Accuracy of Frequently Sold Shop Items: Initial Shopkeeping Tasks

	Number of Participants Recalling a Correct Price	
	Shopkeepers (n = 13)	Students (n = 13)
Fixed Price Items		
Kaini tobacco	13	9
Matches	13	13
Deurali cigarettes	13	13
Mayalu biscuits	13	7
Ganga soap	13	8
Geep batteries	13	10
Yak cigarettes	13	13
Tulsi soap	13	11
Pineapple biscuits	13	7
orange candies	9	9
Variable Price Items		
ledger book	13	9
chappels	10	5
Topaz blades (5)	13	5
T-shirt	12	4
hair ribbon	13	3
ballpoint pen	12	9

American and European readers might expect customers to know what the range of reasonable prices are for an item. However, customers in Bherighat generally do not do comparison shopping. Rather they frequent one or two shops where they are acquainted with the shopkeeper: someone who is often a relative or a neighbor and/or extends credit to them regularly. Shopkeepers, on the other hand, need to have a sense of the most typical price as well as the range of prices for variable price items in order to set their own prices.

Weighing sugar

Table 50A displays the strategies and artifacts used by shopkeepers and students in weighing out particular quantities of sugar on a two-pan balance. Goal-directed organizations were not distinguishable on this set of tasks, but were for finding the weight of a predetermined amount of sugar, the next set of tasks.

The first task did not require a mathematical operation to weigh out the specified amount of sugar, i.e. only a single weight was necessary in the opposing pan to balance. The second task required multiple weights in the opposing pan in order to balance the requested amount of sugar. The participants needed to keep a running total of the weights in the opposing pan through the use of cumulative addition in order to achieve the requested amount of sugar. For the third task the participants had to place weights in both the sugar pan and the opposing pan to achieve the requested amount of sugar. In this case it was necessary to subtract the weights in the sugar pan from the weights in the opposing pan to determine whether one had achieved the requested amount of sugar.

Table 50A

Weighing Sugar on Two-Pan Balance: Initial Shopkeeping Tasks

	Shopkeepers (n = 13)				Students (n = 13)			
	freq. correct	pp[1]	ob	na	freq. correct	pp	ob	na
Weighing Out Sugar								
no operation (1)	13				13			
addition (1)	13				13			
math fact str.		0	0	10		0	0	4
col. algo. str.		0	0	0		8	0	1
reorgan. str.		0	3	0		0	0	0
counting str.		0	0	0		0	0	0
subtraction (1)	13				13			
math fact str.		0	0	10		0	0	1
col. algo. str.		0	0	0		10	0	2
reorgan. str.		0	4	0		0	0	0
counting str.		0	0	0		0	0	0

[1] Number of participants who used a particular artifact and a particular strategy together one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers), na=no external artifact. Because participants can use more than one type of artifact together with more than one strategy to solve a problem, the total may be greater than the number of participants. While the weights were sometimes involved in the calculations, they served a purely mnemonic function rather than a calculation function.

All shopkeepers and students were able to weigh out the correct amount of sugar in all three tasks. To do so they needed to determine the proper combination of weights on one or both pans. This afforded the construction of a solution in advance of placing the final amount of sugar on the scale: something that all of the participants took advantage of. Nine of the shopkeepers found it useful to place some sugar on a pan to hold the scale roughly level while they placed the remaining weights rather than attempting to keep the scale level with their hands. Only one of the students did this. This had more to do with physical convenience than obtaining the correct amount of sugar, however.

A clear difference between the performance of the shopkeeping and student groups appeared in their use of artifacts and strategies on the tasks affording addition and subtraction calculations. The shopkeepers never used written artifacts and column algorithms to determine the weights and their positions necessary to achieve the proper amount of sugar whereas most of the students did so on one or more occasions. Instead the shopkeepers relied primarily on cumulative addition through math facts, e.g. " one hundred....and fifty, one hundred and seventy-five, one hundred and ninety."

Several of the shopkeepers also used a reorganization strategy in conjunction with counting on their fingers to determine the proper amount and position of the weights, e.g. "fifty grams and thirty is (counting on fingers) sixty, seventy, eighty grams.) While counting on is involved, it is a subsumed by the second order reorganization strategy that is used to divide the 30 gram weight into three units of ten and cumulatively add them on to the 50 grams. Several of students used column algorithms without using written artifacts, e.g. "twenty and thirty-five is five...five...fifty-five."

Table 50B displays the strategies, artifacts and goal-directed organizations used by shopkeepers and students finding the weight of a predetermined quantity of sugar with the two-pan balance. One of the three tasks does not afford the use of an arithmetic operation because only a single weight is needed on one pan to counterbalance the sugar on the other pan. It therefore does not support the use of calculation strategies. The two tasks that afford addition and subtraction operations were combined for ease of display as the combinations of artifacts, strategies, and GDO were nearly identical for each within the two groups.

All shopkeepers and students were able to weigh out the correct amount of sugar in the first task which did not require arithmetic calculation. Three of the students were unable to correctly complete one or more of the tasks that afforded arithmetic operations whereas all of the shopkeepers were able to do so.

Table 50B

Weighing Sugar on Two-Pan Balance: Initial Shopkeeping Tasks

	Shopkeepers (n = 13)				Students (n = 13)			
	mean(sd) correct[1]	pp[2]	ob	na	mean(sd) correct	pp	ob	na
Finding Sugar Weight								
no operations (1)								
solution GDO[3]	1.0(0)	0	0	1	1.0(0)	0	0	7
efficient GDO[4]	1.0(0)	0	0	6	1.0(0)	0	0	3
indistinguishable	1.0(0)	0	0	6	1.0(0)	0	0	3
operations (2)								
solution GDO	2.0(0)				1.7(.4)			
math fact str.		0	0	1		0	0	3
col. algo. str.		0	0	0		5	0	0
reorgan. str.		0	2	0		0	0	0
counting str.		0	0	0		0	0	0
efficient GDO	2.0(0)				1.7(.4)			
math fact str.		0	0	8		0	0	1
col. algo. str.		0	0	0		4	0	0
reorgan. str.		0	4	0		0	0	0
counting str.		0	0	0		0	0	0
indistinguishable	---				2.0(0)			
math fact str.		0	0	0		0	0	2
col. algo. str.		0	0	0		2	0	1
reorgan. str.		0	0	0		0	0	0
counting str.		0	0	0		0	0	0

[1] Mean and standard deviation of problems solved correctly using a given GDO.

[2] Number of participants who used a particular artifact and a particular GDO together one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers), na=no external artifact, though the physical weights were sometimes taken off the scale and used as a mnemonic for the weights they represent in grams. Because participants can use more than one type of artifact, the total may be greater than the number of participants.

[3] Solution GDO: shift back and forth between placing weights on both pans
until the scale balances. Goal involves achieving the solution alone.

[4] Efficient GDO: add weight to non-sugar pan until the scale balances or is too heavy. Shift to putting weights on other pan as counterbalance if non-sugar pan is too heavy until the scale balances. Goal involves achieving efficiency of effort in addition to achieving solution.

Two different goal directed organizations seemed to be used by the participants. The solution GDO involved placing weights on the pans in various combinations until balance was achieved whereas the efficient GDO seemed to encompass a linear strategy for achieving the balance by placing weights on the pan opposite the sugar starting with the largest weight estimated to be appropriate and working toward the smaller weights until the pan balances or, if it goes over, placing the next smallest weight on the pan with the sugar as a counterbalance. In some cases the goal-directed organizations were indistinguishable from one another and were coded as such.

Unlike previous weighing tasks which afforded a solution in advance of the actual weighing process, finding the weight of an unknown amount of sugar requires that a solution be constructed only after the weighing process has been completed. For this reason the different GDOs which relate to the actual process of weighing did not appear to affect the types arithmetic strategies and artifacts used. Shopkeepers who used either GDO tended to use math facts or a reorganization strategy with fingers whereas students who use either GDO tended to use math facts or a column algorithm strategy with written numerals and equations.

Ten of the shopkeepers displayed efficient GDO's for both tasks affording arithmetic calculations whereas only five of the students displayed efficient GDO's. However, more students' than shopkeepers' displays were coded as indistinguishable with respect to a particular GDO, leaving open the possibility that those displays which were indistinguishable were in reality efficient GDO's. In some cases different strategies, artifacts, and GDO's co-occurred for students and shopkeepers. In others the same clusters of artifacts, strategies, and GDOs co-occurred for both students and shopkeepers.

Cloth measure conversion

Table 51 displays the artifacts, strategies, and goal-directed organizations that co-occur for shopkeeping and farming participants in converting a length of cloth from a traditional to a metric measure of length and pricing the cloth based on its metric length.

Two different GDOs were use by the participants. The measurement GDO involves the inclusion of measurement units as a part of the problem space. For example: establish a 4 *haat* length of cloth in front of the customer, measure the cloth with the metric ruler find that it is 1 m. 85 cm. in length, if 1 m. of cloth is 20 *rupees* (ru.), then half a meter is 10 ru., so 20 and 10 is 30 ru., and a quarter of a meter is 5 ru., so 30 and 5 is 35 ru., leaving me with 10 cm. If 1 m. is 20 ru., then 1 cm. is 20 *paisa* (pa.), so 10 of them is 200 pa. or 2 ru., so 35 and 2 is 37 ru. for the cloth. The equation GDO keeps measurement units external to the problem space

Table 51

Cloth Measure Conversion: Initial Shopkeeping Tasks

	Shopkeepers (n = 13)				Students (n = 13)			
	f	pp[1]	ob	na	f	pp	ob	na
Measurement GDO[2]								
answer correct[3]	10				0			
math fact str.		0	0	0		0	0	0
col. algo. str.		0	0	0		0	0	0
reorgan. str.		0	2	5		0	0	0
counting str.		0	2	1		0	0	0
answer incorrect	3				1			
math fact str.		0	0	0		0	0	0
col. algo. str.		0	0	0		0	0	0
reorgan. str.		0	0	3		0	0	1
counting str.		0	1	0		0	0	0
Equation GDO[4]								
answer correct	0				2			
math fact str.		0	0	0		0	0	0
col. algo. str.		0	0	0		2	0	0
reorgan. str.		0	0	0		0	0	0
counting str.		0	0	0		0	0	0
answer incorrect	0				8			
math fact str.		0	0	0		0	0	0
col. algo. str.		0	0	0		8	0	0
reorgan. str.		0	0	0		0	0	0
counting str.		0	0	0		0	0	0
Switch GDO[5]								
answer incorrect	0				2			
math fact str.		0	0	0		0	0	0
col. algo. str.		0	0	0		2	0	0
reorgan. str.		0	0	0		0	0	2
counting str.		0	0	0		0	0	0

[1] Number of participants who used a particular artifact and a particular strategy together one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers), na=no external artifact. Because participants can use more than one type of artifact and/or more than one strategy type, the total may be greater than the number of participants.

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

[3] An answer's correctness was considered in relation to the initial measurement rather than a single absolute answer.

[4] 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. (continued)

[5] Switch GDO, the participants initially attempted to solve the problem using a linear GDO, are unsuccessful, and then begins again with an unsystematic form of a measurement GDO. This is the only time during the initial tasks that both pp and na artifacts co-occur within a single problem-solving episode.

which is organized on the basis of an arithmetic equation. For example: measure your *haat* with a metric ruler, finding that it is 46 cm. long, write 4 X 46 on paper, 4 times 6 is 24, carry the 2, 4 time 4 is 16, 17, 18, write 184 (cm.). Establish a proportion on paper where 100/20 = 184/?, write the problem 100/20, 20 goes into 100 5 times, write the problem 184/5, 5 goes into 18 3 times, 18 take away 15 is 3, so 34. Five goes into 34 6 times, so 34 take away 30 is 4, put up a decimal point, bring down a 0, so 5 goes into 40 8 times, so its 36 *rupees* 80 *paisa* for the cloth.

All of the shopkeepers displayed a measurement GDO with 10 of the 13 shopkeepers constructing a correct solution. In contrast, only one of the students began the task displaying a measurement GDO, though two students switched to a measurement GDO after having difficulty generating a satisfactory solution through a equation GDO. Only two of the students were able to arrive at a correct solution to the task. Both used an equation GDO.

Unlike their performances on the sugar weighing tasks, students' performances on the cloth conversion task using the equation GDO were tightly linked with particular strategies and artifacts: column algorithm strategies and written artifacts. The measurement GDO displayed by all of the shopkeepers and one of the students, however, were associated with a counting strategy with or without the use of fingers as calculation artifacts or a reorganization strategies, also with or without the use of fingers as calculation devices.

Profit/loss

Tables 52A, B, and C display the participants' use of GDO's, calculation artifacts, and strategies in three tasks involving the

Table 52A

Profit\Loss Problems: Initial Shopkeeping Tasks

	Shopkeepers (n = 13)				Students (n = 13)			
	f	pp[1]	ob	na	f	pp	ob	na
Unit remains constant (1)								
answer correct	13				13			
math fact str.		0	0	6		0	0	1
col. algo. str.		0	0	0		10	0	2
reorgan. str.		1	0	0		0	0	0
counting str.		0	3	3		0	0	0

1 Number of participants who used a particular artifact and a particular strategy together one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers), na=no external artifact. Because participants can use more than one type of artifact and/or more than one strategy type, the total may be greater than the number of participants' calculation of profit and loss in pricing shop items.

Table 52A displays the shopkeepers' and students' use of strategies and artifacts on profit/loss task in which the initial unit given is identical to the unit required in the solution: "If you bought these chappels (point to the pair of thongs) for 17 rupees and wanted to make a 6 rupee profit, how much would you need to sell them for?"

All of the participants correctly completed the task. Six of the shopkeepers completed the task using a math facts strategy without external calculation artifacts. Six shopkeepers used a counting strategy with seeds or fingers as calculation artifacts or no artifacts. One shopkeeper used a reorganization strategy after writing the numbers down on paper. This contrasted with the students. One student used a math facts strategy to complete the task and the remaining twelve used a column algorithm strategy with written numerals or without external artifacts. The students used a column algorithm strategy with greater frequency than a math facts strategy despite their greater facility with math facts relative to the shopkeepers. This was true of the students' performances on several of the farming tasks as well.

It was not possible to distinguish GDO's in this task event except by inference from the strategies and the artifacts used by the participants and the activities in which they participated. The shopkeepers displayed a wide variety of strategy-artifact couplings whereas the students displayed a narrow range of couplings. This difference suggests that the GDO displayed by shopkeepers may afford obtaining a solution by utilizing artifact-strategy couplings that relate to the characteristics of the numbers and the shopkeepers' knowledge, whereas the students displayed a GDO that specifies the artifact-strategy couplings themselves rather than the achievement of a solution per se. Tables 52B and C indicate that students consistently generated more incorrect solutions than the shopkeepers.

Table 52B displays the artifacts, strategies, and GDO of the students and the shopkeepers on a profit/loss task in which the initial information unit is the individual item, but the solution unit must be a group of item,s i.e. "If you buy twelve notebooks from another shopkeeper for seventy-eight paisa each, and sold them in your shop for 75 paisa each, how much profit would you make from selling all of the notebooks?"

A majority of shopkeepers maintained the initial item unit and converted to the group unit only at the end of the tasks event, e.g. "seventy-eight take away seventy-five is three paisa, so I would loose money. (How much money would you loose all together?) three, six, nine, twelve... (incrementing by 1 notebook with each count of three)...thirty-six, I would loose 36 paisa!" This allowed them to discover that they would be selling at a loss at the outset and also maintained a relatively small number size. A majority of the students converted to the group unit at the outset of the

Table 52B

Profit\Loss Problems: Initial Shopkeeping Tasks

	Shopkeepers (n = 13)				Students (n = 13)			
	f	pp[1]	ob	na	f	pp	ob	na
Unit changes from single item to group of items (1)								
First achieve end unit[2]								
answer correct	0				4			
math fact str.		0	0	0		0	0	0
col. algo. str.		0	0	0		4	0	0
reorgan. str.		0	0	0		0	0	0
counting str.		0	0	0		0	0	0
answer incorrect	2				6			
math fact str.		0	0	0		0	0	0
col. algo. str.		0	0	0		6	0	0
reorgan. str.		0	0	0		0	0	0
counting str.		0	1	1		0	0	0
Maintain initial units[3]								
answer correct	8				1			
math fact str.		0	0	0		0	0	1
col. algo. str.		0	0	0		0	0	0
reorgan. str.		0	1	0		0	0	0
counting str.		0	6	1		0	0	0
answer incorrect	3				2			
math fact str.		0	0	0		0	0	2
col. algo. str.		0	0	0		0	0	0
reorgan. str.		0	0	0		0	0	0
counting str.		0	0	3		0	0	0

1 Number of participants who used a particular artifact and a particular strategy together one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers), na=no external artifact. Because participants can use more than one type of artifact and/or more than one strategy type, the total may be greater than the number of participants.

2 First achieve end unit is a GDO which involves converting the problem to the end unit, then solving for the end unit, and is calculation intensive.

3 Maintain initial unit is a GDO which involves maintaining the initial problem unit until it becomes necessary to convert to the end unit, and is less calculation intensive.

task, e.g. the equations 12 X 78 = 936, 12 X 75 = 900, and 936 - 900 = 36 solved in sequence. Mistaking loss for profit constituted five of the eight errors when doing an immediate conversion to the end unit. No such errors occurred when maintaining the initial unit to the last.

The larger numbers involved in the calculations that immediately convert to the end unit are less problematical if a participant is using written numerals and a column algorithm strategy than if the participant is using objects as calculation artifacts or no external artifacts whatsoever. However, this can not explain why most students convert to the final unit at the outset, nor does it explain why the shopkeepers as a group continue to prefer maintaining the initial unit in their calculations when there is little difference in the size of the numbers or the complexity of the calculations, as is the case on the third profit/loss task below.

Table 52C displays the artifacts, strategies, and GDO of the students and the shopkeepers on a profit/loss task in which the initial information unit is a group, but the solution unit must be a single item, i.e. "If you bought twenty tins of *kaini* (point to chewing tobacco tins) in Surkhet for a total of 80 rupees and paid twenty rupees to have them carried to your shop in Bherighat, how much would you have to sell a tin for to make a two rupee profit on each?"

A majority of shopkeepers maintained the initial unit until mid-way in

Table 52C

Profit\Loss Problems: Initial Shopkeeping Tasks

	Shopkeepers (n = 13)				Students (n = 13)			
	f	pp[1]	ob	na	f	pp	ob	na
Unit changes from group of items to single item (1)								
First achieve end unit[2]								
answer correct	2				3			
math fact str.		0	0	0		0	0	0
col. algo. str.		0	0	0		3	1	1
reorgan. str.		0	1	1		0	0	0
counting str.		0	0	0		0	0	0
answer incorrect	1				6			
math fact str.		0	0	0		0	0	1
col. algo. str.		0	0	0		4	0	3
reorgan. str.		0	1	0		0	0	0
counting str.		0	0	0		0	0	0
Maintain initial unit[3]								
answer correct	9				2			
math fact str.		0	0	1		0	0	0
col. algo. str.		0	0	0		2	0	0
reorgan. str.		0	4	2		0	0	0
counting str.		0	2	0		0	0	0
answer incorrect	1				2			
math fact str.		0	0	0		0	0	0
col. algo. str.		0	0	0		2	0	0
reorgan. str.		0	1	0		0	0	0
counting str.		0	0	0		0	0	0

1 Number of participants who used a particular artifact and a particular strategy together one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers), na=no external artifact. Because participants can use more than one type of artifact and/or more than one strategy type, the total may be greater than the number of participants.

2 First achieve end unit is a GDO which involves converting the problem to the end unit, then solving for the end unit, and is calculation intensive.

3 Maintain initial unit is a GDO which involves maintaining the initial problem unit until it becomes necessary to convert to the end unit, and is less calculation intensive.

the solution process, e.g. "eighty and twenty are one hundred rupees, half of that is 50 rupees (separates the tins into two piles of 10 each), half of that is 25 rupees (separates one pile of 10 into two piles of 5 tins), therefore one tin is 5 rupees, so I would sell it for 7 rupees." Four of the students did as well, though they displayed a column algorithm strategy-written artifact coupling in all cases.

Three of the shopkeepers and nine of the students immediately converted to the final unit which was a single item, e.g. completing equations on paper in the following sequence: 80 / 20 = 4, 20 / 20 = 1, 4 + 1 = 5, 5 + 2 = 7.

Most of the shopkeepers maintained the initial unit past the first calculation, independent of whether it was the group as shown in Table 52C or the single item as shown in Table 52B. This was the case in 21 out of the 24 opportunities for shopkeepers across the two tasks. Most of students converted to the final unit in the first calculation, again independent of whether it was the group or the single item. This was the case in 19 of the 24 opportunities for students across the two tasks. Post-solution explanations suggested that those who maintained the initial unit "chained" or used a solution from the first calculation in the next calculation (78 - 75 = <u>3</u> <u>3</u> X 12 = 36) whereas those who immediately converted to the end unit performed two independent calculations and then combined the results of the independent solutions (12 X 78 = 936 12 X 75 = 900 936 - 900 = 36).

Chaining would satisfy a GDO that affords arithmetic strategies and artifacts being coupled in a variety of ways, a GDO that is in and of itself non-arithmetic such as pricing items for profit. The hierarchical rather than linear ordering of calculations would satisfy a GDO that affords strategies and artifacts being coupled in a limited number of ways, a GDO that is explicitly arithmetic in nature and therefore vested in a particular coupling.

It would therefore appear that the shopkeepers generally displayed GDO, strategy, artifact couplings on these tasks which continuous with shopkeeping. Prior ethnographic observations confirmed this. The students, however, generally displayed a coupling continuous with schooling activity. Prior ethnographic observations confirmed this as well. This should not be interpreted to mean that the students literally viewed these shopkeeping tasks as school tasks. Rather they utilized the GDO-strategy-artifact coupling available to them at that point in time in an event that did not present alternative couplings.

Purchase total\change

Table 53 displays students' and shopkeepers' GDO-strategy-artifact couplings on a series of four tasks that first involve totaling the prices of items to be purchased followed by returning the proper amount of change based on the amount of money provided by the customer.

Table 53

Purchase Total\Change: Initial Shopkeeping Tasks

	Shopkeepers (n = 13)						Students (n = 13)					
	mean(sd) freq.[1]	mean(sd) correct[2]	pp[3]	ob	mo	na	Mean(sd) freq.	mean(sd) correct	pp	ob	mo	na
Integrative GDO[4]	4.0(0)	3.8(.4)					.9(.3)	.5(.2)				
math fact str.			0	0	0	5			0	0	0	0
col. algo. str.			3	0	0	0			1	0	0	1
reorgan. str.			0	1	0	2			0	0	0	0
counting str.			2	0	13	1			0	0	2	0
Summative GDO[5]	0	0					3.1(.9)	2.2(.6)				
math fact str.			0	0	0	0			0	0	0	0
col. algo. str.			0	0	0	0			13	0	0	2
reorgan. str.			0	0	0	0			0	0	0	0
counting str.			0	0	0	0			0	0	0	0

1 Mean and standard deviation of number of problems solved using a given GDO, maximum of 4.0.
2 Mean and standard deviation of problems solved correctly using a given GDO, maximum of 4.0.
3 Number of participants who used a particular artifact and a particular strategy together one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers), mo-money, na=no external artifact. Because participants can use more than one type of artifact and/or more than one strategy type, the total may be greater than the number of participants.
4 Integrative GDO in which the arithmetic calculation is internal to the purchase process.
5 Summative GDO in which the arithmetic calculation a appendage to the purchase process

All of the shopkeepers displayed integrative GDOs on each of the four purchase tasks. The integrative GDO is internal to the purchase process itself and allows the person to take full advantage of number characteristics and their knowledge of numbers. For example, the customer (researcher) asks for a pair of chapels (18 rupees 50 paisa, two packs of Yak cigarettes (10 rupees a pack), and 3 packs of matches (50 paisa per pack). The shopkeeper (participant) calculates out loud "eighteen, twenty-eight (thumb goes to first joint on little finger) thirty-eight (thumb goes to second joint on little finger), thirty-eight rupees and one *mohar* (50 paisa coin), thirty-nine, forty, forty-one rupees fifty paisa total." The customer hands the researcher a 100 rupee note in payment and the shopkeeper returns then change saying "forty-one and one mohar, forty-two (hands customer one mohar coin), forty-three forty-four, forty-five (hands customer three one rupee notes), fifty (hands customer five rupee note), one hundred (hands customer fifty rupee note).

Eleven of the thirteen students displayed a summative GDO which affords arithmetic calculation not as paced and integrated with the purchase process, but rather as a summative appendage to it. For example, after the customer (researcher) has asked for a pair of chapels, two packs of Yak cigarettes, and three packs of matches the shopkeeper (participant) writes the prices on paper, doubling the price of the Yak cigarettes, and totals them using a column algorithm strategy. After the customer has handed the shopkeeper a one hundred rupee note the shopkeeper writes another equation subtracting the customer's payment from the total price and counts out the proper change which is then handed to the customer "fifty (fifty rupee note), fifty-five (five rupees note), fifty-seven (two rupee note), fifty-eight (one rupee note), and one mohar (one fifty paisa piece).

The integrative GDO afforded column algorithm strategies and written artifacts in addition to reorganization and counting strategies with fingers and money as calculation artifacts. On the other hand, the summative GDO afforded the use of column algorithm strategies alone, usually with written numerals and equations. Two students attempted working from a summative GDO without external calculation artifacts. Both incorrectly totaled the customer's purchases and one incorrectly calculated the customer's change as well.

Unit/subunit pricing

Table 54 displays participants'G DO-strategy-artifact couplings on a set of four tasks that involve pricing larger units of items based on smaller unit prices, e.g. price of a bundle of match boxes based on the price of a single box and pricing smaller units based on larger unit prices, e.g one cigarette based on the price of a pack of cigarettes.

As with the purchase total/change problems, shopkeepers primarily displayed integrative GDOs in solving the four unit pricing tasks whereas

Table 54

Unit\Subunit Pricing: Initial Shopkeeping Tasks

	Shopkeepers (n = 13)					Students (n = 13)				
	mean(sd) freq.[1]	mean(sd) corr.[2]	pp[3]	ob	na	mean(sd) freq.	mean(sd) corr.	pp	ob	na
Integrative GDO[4]	3.2(.6)	2.9(.3)				1.4(.5)	.7(.8)			
math fact str.			0	0	4			0	0	0
col. algo. str.			0	0	0			10	0	0
reorgan. str.			0	13	0			0	0	0
counting str.			0	9	0			0	4	0
Summative GDO[5]	.8(.2)	.5(.6)				2.6(.6)	1.5(.6)			
math fact str.			0	0	0			0	0	0
col. algo. str.			0	0	0			13	0	0
reorgan. str.			1	4	0			0	0	0
counting str.			0	0	0			0	0	0

[1] Mean and standard deviation of number of problems solved by a participant using a given GDO, maximum of 4.0.
[2] Mean and standard deviation of problems solved correctly by a participant using a given GDO, maximum of 4.0.
[3] Number of participants who used a particular artifact and a particular strategy together one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers), na=no external artifact. Because participants can use more than one type of artifact and/or more than one strategy type, the total may be greater than the number of participants.
[4] Integrative GDO in which the arithmetic calculation is integrated with the enumeration process.
[5] Summative GDO in which the arithmetic calculation a appendage to the enumeration process.

students primarily displayed summative GDOs. The integrative GDO is in this case is characterized by determining the price of the desired unit though the process of enumeration. For example, to determine the price of a packet of twelve match boxes in a 2 by 2 by 3 array when a single packet cost fifty paisa the shopkeeper (participant) counts four boxes at a time along the length of the array, incrementing by two rupees each time: "...two, four, six rupees for the packet." The summative GDO is characterized by enumeration followed by calculation as in "two, four, six, eight, twelve boxes" then a calculation such as twelve times fifty using a column algorithm strategy or "half of twelve is six, so six rupees for the packet" using a reorganization strategy.

The integrative GDO for the shopkeepers was most often coupled with counting and reorganization strategies and using the actual items as calculation artifacts. Those tasks on which shopkeepers displayed a summative GDO were coupled with reorganization strategies and the actual objects, with the exception of one participant who used written numerals as an initial mnemonic on which to base his reorganization strategy.

The students displayed a summative GDO coupled exclusively with column algorithm strategies and written numerals. Their display of integrative GDOs was also generally coupled with column algorithms and written numerals. Four of the students did, however, use a counting strategy with the items as calculation artifacts one or more times.

Taken collectively, findings from the shopkeeping tasks suggest that students and shopkeepers generally display different goal-directed organizations in participating in shopkeeping practices involving arithmetic. The students' GDOs' often include an arithmetic component that constrains the strategies and artifacts coupled with them, usually limiting the coupling to column algorithm strategies and written numerals on the more complex tasks, a plus math facts on the less complex tasks. This may in turn couple with the higher social status of written math and column algorithms in Bherighat associated with schooling, as previously described, rather than with shopkeeping as an activity in which arithmetic is a means to a non-mathematical end.

The shopkeepers's GDO's generally includes efficiency and observability/comprehensibility to customers as components and not arithmetic. Thus they afford a relatively broad repertoire of strategy and artifact couplings that allow them to take advantage of relations between specific numbers, items, measures, and calculation knowledge.

Clearly there is variability within the shopkeeping and student groups that mitigates against interpreting prior participation in an activity as the sole determinant of an individual performance on a shopkeeping task. This provides necessary, but not sufficient, evidence that the individual has a constructive role to play in these task events and leaves open the possibility that differential forms of participation in prior activities may influence these performances. At the same time, GDO-strategy-artifact couplings were at no point equivalent between the shopkeeping and student groups, suggesting a strong association between participation in shopkeeping and schooling activities and performance on the shopkeeping tasks.

Mathematics Classroom Tasks

Six categories of problem solving tasks were derived from farming activity in Bherighat: quantifying bricks, picture problems, determining fractions with pictures, written problems involving the four operations, measurement word problems. All five categories of tasks routinely occurred as a part of elementary level mathematics instruction/learning in the Bherighat schools. Each task category was analyzed separately: describing the participants' uses of artifacts, strategies, goal-directed organization, and the correctness of their solutions.

Unlike the farming and schooling tasks, measures were rarely presented as part of the schooling tasks and the task "content", e.g. bricks-to-be-quantified, were generally taken to be non-negotiable by the participants, whereas artifacts, goal-directed organization, and strategies were underspecified by the task presentation and varied in the solution process.

Participants' requests for clarification were encouraged and responded to for this set of tasks, e.g. "What does this sign mean?" "It means add these numbers together.", as described in Chapter 5. All analyses are based on the participants' final attempt to complete the tasks rather than initial queries for information.

Quantifying bricks

Table 55 displays the participants' GDO-strategy-artifact couplings on three tasks involving the quantification of the total number of "bricks" depicted graphically in a series of rectangular stacks.

Table 55

Quantifying Bricks: Initial Mathematics Classroom Tasks

	Shopkeepers (n = 13)					Students (n = 13)				
	mean(sd) freq.[1]	mean(sd) corr.[2]	pp[3]	ob	na	mean(sd) freq.	mean(sd) corr.	pp	ob	na
Integrative GDO[4]	2.7(.3)	2.2(.2)				.8(.2)	.6(.2)			
math fact str.			0	0	0			0	0	0
col. algo. str.			0	0	0			0	0	0
reorgan. str.			7	13	0			1	2	0
counting str.			0	5	0			0	2	0
Summative GDO[5]	.3(.1)	.2(.1)				2.2(.4)	1.9(.4)			
math fact str.			0	0	0			0	0	0
col. algo. str.			0	0	0			13	0	0
reorgan. str.			4	4	0			0	13	0
counting str.			0	0	0			0	0	0

[1] Mean and standard deviation of number of problems solved by a participant using a given GDO, maximum of 3.0.

[2] Mean and standard deviation of problems solved correctly by a participant using a given GDO, maximum of 3.0.

[3] Number of participants who used a particular artifact and a particular strategy together one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers/pictures), na=no external artifact. Because participants can use more than one type of artifact and/or more than one strategy type, the total may be greater than the number of participants.

[4] Integrative GDO in which the arithmetic calculation is integrated with the enumeration process.

[5] Summative GDO in which the arithmetic calculation a appendage to the enumeration process.

Eleven of the thirteen shopkeepers initially asked what the addition sign between the brick stacks meant, but completed the tasks once its meaning was explained. None of the students posed this form of question. The shopkeepers generally displayed an integrative GDO on the tasks. The GDO involved determining the quantity of a row or column of bricks and then counting by that increment across the stacks of bricks, e.g. "one, two, three, four...twenty (in the column), forty, sixty, eighty, hundred (20 x 5 stack) four, eight, twelve, sixteen, eighteen, twenty (4 x 5 stack) one hundred and twenty, twenty-one, twenty-two, twenty-three (3 x 1 stack), one hundred and twenty-three." All used a reorganization strategy in determining the increment by which to perform cumulative addition. Seven of these shopkeepers made a written record of their cumulative addition on one or more of the tasks, e.g. "twenty (writes 20), forty (writes 40)...." The written record functioned as a mnemonic device according to the shopkeepers's post-solution descriptions. Five of the shopkeepers used a counting strategy coupled with the integrative GDO on one or more of the tasks, counting each brick and incrementing by one.

Four of the shopkeepers displayed a summative GDO coupled with reorganization strategies and written calculation artifacts on one or more of the tasks. This involved determining the quantity of a row or column of bricks, cumulatively adding by that increment within each stack of bricks, and writing down the total number of brick for that stack. After completing this for each of the stacks the shopkeeper combined the total number of bricks from each by referring to the written numerals and cumulatively while incrementing on his fingers, e.g. "hundred (counts to 10th joint on fingers), thirty (counts 3 more joints), one hundred and thirty- three (after adding on the additional 3 bricks from the last stack).

Several students displayed an integrative GDO on one or more of the tasks, mirroring couplings with artifacts and strategies identical to those of the shopkeepers who displayed an integrative GDO. Most, however, displayed summative GDO's in solving the tasks, coupled with a combination of reorganization and column algorithm strategies and objects and written artifacts, e.g. "one, two, three, four...twenty (in the column), forty, sixty, eighty, hundred (write 100 for 20 x 5 stack) four, eight, twelve, sixteen, eighteen, twenty (write 20 for 4 x 5 stack), three (write 3 for 3 x 1 stack). The numerals are written in equation format and a column algorithm is used to combine them to form a total.

Picture problems involving the four operations

Table 56 displays the participants' GDO-strategy-artifact couplings on four tasks involving picture problems for each of the four arithmetic operations. Each of the tasks involves coordinated graphic and numeric equation depictions of each problem.

Table 56

Picture Problems Involving the Four Operations: Initial Mathematics Classroom Tasks

	Shopkeepers (n = 13)					Students (n = 13)				
	mean(sd) freq.[1]	mean(sd) corr.[2]	pp[3]	ob	na	mean(sd) freq.	mean(sd) corr.	pp	ob	na
	3.4(.2)	2.3(.5)				4.0(0)	4.0(0)			
math fact str.			0	8	0			13	0	0
col. algo. str.			0	0	0			0	0	0
reorgan. str.			0	1	0			0	0	0
counting str.			0	7	0			0	0	0

1 Mean and standard deviation of picture problems solved with a maximum of 4.0.
2 Mean and standard deviation of problems solved correctly using a given strategy with a maximum of 4.0.
3 Number of participants who used a particular artifact and a particular strategy together one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers/pictures), na=no external artifact. Because participants can use more than one type of artifact and/or more than one strategy type, the total may be greater than the number of participants.

Ten of the thirteen shopkeepers initially asked questions regarding what the tasks were. All were able to complete the tasks once both the graphic and numerical forms of problem representation were explained. None of the students posed this form of question.

The shopkeepers solved most of the tasks using the pictures as calculation artifacts rather than the numerical equations displayed beside the pictures. In two cases the think-out-loud and post-solution descriptions with gestural information did not allow us to distinguish between whether the shopkeeper used the picture or the numerical equation to solve the task. One similar case existed for a student. These cases were excluded from analysis.

The pictorial artifacts were coupled with math fact (or subitizing), reorganization, or counting strategies for the shopkeepers. The students displayed an invariant coupling between a math fact strategy and the use of the written equation.

Two important issues arose from this analysis. First, there was no apparent distinction to be made between GDO in the performance of this task. All of the participants described their solution process as "getting the right answer." It may well be that couplings in which arithmetic is an integral part of the GDO do not afford variance in GDO. Prior ethnographic work suggests that such couplings are most frequently encountered as part of classroom-based mathematics practices. Though the shopkeepers and students displayed the same GDO coupled with a single category of calculation artifact, pictures for the shopkeepers and written equations for the students, the shopkeepers displayed a greater repertoire of strategies than did the students. This supports the notion that artifacts, strategies, and GDO's occur as couplings rather than some form of a causal hierarchy in which GDO's determine strategies which determine artifacts.

The second issue involves the need to distinguish between presented and constructed artifacts. While artifacts by definition have a constructed origin, practices involving arithmetic in farming and shopkeeping activities and the tasks drawn from these activities in this study do not involve the use of external calculation artifacts that were previously constructed for the purpose. Rather artifacts integral to or available during those practices are used in calculation. This is in marked contrast to the presentation of artifacts expressly constructed for the purpose of calculation as is often the case in classroom-based mathematical practices, at least during the initial presentations of problems. Both the students and the shopkeepers used artifacts which were "pre-packaged" for calculation. The former used the display of a mathematical equation and the latter used the display of object drawings.

Determining fractions with pictures

Table 57 displays the participants' responses on three tasks that involve determining the relative amount of the darkened portion of a circle. The only distinction between the groups of participants on these tasks was the type of strategy used and the solution form. Differences in GDOs were not apparent. Shopkeepers exclusively used verbal statements of half, half of a half, or half of a half of a half to describe the darkened portion of the circles. Students usually responded with 1/2, 1/4, and 1/8 in writing, though several students responded orally with "one half."

Table 57

Determining Fractions with Pictures: Initial Mathematics Classroom Tasks

	Shopkeepers (n = 13)		Students (n = 13)	
	mean(sd) freq.[1]	mean(sd) corr.[2]	mean(sd) freq.	mean(sd) corr.
Recognition Strategy[3]	0	0	2.6(.3)	2.6(.3)
Successive Halving Strategy[4]	3.0(0)	2.8(.1)	.4(.2)	.4(.2)

[1] Mean and standard deviation is based on three tasks solved by each participant with a maximum of 3.0.
[2] Mean and standard deviation of the number correct is based on the total number of problems solved correctly by each group using one of two strategies.
[3] Recognition strategy in which the task is organized to produce a numeric response, e.g. "1/4", usually in writing.
[4] Successive halving strategy in which the task is organized to produce an oral response based on a half, e.g. "half of a half."

Shopkeepers' post-solution descriptions suggested that they used terms such as "half of a half" along with visualizing what a half would be and then what half of that half would be. Students' post-solution descriptions suggested that they responded to the tasks through recognizing 1/4 and 1/8 portions without going through a process of successive halving. Oral and written response artifacts were differentially coupled to successive halving and portion recognition strategies for shopkeepers and students, respectively.

These distinctions reflect shopkeepers' general unfamiliarity with written fraction notation, their ability to describe symmetrical portions through the process of successive halving, and students' propensity to provide written solutions even when written calculation is not used.

It is unclear whether or not different GDO's were displayed in solving these tasks. The fact that students provided a written fraction response in 31 of 36 instances in which they did not do written calculation suggests that they were displaying GDO that might otherwise be coupled with activity in a mathematics classroom. However, shopkeepers could not have done so even if they were displaying a similar GDO due their lack of familiarity with written fraction notation.

Written problems involving the four operations

Table 58 displays the participants' responses to four tasks consisting of problems in a the vertical equation format common to Nepali elementary school arithmetic texts and those of many other nations, including the United States. Each of the tasks contained four equations presented as addition, subtraction multiplication, or division problems. Problems which were exclusively single digit were excluded from this analysis because they could easily be solved by all the participants using a math fact strategy. Each of the four tasks therefore contained three equations involving a single type of operation.

Table 58

Written Problems Involving the Four Operations: Initial Mathematics Classroom Tasks

	Shopkeepers (n = 13)					Students (n = 13)				
	mean(sd) freq.[1]	mean(sd) corr.[2]	pp[3]	ob	na	mean(sd) freq.	mean(sd) corr.	pp	ob	na
Strategy GDO[4]	0	0				3.8(.1)	3.8(.1)			
math fact str.			0	0	0			0	0	0
col. algo. str.			0	0	0			12	0	0
reorgan. str.			0	0	0			0	0	0
counting str.			0	0	0			0	0	0
Solution GDO[5]	4.0(0)	3.3(.3)				.2(.1)	.2(.1)			
math fact str.			0	0	3			0	0	0
col. algo. str.			1	2	1			1	0	0
reorgan. str.			1	5	8			0	0	1
counting str.			3	6	4			0	0	0

[1] Mean and standard deviation of number of tasks solved by a participant using a given GDO, maximum of 4.0.
[2] Mean and standard deviation of tasks solved correctly by a participant using a given GDO, maximum of 4.0. Note that a task was counted as solved correctly if all three problems in the task were solved correctly.
[3] Number of participants who used a particular artifact and a particular strategy together one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers), na=no external artifact. Because participants can use more than one type of artifact and/or more than one strategy type, the total may be greater than the number of participants.
[4] The Strategy 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 12 problems.
[5] 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 12 problems.

Twelve of the shopkeepers requested that one or more of the operation signs be explained to them and of those twelve, five also asked for one or more numbers to be read to them. The necessary information was provided upon request. None of the students requested additional information.

All of the shopkeepers displayed a solution GDO that afforded the use of more than one type of artifact and strategy across the three problems on each of the four tasks. A solution GDO affords different couplings of artifacts and strategies in relation to the particular numbers involved, the operation requested, and the person's arithmetic knowledge to achieve a solution. For example, a shopkeeper solved 17 - 4 as "seven take away five is twelve, so taking away only four will be thirteen", a reorganization strategy without the use of external calculation artifacts. The same shopkeeper solved 25 - 19 as "twenty-four (tip of little finger), twenty-three (first joint on little finger), twenty-two (second joint on little finger), twenty-one (last joint on little finger), twenty (tip of next finger), nineteen (first joint of next finger), one, two, three, four, five, six...six (counting total number of finger joints and tips covered from 24 to 19), a counting strategy with the use of fingers as counting artifacts.

All but one of the student participants displayed a strategy GDO in which the artifact and the strategy are invariantly coupled with the GDO, in this case column algorithm strategies and written artifacts. One student utilized both a column algorithm strategy-written artifact coupling and a reorganization strategy-no external artifact coupling on the subtraction, multiplication, and division tasks, but displayed a strategy GDO on the addition task.

Measurement word problems

Table 59 displays the participants' responses on three tasks that involve determining the number of smaller measurement units in half or a quarter of the larger measurement unit in the form of a word problem, e.g. "If there are 1000 grams in a kilo, how many grams are there in half of a half of a kilo?"

All of the shopkeepers reported knowing the answers to the tasks as math facts with the exception of two shopkeepers who used a reorganization strategy to determine the number of grams in a quarter of a quarter of a kilo. All of the students wrote all of the tasks down on paper as proportions with a missing term. However, only three students actually used a column algorithm strategy one or more times in solving the tasks which asked for the number of small units in one half of the larger unit and six of the students in solving the task which asked for the number of small units in one quarter of the larger unit.

This suggests that all of the students were displaying a GDO that was invariantly coupled with written artifacts and a particular equation format, independent of whether a math fact strategy or a column algorithm strategy

Table 59

Measurement Word Problems: Initial Mathematics Classroom Tasks

	Shopkeepers (n = 13)				Students (n = 13)			
	mean(sd) corr.[1]	pp[2]	ob	na	mean(sd) corr.	pp	ob	na
Number of smaller units in one half of larger unit (2)	2.0(0)				2.0(0)			
math fact str.		0	0	13		12	0	0
col. algo. str.		0	0	0		3	0	0
reorgan. str.		0	0	0		0	0	0
counting str.		0	0	0		0	0	0
Number of smaller units in one quarter of larger unit (1)	1.0(0)				1.0(0)			
math fact str.		0	0	10		7	0	0
col. algo. str.		0	0	0		6	0	0
reorgan. str.		0	1	2		0	0	0
counting str.		0	0	0		0	0	0

[1] Mean and standard deviation of number of correct solutions is based on the total number of problems solved correctly by each group.

[2] Number of participants who used a particular artifact and a particular strategy together one or more times: pp=paper & pencil, ob=object (seeds/stones/fingers), na=no external artifact. Because participants can use more than one type of artifact and/or more than one strategy type, the total may be greater than the number of participants.

was used. The GDO displayed by the shopkeepers afforded a correct solution, generally through the use of a math fact strategy, but was not invariantly coupled with the particular type of external artifact to be used.

Summary

Differential couplings between external artifacts, calculation strategies, and goal-directed organizations were analyzed in participants' solutions to the simulated shopkeeping and math classroom tasks. These analyses indicated that artifacts, strategies, and GDOs did not exist in antecedent-consequent causal relation to one another, where a particular GDO determines the use of a particular strategy, or a particular strategy requires the use of a particular artifact. At the same time, occasions did exist when they functioned "as if" they were causally linked in this manner, e.g. a strategy GDO linked invariantly with a column algorithm strategy and written artifacts within and across students, as depicted in Table 58.

Couplings among strategies, GDOs, and artifacts do not reside in the individual nor in the activity from which the tasks were simulated, but rather are the relation between them. This is not equivalent to interaction, a construct that takes as its starting point separate entities which affect each other. A useful metaphor by which to understand this distinction is the concept of area. Area is the relation between length and width. Area is not "caused" by nor does it reside in either, yet it cannot exist without both (Bisanz, 1994). Individuals and activities together create couplings of artifacts, strategies, and GDO's, though both individuals and activities have their own developmental systems and histories. This account is consistent with recent descriptions of emergent developmental systems in evolutionary biology, systems that cannot adequately be explained by one or more of the Aristotelian forms of causation. (cf. Varela, Thompson, & Rosch, 1992; Oyama, 1985).

Bearing the concept of individual-activity coupling in mind, this summary first considers the couplings from the perspective of the individual, then from the perspective of the tasks-as-simulations of an activity. Finally, an argument is made for the study of the couplings themselves as a learning/developmental object.

Shopkeepers were generally more accurate than students on the shopkeeping tasks (greater accuracy on 8 of the tasks and equivalent accuracy on 1) and students were generally more accurate than shopkeepers on the school tasks (greater accuracy on 3 of the tasks and equivalent accuracy on 2). On the farming tasks, shopkeepers consistently displayed greater accuracy than students (greater accuracy on 5 of the tasks and equivalent accuracy on 1). This is consonant with expectations and provides evidence that the task simulations did bear relation to the activities they were derived from. It does, however, suggest that the shopkeepers are significantly more accurate in farming practices involving arithmetic than are the students despite both groups' participation in framing activity. Ethnographic evidence indicates that while students do participate in farming activity, their participation is peripheral relative to that of the shopkeepers.

Shopkeepers displayed a greater repertoire of GDO-strategy-artifact couplings as a group than did the students on the shopkeeping tasks (greater repertoire on 7 tasks, less on 1) and on the schooling tasks (greater repertoire on 2 tasks, equivalent repertoire on 2). Note that not all tasks could be fully analyzed for GDO-strategy-artifact couplings. However, on the two farming tasks on which couplings could be analyzed, shopkeepers and students displayed a greater repertoire of couplings on one task each. Intra-individual repertoires were generally not analyzed in this phase of the study. The single exception was the set of written problems involving the four operations (Table 58): a simulated school task. Each of the shopkeepers used a variety of couplings across problems. Most of the students displayed the same coupling across the problems.

A majority of shopkeepers and students displayed GDOs on the shopkeeping and schooling tasks consistent with the primary activity in which they participated (shopkeeping or schooling) and not necessarily consistent with the activity from which the task simulations were derived, except where they coincided. These consistencies were not independent of their participation in farming. Both students and shopkeepers participated in farming activity. Evidence suggests that their participation was not equivalent. Analyses of the two farming tasks that afforded an examination of GDOs suggest that those displayed were consistent with students and shopkeepers as, respectively, peripheral and full participants in farming activity: assuming that peripheral participation, unlike full participation, involves GDO-artifact-strategy couplings bearing strong relation to their full participation in another activity.

GDO-strategy-artifact couplings between shopkeepers and the three sets of task simulations generally took advantage of the characteristics of the particular numbers involved as they related to the participant's prior knowledge and the task characteristics as they related to an activity, though not necessarily the activity the task was derived from. GDO's displayed by the shopkeepers generally indicated that they did not organize the tasks as mathematical problems, but rather organized them as problems to be resolved using various means that happened to be arithmetic in most cases. This was true for the classroom-derived tasks as well as those which simulated shopkeeping and farming and afforded all four forms of calculation strategies, though least frequently column algorithm strategies, and all three categories of external artifact use, though least frequently written artifacts.

In contrast to this, a single coupling dominated students' construction of solutions to the three sets of tasks: column algorithm strategies with written numerals/equations and GDOs that afforded a mathematical organization to the tasks. Whether because it was a mathematical organization or because of the nature of the particular mathematical organization, the coupling was relatively invariant both for a given task across students and across tasks for a given student.

Thus far findings have been summarized from the perspective of the individual and would seem to support a generalization model of transfer, i.e. students and shopkeepers carry with them general knowledge of arithmetic abstracted from a prior activity and apply it to tasks derived from another activity. However, if we look across farming, schooling, and shopkeeping task simulations for each group of participants, taking a task-based perspective, GDO-strategy-artifact couplings may vary in consistent ways by tasks simulating different activities. Strategy-artifact couplings not generally associated with activities in which the participants regularly engage are examined for this analysis, under the assumption that these couplings are the most likely to vary across tasks.

For farming and shopkeeping tasks an average of 1.4 and 2.0 shopkeepers respectively (out of a possible 13) used column algorithms and/or written artifacts one or more times. However, for the schooling tasks an average of 6.0 shopkeepers used a column algorithm and/or written artifacts one or more times to solve a given task. These averages were weighted by the number of tasks affording an analysis of both strategies and artifacts linked to with a particular activity. Though the shopkeepers had not participated in schooling activity, some had obtained knowledge of written numerals and column algorithms from younger relatives who attended school.

The task constraints and affordances that were related to activities through simulation were also related to particular strategy-artifact couplings. Whether the tasks were simulations of farming or shopkeeping activities, activities in which they were direct participants, or were simulations of schooling, an activity in which they were not participants, the tasks afforded couplings that were sensitive to their activities of origin. For the school tasks this ran counter to the couplings displayed by shopkeepers in association with farming and shopkeeping tasks.

In an equivalent analysis of farming and schooling tasks with students, an average of 5.0 and .3 students respectively (out of a possible 13) used object artifacts (fingers, stones, or task objects) or no external artifact coupled with reorganization and/or counting strategies one or more times. For the shopkeeping tasks an average of 1.5 students (out of a possible thirteen) used object artifacts or no external artifact with reorganization and/or counting strategies one or more times to solve a given task. Though the students had not participated in shopkeeping activity as shopkeepers, some did have knowledge of shopkeeping practices as customers.

The task constraints and affordances were again related to activities through simulation and to particular strategy-artifact couplings. Whether the tasks were simulations of farming or schooling activities, activities in which they were direct participants, or simulations of shopkeeping, an activity in which they were not participants, the tasks afforded couplings that were sensitive to their activities of origin. For the shop tasks this ran counter to the couplings displayed by students in association with schooling tasks. This coincides with our ethnographic findings that column algorithm strategies and written artifacts are most frequently displayed in relation to schooling activity by Bherighat villagers in general, but object artifacts or no external artifact with reorganization and/or counting strategies are most commonly displayed through both farming and shopkeeping activities.

Interestingly, the farming tasks afforded a much larger average number of students displaying object artifacts or no external artifact with reorganization and/or counting strategies than did the shopkeeping tasks. It is possible that the student participants were better able to characterize the shopkeeping tasks as arithmetic tasks than the farming tasks with which they had already had some direct experience, hence the lower average number of students displaying object artifacts or no external artifact with reorganization and/or counting strategies on these tasks. GDO's displayed by most students on the shopkeeping tasks would support this interpretation.

These findings are consonant with an isomorph approach to transfer in so far as many of the GDO-strategy-artifact couplings analyzed in this manner appear to have more to do with the nature of tasks bearing relation to a particular activity, and less to do with the preponderance of participants' prior experience presumed to be the basis for generalization. Prior experience with arithmetic in farming displayed in student-farm task couplings did not appear to generalize to the shopkeeping tasks despite the seeming appropriateness of some of the couplings. The nature of some of the shopkeeper-school task couplings, on the other hand, seem related to the specific experiences shopkeepers had learning column algorithms and written artifacts from younger family members and relatives, not the activities of farming or shopkeeping.

It would be possible to resolve the participant-based and the task-based summaries of findings at this point by stating that there is an interaction between participants' prior knowledge and the nature of the tasks, and perhaps create a multivariate model to further articulate and lend probabilistic support to the details of this interaction. This would in turn support both problem isomorphism and knowledge generalization as integral to transfer: what some have termed the low and high roads to transfer (Perkins & Solomon, 199?).

However, doing so would leave unresolved the actual couplings by which shopkeepers and students develop an understanding of arithmetic over time in a new activity, and consequently leave the role of knowledge transformation unexamined. It would also leave unresolved the role of leading and non-leading activities in the process, making tenuous any conclusions tying changes in mathematical reasoning to broader changes in the fabric of rural Nepali society.

Measures of central tendency and singular rather than temporally-ordered tasks have been useful thus far as "interpretive stand-ins" for persons in transition between schooling and shopkeeping activities. To address the above it is necessary to move to an examination of the actual process of students becoming shopkeepers and shopkeepers becoming students.

X. APPRENTICESHIP AND TRACKING TASKS: ANALYSES AND FINDINGS

The 13 farmer/students were apprenticed to a shopkeeper over a period of a month and the 13 farmer/students were enrolled in an adult education class in which mathematics and literacy were taught for the period for a month. Thirteen farmers were also apprenticed to the shopkeeper and 13 farmers were enrolled in the adult education class. As stated previously, data from the farmers will not be analyzed as part of this dissertation.

Tracking tasks were administered to each participant at days 8, 16, 24, and 32 of their participation in the new activity. As the tracking tasks were derived from the initial assessment tasks, a subset of the initial assessment tasks were included in the tracking task sequence as representative of arithmetic knowledge on day 0, prior to their participation in the new activity. The analyses which follow utilize three of the five points in time (days 0, 16, and 32), one shopkeeping tasks (forearm length/meter price conversion problem) and four mathematics classroom tasks (a double digit over single digit problem involving carrying for addition, subtraction, multiplication, and division). These point in time and the tasks are representative of the larger data set and address the major aspects of the research questions presented in chapter V.

Brief descriptions of participation in the new activities follow.

Becoming a Shopkeeper

The shopkeeper who owned the largest shop in the village was chosen as the master shopkeeper to whom the farm/students were apprenticed. The 42 year old master had worked as a shopkeeper for 9 years and had completed 9th class in high school. The master's shop was located in the main bazaar area of Bherighat. The bazaar 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 foam rubber cushion next to a money box. The customers and apprentices sat or squatted on the floor around the shopkeeper.

The thirteen farmer/student participants worked in the shop in 6 pairs and one working individually. A schedule was established whereby each pair of farmer/students were able to spend two hours in the shop with the master shopkeeper every other day over a period of 32 days. This allowed each apprentice to spend 16 days or 32 hours learning from the master shopkeeper and assisting him with customers, less 3 to 5 hours time spent participating in tracking tasks outside the shop.

The master shopkeeper agreed that the apprentices' training should model that of past apprentices he had trained, roughly following a sequence described in chapter V. By the end of the 32 day period all of the shopkeepers had spent at least some time managing the store on his own.

However, this sequence was highly permeable in three ways. One, the apprentice always had the master's practice before him in it entirety, quite independent of the apprentice's point in the sequence, though the apprentice's ability to interpret the practice varied in part with his place in the sequence. 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 situations 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 farmer/students at intervals during their apprenticeships consistently indicated that they were viewing their participation as something that was related to school in so far as they were struggling with using column algorithms and written artifacts from school with new GDO's, but saw their learning as relevant to shopkeeping, not to schooling. They described themselves as learning to be a shopkeeper. In fact, five of the participants eventually went on to open stores of their own.

Being an Adult Education Student

One of the 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 5 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 as a result of his experience.

The classes were held in the panchyat or 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. For cloudy days, two kerosene pressure lanterns were used to light the hall.

Thirteen farmer/shopkeepers participated in the adult education class. Each class met for two hours every other day for 32 days, following a schedule equivalent to that of the farmer/students apprenticed to the shopkeeper. This allowed each student to spend 16 days and 32 hours learning in the classroom, less 3 to 5 hours time spent participating in tracking tasks during class time outside of the class.

The course followed the standard Ministry of Education and Culture's curriculum for adult education in numeracy and literacy along with information about health and ecology. A series of five texts published by His Majesty's Government of Nepal were issued to each of the participants. The texts were combined textbooks and workbooks designed as part of the curriculum. The research assistant was told to largely ignore the teachers guide and structure the course like a normal school course. This was done for three 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. Three, most adult education teachers in Nepal are also school teachers. Without intensive training, practice, and different expectations on the part of the adult students, classroom teachers in Nepal are destined to teach adult education classes as they teach their classes in school.

Literacy and numeracy lessons alternated throughout the curriculum. Both were addressed during each class session. The arithmetic portion of the curriculum begins 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, single 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 combined pictures with numbers initially, followed by arithmetic problems depicted in the 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 instructor and the students followed the standard teacher question-student response (choral or individual)-instructor evaluation of response characteristic of most classrooms today (Cazden, 1984). This structure was used more in its rhetorical form, as a lecture, rather than as a form of involving and assessing students' progress. As the students progressed in the workbook sections of their texts at their seats, the teacher would assign additional arithmetic problems to those who completed a workbook section in advance of others and individually attend to those who were struggling with a particular lesson. As both classes contained students with a diverse range of backgrounds in arithmetic, the teacher gave several sets of homework adapted to the needs of different students.

The course was mastery-based. Therefore all who successfully completed all five texts were presented with a certificate. All 13 farmer/shopkeepers successfully completed the course.

Observations of and discussions with the farmer/shopkeepers at intervals during their attendance indicated that they were viewing their participation as something that was related to shopkeeping in so far as they were learning new forms of arithmetic calculation, those involving written artifacts and column algorithms. Unlike becoming a shopkeeper, moving from peripheral to fuller participation over time, each participant became a student the first day they attended the class. Their greatest challenge was mastering a new system of calculation artifacts and the algorithms associated with them through school activity. Calculation and the relation between different mathematical operations was not particularly problematical. They did not see themselves as becoming students, but rather shopkeepers who were students for the sake of learning that which would assist them in shopkeeping and, in some cases, expand the variety of goods 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 new forms of arithmetic in the course.

Tracking Farmer/Students Becoming Shopkeepers

Table 60 displays transition patterns in the arithmetic of farmer/students apprenticed to shopkeepers at day 0 (before the apprenticeship), day 16, and day 32 (the end of the apprenticeship) using the actual number of participants.

The first pattern is based on the type of calculation artifacts used to solve the cloth measurement problem. A distinction is made between written artifacts such as numerals and equations, object-based calculation artifacts such as tallys, stones, or fingers, or the use of both. All problems were solved with the use of some form of calculation artifact.

Ten of the 13 students apprenticed to shopkeepers retained written numerals as their primary calculation artifact throughout the apprenticeship. Though several or the participants combined written and object artifacts in their calculations at different times, only one participant displayed the exclusive use of object calculation artifacts (in this case fingers) and then only on day 32.

The next pattern is based on whether the participants used column algorithm strategies in their calculations, reorganization strategies such as decomposition and iteration, or a combination of both. Counting strategies and math fact strategies were not displayed in isolation by any of the participants on this task.

Initially ten participants displayed the exclusive use of a column algorithm strategy. By day 32 only 4 participants did so, whereas 3 participants had switched to exclusively using a reorganization strategy by day 32. While three of the farmer/students initially displayed a combination of strategies, by day 32, 6 of the apprentices displayed a

Table 60

Cloth Measure Conversion: Number of Farmer/Students Displaying Artifacts, Strategies, and GDO's 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			
equation1	10	8	3
mesurement2	1	4	9
both3	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 attempted to solve the problem using a linear GDO, are unsuccessful, and then begins again with an unsystematic form of a measurement GDO. This is the only time during the initial tasks that both pp and na artifacts co-occur within a single problem-solving episode.

combination of strategies.

The final pattern is based on whether the participants used an equation

GDO, a measurement GDO, or switched from one to the other over time. The equation GDO organized strategies and artifacts through the establishment of a set of equations which 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 often occurs in coordinating the various calculations to be performed. Figure 13

Figure 13

Cloth Conversion Tracking Task at Day 8 of Apprenticeship, ID 6

Yan Bahadur is a 23 year old 10th grade high school student working on the cloth problem after 8 days of his apprenticeship. Playing the role of customer, I ask for 4 haat of cloth (a length from the elbow point to tip of the middle finger) and that he has told me that the particular cloth I have chosen costs 40 rupees a meter. I asked him how much money I owe him.

Yan Bahadur first measures his forearm using the meter ruler, coming up with 45 centimeters. He writes down 4 times 45 on paper in column algorithm format. Then he calculates out loud "4 times 5, 0 (writes zero), 2 in the hand (two carried), 4 times 4, 16, 17, 18 (writes 18) 180." Then Yan Bahadur decides 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) and comes up with the written answer 2.50 which he calls "two and a half rupees." He looks a bit askance at the figure. Then he writes 180 times 2.5 and, using a column algorithm, comes up with 450. Yan Bahadur scans his calculations on paper, looks at me, and says "You owe me 450 rupees for the cloth?!"

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 a certain extent, measurement units are never confused, and unnecessary precision never occurs because the systems of measurement are never removed from the process of calculation.

Of the ten farmer/students who began with an equation GDO, only three displayed the GDO on the task at day 32. There was an almost mirror increase in the number of participants who displayed a measurement GDO across the three points in time. One or more participants at each of the three points in time first displayed an equation GDO, but switched to a measurement GDO within the same task.

Table 60 does not directly display the relations between artifacts, strategies, and GDO's over time, nor does it allow the reader to directly trace patterns of individual change over time. Table 61 does allow this. In it we see that only three of the thirteen participants exhibited total continuity in the artifacts, strategies, and GDO's used before and throughout the apprenticeship. Of the ten who changed, only one changed to the exclusive use of object calculation artifacts. The rest of the

Table 61

Cloth Measure Conversion: 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

[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

farmer/students either retained the use of written artifacts in full (n = 7) or in combination with object artifacts (n = 3). However, of these ten, all displayed the use of a measurement GDO or switched to a measurement

GDO on the task on day 32. All but one of these participants used reorganization strategies or a combination of column algorithms and reorganization 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 participant had already displayed a measurement GDO on day 0. Of the five participants, only one changed strategy: two retaining a column algorithm strategy and two retaining a combination of strategies. It appears that the construction of a measurement GDO is 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.

Of the eight participants who exhibited change from day 16 to day 32, five shifted from an equation GDO to a measurement GDO or a combination of both, one retained and earlier shift to a measurement GDO, and shifted from a combination of both to a measurement GDO. Of the eight, only one retained a column algorithm strategy. It again appears that the construction of a measurement is necessary but not sufficient for the use of reorganizations strategies, and that the form of artifact is neither necessary nor sufficient in relation to these changes.

In general among the 10 participants who displayed some change, there was continuity in the use of written artifacts as the farmer/students became fuller participants in shopkeeping, discontinuity in GDO's from an equation GDO to a measurement GDO, and both continuity and discontinuity in the strategies displayed.

Examining the relation between artifacts, strategies, and GDO's as the coupling of person and activity, and as development, we see that a new form of arithmetic has been constructed that is neither a product of the individual participant, the prior schooling activity, or their fuller participation in the activity of shopkeeping. Seven of the participant-shopkeeping couplings that have changed demonstrate this transformation most clearly in Table 61: displaying the use of written artifacts, a reorganization strategy or a combination of reorganization strategy and column algorithm strategy, and a measurement GDO.

These seven participant-activity couplings displayed a form of arithmetic that retains the relatively high social status of written calculation artifacts and its relatively greater record permanence coupled with reorganization or a combination of reorganization and column algorithm strategies and a measurement GOD. Figure 14 provides an illustration of this.

Three participant-activity couplings displayed a limited version of this relation between artifacts, strategies, and GDO on day 0. All three participants had experience purchasing cloth in shops. However, so had the

Figure 14

Cloth Conversion Tracking Task at Day 32 of Apprenticeship, ID 6

Yan Bahadur is a 23 year old 10th grade high school student working on the cloth problem after 32 days of his apprenticeship. Playing the role of customer, I ask for 3 haat of cloth (a length from the elbow point to tip of the middle finger) and that he has told me that the particular cloth I have chosen costs 30 rupees a meter. I asked him how much money I owe him.

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
```

three participants who exhibited continuity in their use of written artifacts, column algorithm strategies, and equation GDO over the entire period of the apprenticeship. What did seem to distinguish between these two groups of participants was the latter's poor performance in 10th grade school mathematics (two of the three failed the final end of year exam and the third passed only by the teacher providing five "grace" points), and the shopkeeper to whom they were apprenticed finding all three to be "frustrating", "lazy", "more interested in gossiping with customers than selling them things" and "could not add one plus one if they had to."

Tracking Farmer/Shopkeepers as Students

Table 62 displays transition patterns in the arithmetic of farmer/shopkeepers enrolled in the adult education class at day 0 (before

Table 62

Written Problems: Number of Farmer/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			
strategic1	0	4	1
solution2	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 4 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 4 problems.

participation), day 16, and day 32 (the end of the class) using the actual number of participants. The task in this case consists of a school math exercise consisting of four two-digit by single-digit arithmetic problem, each displayed in writing as an addition, subtraction, multiplication, or division equation. The exercise is considered to be a single task for purposes of analysis.

The first pattern is based on the type of calculation artifacts used to solve the math exercise. A distinction is 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 counted as written calculation artifact use, as it was the means of introducing the task, much as and orally presented problem was not coded as using aural artifacts. The exercise was always completed by using some form of calculation artifact at some point in the process.

None of the 13 shopkeepers enrolled as students retained objects as their primary calculation artifact throughout the apprenticeship, though ten of the thirteen participants used such artifacts exclusively at day 0. By the end of the course eleven of the farmer/shopkeepers had adopted a combination of written and object artifacts and two and adopted the exclusive use of written artifacts.

The next pattern is based on whether the participants used column algorithm strategies in their calculations, reorganization strategies such as decomposition and iteration, or a combination of both. Counting strategies and math fact strategies were not displayed in isolation by any of the participants on this task.

Nine farmer/shopkeepers initially displayed the exclusive use of reorganization strategies, and there displayed the use of both column algorithm and reorganization strategies. By the end of the course only two of the participants displayed exclusive use of reorganization strategies and ten displayed the use of both.

The final pattern is based on whether the participants used a strategic GDO or a solution GDO. The solution GDO organizes strategies and artifacts around achieving a desired solution. This permits the strategies and artifacts to be adapted the nature of each problem in relation to the participant's knowledge. The greatest challenge for the shopkeepers often occurs in knowing what the written artifacts and equations stand for. Figure 15 provides an illustration of this.

The strategic GDO organized 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 thirteen of the farmer/shopkeepers began with a solution GDO and all but one ended the course using a solution GDO, though four of the

Figure 15

<u>Subtraction Portion of Arithmetic Exercise Tracking Task at Day 8 of Apprenticeship, ID 19</u>

Prem Bahadur is a 42 year old shopkeeper working on a subtraction problem as part of the math exercise after 8 days of class. He has worked as a shopkeeper for five years.

Prem Bahadur looks at the problem written on the paper in Devnagri numerals as:

```
(2)  53
   - 17
```

He says that he recognizes the number seventeen, but not the other number or the line to the left of the seventeen. I tell him that the other number is 53 and the line to the left of the 17 means to subtract. He asks which number from which. I tell him seventeen from fifty-three.

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 fingers 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."

participants displayed a strategic GDO on the day 16 task.

Table 62 does not directly display the relations between artifacts, strategies, and GDO's over time, nor does it allow the reader to directly trace patterns of individual change over time. Table 63 does allow this. In it we see that none of the thirteen participants exhibited total continuity in the artifacts, strategies, and GDO's used before and throughout their participation in the course. All ten of the participants who began by exclusively using object artifacts on day 0 changed using a combination of written and object calculation artifacts by the end of the course on day 32. Two of the three participants who had begun on day one by using both types of calculation artifacts changed to exclusively using written artifacts on day 32.

Of the eleven 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 an overall direction toward incorporating written artifacts and column algorithms into their repertoire without along with object artifacts and reorganization algorithms. All nine of these participants also displayed solution GDOs at day 32, as they did at day 0.

Of the ten farmer/shopkeepers who exhibited change from day 0 to day 16, four shifted from a solution GDO to a strategic GDO. All other participants maintained the solution GDO they displayed on day 0. Three of the four participants who changed to the use of a strategic GDO

Table 63

Written Problems: Number of Participants Displaying Artifacts

Strategies, and GDO's Across Time (n = 13), Schooling Tracking Tasks

Participant ID	Day 0 Art./Str./GDO[1]	Day 16 Art./Str./GDO	Day 32 Art./Str./GDO
14[2]	o/b/so___|	|___b/b/so__________	b/b/so
15[2]	o/r/so__________	o/r/so___|	|___b/b/so
16[2]	o/r/so__________	o/r/so___|	|___b/b/so
17[2]	b/c/so___|	|___b/b/st___|	|___w/c/so
18[2]	o/r/so___|	|___b/b/so__________	b/b/so
19[2]	o/r/so___|	|___b/b/so__________	b/b/so
20[2]	o/r/so___|	|___b/b/so__________	b/b/so
21[2]	o/r/so___|	|___b/b/so__________	b/b/so
22[2]	b/b/so___|	|___w/r/st___|	|___b/r/so
23[2]	b/b/so___|	|___w/c/st___|	|___w/b/st
24[2]	o/r/so__________	o/r/so___|	|___b/r/so
25[2]	o/r/so___|	|___o/r/st___|	|___b/b/so
26[2]	o/r/so___|	|___b/b/so__________	b/b/so

[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 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

on day 16 displayed some use of written artifacts and column algorithms on day 0, prior to their participating in the adult education course.

Eight of the thirteen participants changed strategies from day 0 to day 16: six to using both strategies when only one had been used at day 1, one to exclusively using a column algorithm strategy at day 16 when both strategies had been used at day 0, and one to exclusively using a reorganization strategy on day 16 when both had been used at day 0. The later 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 at 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 the seven farmer/shopkeepers, four changed from the exclusive use of a single strategy to the use of both calculation strategies.

In general there was continuity in the use of the solution GDO by the participants. Though four of the farmer/shopkeepers changed to a strategic GDO at day 16, all but one had returned to the use of a solution GDO by the end of the adult education class on day 32. Participants' use of calculation artifacts and strategies generally shifted toward using both types of artifacts and both types of strategies in solving the addition, subtraction, multiplication, and division problems in the arithmetic exercise, exhibiting both continuity and discontinuity across time. This was supported by the relative continuity of the solution GDO over time; a GDO which supports the adaptive use of a variety of calculation artifacts and strategies.

Examining the relation between artifacts, strategies, and GDO's as the coupling of person and activity, and as development, we again see that a new form of arithmetic has been constructed that is neither a product of the individual participant, the prior shopkeeping activity, or their participation as students in the adult education class. Nine of the participant-schooling couplings that have changed demonstrate this transformation most clearly in table 63: displaying the use of both written and object artifacts, a combination of reorganization and column algorithm strategies, and a solution GDO.

These nine participant-activity couplings developed a form of arithmetic that creates a high degree of adaptive flexibility over time, incorporating new artifacts and strategies and strategies into an already flexible arithmetic repertoire. There was no consistent pattern to how the other four participants differed from these nine.

Unlike the farmer/students whose transformations in arithmetic took them toward fuller participation in the activity of shopkeeping, the farmer/shopkeepers transformations in arithmetic were generally motivated by the increased adaptability and utility of arithmetic in their shops.

Summary

Taken overall, the findings indicate that the farmer/shopkeepers built on and further developed a flexible repertoire of calculation artifacts and strategies, supported by the maintenance of a solution GDO. The adaptive flexibility of these couplings developed through their participation in the adult education course would serve them well in their shops. Relative to the farmer/shopkeepers, the farmer/students displayed more limited development toward a flexible repertoire of calculation artifacts, strategies and GDO during the course of their apprenticeship. Continuity lay in their use of written artifacts over time, rather than GDO's, while exhibiting discontinuities and change in calculation strategies and GDO's: the overall transformation developing a form of arithmetic that maintained the high status written artifacts while creating some adaptive flexibility in calculation strategies.

In concluding this chapter, I would like to reflect back on the issue of leading and non-leading activities as they relate to learning and development across school and work.

The farmer/students apprenticed to shopkeepers were in transition from one leading activity to another, following a school-to-work sequence characteristic of generations to come in Nepali society. However, the two activities are defined by motives that bear little relation to one another in rural Nepal. The motives are learning, with learning as the object of the activity along with its representation as a credential, and becoming a shopkeeper, with selling goods for profit up front as the object. These unrelated motives and objects allowed schooling activity, and the arithmetic originating with it, to achieve a status disconnected from and beyond that of arithmetic originating in shopkeeping activity. This was reflected in the farmer/students developing a form of arithmetic that maintained the high status written artifacts while creating some adaptive flexibility in calculation strategies.

One the other hand, farmer/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 characteristic of perhaps only the current generation of shopkeepers in Nepali society. The motive of the adult education activity was to facilitate the construction of new arithmetic and literacy knowledge and skills that would benefit farmer/shopkeepers in running and possibly expanding their shops. This was reflected in farmer/shopkeepers developing a flexible repertoire of arithmetic artifacts, organizations, and operations through the adult education class.

School and work, along with play, are clearly categories of leading activities in rural Nepali society. However, the point in the development of an individual or a generation of individuals at which an individual participates in an activity clearly has much to do with whether it is leading or not. It is in this way that activities mediate between societal change and the learning and development of individuals.

XI. CONCLUSIONS AND DISCUSSION

This chapter provides revists the research questions outlined in Chapter V in light of the findings contained in chapters VI through X. Each of these questions reflects on a different aspect of the relation of societal change to individual learning and development, and on the methodology used to examine these relations.

What is the relation of the history of arithmetic within Bherighat farming, schooling, and shopkeeping activities to broader changes in Nepali society?

Practices that include arithmetic as a part of farming, schooling, and shopkeeping activities in Bherighat are related to a broader set of changes in Nepali society in two ways: through their location in a societal history and through the changing relations of those activities to each other as a part of that history.

Farming has been the central activity in rural Nepali society for centuries, encompassing work, family, and community in a relatively seamless whole. As an activity, farming is coextensive with the history of Nepal as a geographical, political and economic enterprise. The place of farming in Nepali society as well as its relation other often newly formed activities has evolved with the Kingdom's increasing participation in a global economy. Beginning in the late 1940s-early 1950s, Nepali society began moving toward a new system of economics based on monetary exchange, away from direct exchanges of goods, toward knowledge production as a function of institutions beyond the family. Farming activity has become less encompassing and more specialized as a result. This was part of an ongoing differentiation of learning, work, and familial activities in Bherighat, and in Nepali society in general.

Arithmetic, or real numbers and computations performed with them, is integral to farming activity, not as a system of disciplinary knowledge, but rather as a cultural means for creating, maintaining, and communicating information critical to the activity.

Goal-directed organizations, arithmetic strategies, calculation artifacts, and systems of measurement in Bherighat farming have exhibited a relatively high level of consistency and continuity across time in relation to the activity's coextensive history with Nepali society. Many current counting strategies, counting artifacts such as fingers, seeds, and stones, and GDO's such as dividing meat equally among individuals, as well as systems of measurement such as *muti, muri, pathi*, and *maana* were displayed by Bherighat farmers a century ago, before the village shifted from the hillside to its current site in the valley, and continue to be displayed today.

Other aspects of arithmetic relate to changes in farming as a refraction of Nepal's entry into the global market. Growth in cash cropping has introduced monetary exchanges and some aspects of the metric system of measures into farming activity, necessitating resolution strategies such as the creation of proportions for conversion from one system of measurement to the other and new measurement facts, disputes, such as those around buying and selling grain by metric weight rather than by traditional volume, and new practices, such as the recording of crop yields.

The advent of schooling and shopkeeping activities in Bherighat were also associated with broader transformations in Nepali society, the former with the desire for a national system of secular education in line with Great Britain and North America and the latter with the increasing availability of cash and access to goods from India and Kathmandu by road. Unlike farming, rural schooling and shopkeeping activities were not coextensive with the history of Nepali society. Therefore the advent of rural shopkeeping and school activities resulted in the narrowing of lived experience in Bherighat that had been organized as a part of farming activity. At the same time these activities developed economic, artifactual, and temporal relations with farming activity, both because of their interdependent organization at the societal level and because Bherighat villagers became participants in these activities in addition to farming.

The institution of schooling has developed and interwoven in various ways with life in Bherighat. The high school sponsors a yearly traditional dance involving the village. Worship of the Hindu deity *Saraswati*, the goddess of knowledge and learning, has developed into a school celebration. The concept of a "club" has developed as a part of the Bherighat community, sustaining same-age social groupings after leaving school. However, arithmetic in schooling activity did not develop as part of the structure of Bherighat village so much as it was presented as a cultural package from without; pre-organized on the basis of British and American mathematics curriculums in force in the 1950's and early 1960's. It is only recently that a major rethinking of mathematics education in Nepal has begun, though in again it is in relation to mathematics education reforms taking place in Great Britain and North America.

Arithmetic was seen as the base from which to build other mathematical understandings and as such was not developed beyond that taught and learned in the primary grades. At the time of this study, arithmetic was taught and learned as math facts, the four basic mathematical operations, and column algorithm strategies, with the occasional introduction of word problems that were then translated into column algorithms. Written artifacts were given a singularly elevated status over other forms of arithmetic artifacts. The use of alternative strategies and artifacts were actively discouraged through the creation and maintenance of goal-directed organizations affording strategies and artifacts deemed to be properly associated with arithmetic.

The activity of the math class is organized in a manner that reflects the function of the institution of schooling, as creating and maintaining learning activity, where learning and knowledge are both means and ends (Engstrom, Hakkarainen, & Hedegaard, 1984). This has the effect of maintaining a hermetic relation between GDO's, strategies, and artifacts, at least within arithmetic. Unlike arithmetic associated with farming activity in Bherighat, arithmetic associated with schooling activity has displayed total continuity and consistency over the time schooling has existed in the village. It social status, marked by its adherence to written forms, as well as the hermitic cluster of GDO's, strategies, and artifacts has facilitated its identifiable use in farming and shopkeeping activities by those who have participated in schooling.

Arithmetic learning, knowledge, and skill is also designated as "portable" by virtue of its ties to learning activity at school, i.e. it is to be useful elsewhere at home, in the community, or at work. (Glick, 1993). The hermetic aspect of arithmetic originating in school learning activity and its high social status combines with this assumption of portability to produce an outflow of arithmetic originating in school into other spheres of activity. Its power was demonstrated by the elder Bherighat farmers and shopkeepers who redefined their arithmetic as estimation in response to the status of "school arithmetic."

Shopkeeping in Bherighat began on the edge of the school compound and was initiated by farmers as a way of providing a small cash supplement to their subsistence farming. The opening of a road head to India near Bherighat, the increased uses for cash in the village, and a new generation of shopkeepers, some of whom had attended school, all contributed to the expansion of shopkeeping in the village.

Like schooling, the activity of shopkeeping was not coextensive with rural Nepali society nor the history of Bherighat. Like farming, however, the activity of shopkeeping and associated arithmetic exhibited innovation as well as constancy over time. The use of stones and fingers, counting and reorganization strategies of various sorts, and GDO's of efficiency, purchase, and public display developed to include written numerals and column algorithms under the same set of GDO's. The latter were perceived as useful for calculations with large numbers, when a permanent record of the calculation was required, or where a mnemonic device to support calculation was desirable.

The introduction of metric forms of measurement into shopkeeping activity through government regulation and use by wholesale sources in India motivated the development of arithmetic that efficiently converted quantities and prices between traditional and metric forms of measurement. This is also an example of the mediating role of shopkeeping activity in the village, serving as a transformational activity, both for arithmetic that is sensitive to new and old measurement forms and individual identities from tradition (farming) to the modern (shopkeeping). Examples of shopkeeping's mediation between schooling and farming in addition to converting between metric and traditional forms of measurement are farmer/shopkeepers with sons becoming shopkeepers after leaving school, its use as a social gathering place for both students and farmers, the use of arithmetic strategies and artifacts with origins in schooling and farming, and selling goods for cash that are of value to farmers and students.

Four key aspects of these relations between farming, shopkeeping, and schooling activities in Bherighat and change in Nepali society were simulated in the study:

> increasing economic demands for cash income, the inability of agriculture to satisfy this demand in some cases, increasing accessibility of wholesale shop merchandise,
>
> increasing demand for cash income, increasing growth of crops for cash in some cases, increasing need for detailed record keeping and large-number calculation in agriculture,
>
> increasing numbers of students who are unable to go on to higher education, decreasing appeal of working full time in agriculture after having attended school for a number of years, increasing availability of cash for purchasing goods,
>
> increasing availability of cash for purchasing goods and increasing accessibility to a wide variety of wholesale

goods, increasing size and complexity of rural shops, increasing need for detailed record-keeping and large-number calculation.

What is the relation of evolving ties in arithmetic between farming, schooling, and shopkeeping activities to the paths taken by persons between the activities?

The development of farming, schooling, and shopkeeping activities in Bherighat are related not only to transformations in the fabric of Nepali society and increasing differentiation between familial, learning, and work, but also the lives of the individuals participating in them. This is equally true for the arithmetic that developed as part of these activities. However, the lives of individuals participating in these activities are generally not coextensive with the development of the activities themselves. This brings us to the issue of heterochronicity first mentioned in chapter VI.

Heterochronicity refers to the different and partially overlapping histories of societies, activities, individuals' lives, and artifacts (Hutchins, 1992; Beach, In press). Whether and how these histories overlap and the relative differences in their cycles of change, or spans of existence, has a lot to do with what people learn and develop, both within and across generations.

The activities of farming, studying in school, and shopkeeping have different spans of existence that overlap at different points in the history of the Bherighat, and bear different temporal relations with societal change in

Nepal. Farming activity is coextensive with the history for the village. Schooling has existed in the village since 1960 and shopkeeping since 1963. Different generations of participants intersect the histories of these activities at different points, differentially affording and constraining opportunities for participation, learning, and development.

Heterochronicity exists in two forms here. The first form exists between activities: the development of farming, schooling, and shopkeeping activities only partially overlap each other in Bherighat. A second, related form of heterochronicity exists between the particular activities and the lives of different generations of villagers. The farmers and shopkeepers born in Bherighat in the 1940's did not have the opportunity to attend school during their youth because schooling was outlawed for those who were not members of the royal court. Villagers who were born in the mid-to late 1950's had potential access to schooling and shopkeeping in addition to farming at a relatively young age.

Clearly the span of time it takes to live out one's life and the historical period in which one does so provides very different opportunities for learning and development. This is particularly true during times of rapid societal change. For example, a farmer born in the 1940's who became a shopkeeper in the 1960's, which is when shops were being opened in Bherighat for the first time, had to build directly on the knowledge of arithmetic used in farming. There were was no preexisting shopkeeping activity or expertise to draw upon. A student or a farmer in the 1980's who becomes a shopkeeper in the 1990's can potentially draw on the arithmetic expertise of the more than 50 shopkeepers currently running shops in the village. For similar reasons, adult farmers and shopkeepers who previously would have been full participants in all activities in which their children participated currently find themselves learning some aspects of "written arithmetic" from their sons and daughters who attend school.

The farming participants in this study were of a generation that had not had the opportunity to directly participate in schooling activity nor in shopkeeping other than as customers until later in life. Over half of the farmers would have participated in school and shopkeeping activities if they had the opportunity. Most of the farmers felt that the quality of their arithmetic had little effect on the quality of their farming. They used few math facts when compared to the farmer/shopkeepers and the farmer/students, relied heavily on finger and stone/seed calculation artifacts or not external artifact, and strategies that involved reorganization and counting. Most of the farmers could not read or write numerals beyond a single digit, but a far greater percentage of farmers than farmer/students used the more articulated versions of finger calculations with joints as floating value locations.

The arithmetic displayed by the farmers was not necessarily limited to farming activity, as illustrated by their performances on the initial shopkeeping and schooling tasks. They also had indirect contact with schooling through their sons and daughters and with shopkeeping as customers. Therefore their knowledge of arithmetic was neither solely a product of their participation in farming activity nor was it potentially applicable only to farming activity. At the same time, they were full participants in farming, not schooling or shopkeeping and their identities were as farmers, not as shopkeepers or students.

Some Bherighat farmers other than those in our participant sample had attended adult education classes when they were available in the village and others had opened shops. Both of these life paths or trajectories were simulated as they were related respectively to:

> increasing demand for cash income, increasing growth of crops for cash in some cases, increasing need for detailed record keeping and large-number calculation in agriculture,
>
> increasing economic demands for cash income, the inability of agriculture to satisfy this demand in some cases, increasing accessibility of wholesale shop merchandise.

The farming/shopkeeper participants in this study were, like the farmers, of a generation that had not had the opportunity to directly participate in schooling activity. All of the farmer/shopkeepers had become shopkeepers after having spent five or more years participating in farming alone. Over half of the farmer/shopkeepers would have also participated in schooling if they had the opportunity. All of the farmer/shopkeepers felt that the quality of their arithmetic had great effect on the quality of their shopkeeping, but like the farmers, felt that it had little effect on the quality of their farming activity. They used almost as many math facts in place of addition and subtraction calculations as the farmer/students but fewer multiplication and division math facts, relied heavily on finger and stone/seed calculation artifacts or no external artifact, but also used written numerals on occasion, and strategies that involved reorganization and counting. All of the shopkeepers could read and write single digit numerals and most could read and write double-digit numerals, though like the farmers they did not recognize calculation signs and equation formats. Like the farmers, but unlike the farmer/students the farmer/shopkeepers used the more articulated versions of finger calculations with joints as floating value locations.

The arithmetic displayed by the shopkeepers was not necessarily limited to farming or shopkeeping activity, as shown by their performances on the initial schooling tasks. They also had indirect contact with schooling through their sons and daughters and through customers who were students and teachers. Therefore their knowledge of arithmetic was not solely a product of their participation in farming and shopkeeping activity nor was it potentially applicable only to farming and shopkeeping activity. At the same time, they were full participants in farming and later in shopkeeping as well, not schooling, and their identities were as farmers and shopkeepers, not students.

From a developmental perspective, farmer/shopkeepers' knowledge and use of arithmetic in shopkeeping could only have been constructed in relation to their knowledge of arithmetic in farming, even if in opposition to it. In this sense "shopkeeping arithmetic" for farmer/shopkeepers was mutually constituted by their full participation in farming, then farming/shopkeeping. Determining the relative contribution of either of the two activities to their knowledge of arithmetic is thus rendered nonsensical.

Some Bherighat farmer/shopkeepers other than those in our participant sample had attended adult education classes when they were available in the village. This life path or trajectory was simulated in the study as it was related to:

> increasing availability of cash for purchasing goods and increasing accessibility to a wide variety of wholesale goods, increasing size and complexity of rural shops, increasing need for detailed record-keeping and large-number calculation.

The farmer/student participants in this study had the opportunity to directly participate in schooling activity, unlike the farmers and the shopkeepers of the previous generation. All had become students several years after having begun participating in some aspect of farming activity. Over three quarters of the farmer/students would have also participated in shopkeeping if they had the opportunity, explaining that a lack of sufficient start up capital or the need to support their family prevented them from doing so. All of the farmer/students felt that the quality of their arithmetic had great effect on the quality of their shopkeeping. Unlike the farmers and the farmer/shopkeepers, over half of the farmer/students felt that the quality of their arithmetic had an effect on the quality of their participation in farming activity. This may have been a function of both the elevated status of arithmetic seen as originating in school and their generally peripheral participation in farming activity.

The farmer/students displayed math facts with a greater frequency than any of the other participant groups, relied heavily on written numerals and equation artifacts when not using math facts, and strategies that involved column algorithms or math facts. All of the farmer/students could read and write multiple digit numerals and equations. Unlike the farmers and the farmer/shopkeepers, the farmer/students generally used the less articulated versions of finger calculations with fingers as fixed value locations.

The arithmetic displayed by the farmer/students was not necessarily limited to farming or schooling activity, as shown by their performances on the initial shopkeeping tasks. They also had indirect contact with shopkeeping as customers. Therefore their knowledge of arithmetic was not solely a product of their participation in farming and schooling activity nor was it potentially applicable only to farming and schooling activity. At the same time, they were peripheral participants in farming and slightly later full participants in schooling, not shopkeeping, and their identities were as farmers and students, not shopkeepers. As a caveat to this, the relatively higher status of participating in schooling over farming and the received view of schooling as a means of moving away from participating in farming activity had the effect of farmer/students defining themselves primarily as students and only secondarily as farmers.

From a developmental perspective, farmer/students' knowledge and use of arithmetic in school could only have been constructed in relation to their knowledge of arithmetic in farming, even if in contradiction to it. In this sense "school arithmetic" for farmer/students was mutually constituted by their peripheral participation in farming, then farming/schooling. Determining the relative contribution of either of the two activities to their knowledge of arithmetic is again rendered nonsensical, as it was in the case of farmer/shopkeepers.

Some Bherighat farmer/students other than those in our participant sample had become shopkeepers, or farmer/student/shopkeepers. This life path or trajectory was simulated in the study as it was related to:

> increasing numbers of students who are unable to go on to higher education, decreasing appeal of working full time in agriculture after having attended school for a number of years, increasing availability of cash for purchasing goods.

Consistent with heterochronicity among the three activities and between the activities and the lives of individual participants, paths taken by Bherighat's farmers, farmer/shopkeepers, and farmer/students prior to the inception of the study are clearly associated with differences in arithmetic knowledge and use. In some cases these differences appear as differences of frequency and in others as differences of kind. In so far as these paths or potentials for transition between farming, schooling, and shopkeeping activities vary with changes in Nepali society, so do constraints and affordances for the development of various understandings and uses of arithmetic.

<u>What is the relation of the paths taken by persons between studying and shopkeeping activities to continuities, discontinuities, and transformations in their arithmetic practices?</u>

Four paths were examined in this study: farmer to farmer/shopkeeper or to farmer/student, farmer/shopkeeper to farmer/student, farmer/student to farmer/shopkeeper. Each of these paths are instantiations of changing relations between farming, schooling, and shopkeeping activities in Bherighat and as such, changing arithmetic knowledge in the village.

Two of these paths, farmer/shopkeeper to farmer/student and farmer to farmer/shopkeeper, represent the recent past to the present in Bherighat and will probably not continue far into future. Fewer farmers are becoming shopkeepers and fewer shopkeepers will be in need of adult education classes in the near future. The other two paths, farmer to farmer/student and farmer/student to farmer/shopkeeper, are indicative of the present and future of Bherighat. More farmer/students are becoming shopkeepers. Given the future of the local economy, there will also be a consistent percentage of farmers who will not attend school, but will later attend adult education classes.

Two of these paths between school and work activities were analyzed for the continuities, discontinuities, and transformations in arithmetic they induced in this dissertation: farmer/shopkeeper to farmer/student, farmer/student to farmer/shopkeeper.

Findings from the initial tasks in which all participants were presented with simulations from each of the three activities provided evidence of differences based on prior individual experience, e.g. shopkeepers displayed a greater repertoire of GDO-artifact-strategy couplings on shopkeeping tasks and on schooling tasks than did the students, students used column algorithm strategies and written numerals on most shopkeeping tasks as well as schooling tasks, a majority of shopkeepers and students displayed GDOs on the tasks consistent with the primary activity in which they had previously participated and not necessarily consistent with the activity from which the task simulations were derived.

Other analyses of the same data provided evidence of differences based on the task's association with the new activity, e.g. shopkeepers used column algorithm strategies and written numerals more frequently on the schooling tasks than on the farming and shopkeeping tasks, and students used counting and/or reorganization strategies coupled with object artifacts more frequently on the farming and shopkeeping tasks than on the schooling tasks.

Taken together, these findings are consonant with some combination of the generalization and isomorphism approaches to transfer, suggesting that both the nature of the new task-activity and the person's prior experience interact to produce learning transfer. This is similar to the position taken by Perkins and Solomon (1987). As discussed in chapters II and III, however, a conception of transfer that involves both abstract-general and context-specific forms of knowledge, or generalization as well as isomorphism leaves the theoretical tension that exists between these two aspects unresolved. It also denies that new knowledge can be created in the process of transfer and therefore has little to contribute to development. Furthermore, this conception of transfer is unnecessarily restrictive in its view of how prior knowledge is used to learn something new and does not allow for an analysis of the process as it relates to societal and cultural change. In short, a combined generalization and isomorphism approach to transfer is inadequate for explaining how people learn and develop in the process of transition between historically contingent activities such as school and work.

Building on Vygotskian theory and activity theory, the alternative conceptualization proposed in chapter III states that transformation as well as continuity and discontinuity in knowledge better describes transition between activities, where transformation, or the creation of new knowledge, is neither a product of the prior activity, the new activity, or the person, but rather is an aspect of the individual's developmental history coupled with the histories of the activities as they unfold together over a particular period of time. Stated differently, the learning and development of individuals becoming someone or something new is mediated in its relation to change at the societal level by activities such as school and work that possess their own histories of development, artifacts, and forms of knowledge and skill.

Longitudinal analyses of arithmetic among farmer/students becoming shopkeepers and farmer/shopkeepers becoming students indicated that all of participants displayed some aspects of continuity and discontinuity in arithmetic goal-directed organizations, artifacts, and strategies between schooling and shopkeeping activities. Ten of the thirteen farmer/students apprenticed to the shopkeepers also demonstrated some degree of transformation in their arithmetic, constituted by a combination of both continuity and discontinuity among GDOs, strategies, and artifacts. All thirteen of the farmer/shopkeepers enrolled in the adult education class demonstrated some degree of transformation in their arithmetic.

Kindermann and Valsiner (1989, p. 18) state that in developmental psychology "...it is necessary to view target phenomena in terms of a reorganization of real elements and not as an increase or decrease of differential ones." Continuity or discontinuity in GDOs, artifacts, or strategies over time across activities can be seen as a simple increase or decrease in the differential elements that make up arithmetic-in-practice. Their reorganization as elements of new practices involving arithmetic in the new activity, or transformation, are precisely the sort of phenomena referred to by Kindermann and Valsiner as central to understanding human development. At the same time, the specific nature of the continuities, discontinuities, and transformations in arithmetic knowledge over time, from school to work and frcm work to school can be fully understood only in relation to school and shopkeeping activities as they mediate between individual learning and development on the one hand, and changes in Nepali society on the other.

A majority of the farmer/students apprenticed to shopkeepers retained written numerals as their primary artifact for calculation throughout their apprenticeship. However, most farmer/shopkeepers in the adult education class shifted from the use of object artifacts such as fingers and stones to the combined use of object and written calculation artifacts.

A majority of the farmer/students apprenticed to shopkeepers shifted from the exclusive use of column algorithm strategies to the exclusive use of reorganization strategies, or their use in combination with column algorithm strategies. In a similar manner, most farmer/shopkeepers in the adult education class shifted from their exclusive use of reorganization strategies to their use in combination with column algorithm strategies.

Last, a majority of the farmer/students apprenticed to shopkeepers shifted from their use of an equation GDO to the use of a measurement GDO. However, most farmer/shopkeepers in the adult education class retained their use of a solution GDO rather than shift to the use of a strategic GDO.

Figure 16 illustrates these. It shows three generalizations regarding continuities, discontinuities, and transformations in the arithmetic of farmer/students becoming shopkeepers and farmer/shopkeepers becoming students.

Figure 16

Three Generalizations Regarding Continuities, Discontinuities, and Transformations Among Farmer/Students Becoming Shopkeepers and Farmer/Shopkeepers Becoming Students

	Farmer/student to shopkeeping	Farmer/shopkeeper to schooling
Artifacts	continuity	both
Strategies	both	both
Goal-Directed Organization	discontinuity	continuity

that arithmetic experiences through participation in schooling and shopkeeping activities are non-additive. If they were additive, whether a villager learned arithmetic by participating in school, then shopkeeping or by participating in shopkeeping, then schooling should make no major difference in the individual's knowledge and use of arithmetic. Yet it is clear that students becoming shopkeepers retain arithmetic artifacts from their participation in schooling, abandon their use of GDOs that hold measurement external to the problem-solving process, and come to use a combination of column algorithm and reorganization strategies. In contrast to this, shopkeepers who attend adult education class come to use a combination of written and object artifacts and column algorithm and reorganization strategies while continuing to use a goal-directed organization that is sensitive to the nature of desired solution, but does not otherwise restrict the calculation process to a particular strategy or artifact.

These differences in continuity and discontinuity, and therefore transformation can be understood by examining the particular school and work activities as they relate both to Nepali society and the lives of the individuals participating in them. The concept of leading and non-leading activity as defined in activity theory is a useful starting point for this.

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, schooling, work, and retirement may be the sequence of leading activity categories characteristic of many industrialized societies. In others, the sequence may be play followed by work.

This has been interpreted as meaning that a given society defines a developmental sequence of activity categories that directly determines aspects of its individual members' learning and development. Our findings suggest, however, that whether or not an activity is "leading" and therefore dominant in the individual's learning and development is co-determined by the genetic sequence of activity categories characteristic of a society and the point in the individual's developmental history at which he or she participates in the activity. This conception of leading activity avoids the assumption that paths taken from participation in one activity to participation in another are somehow equivalent independent of their directionality, acknowledging the existence of societal constraints and affordances on the sequencing of activity categories and paths between them. At the same it also takes the individual's developmental history as central to whether an activity is leading or not.

The students apprenticed to shopkeepers were in transition from one leading activity to another, following a school-to-work sequence characteristic of generations to come in rural Nepali society. With respect to their own developmental histories they were becoming shopkeepers.

They were not learning something about shopkeeping to be of use in some other activity. These two leading activities are defined by motives that bear little explicit relation to one another, at least in rural Nepali society. The motives are learning for a credential, with learning as the object of the activity, and becoming a shopkeeper, with selling goods for profit as the object. Schooling is not intended as preparation for shopkeeping. Students desire to become shopkeepers in Bherighat as a way of avoiding continuing work in agriculture. This is less an issue of economics and more an issue of status, having completed many years of schooling.

It is therefore not surprising that the students struggled mightily to retain their use of written calculation artifacts in becoming shopkeepers; written numerals being the main socially-acknowledged indicator of knowing and doing *hisaab*, or "true" arithmetic. At the same time, becoming a shopkeeper required GDOs which are capable of organizing multiple mathematical operations involving different dimensions of measurement in a manner that is efficient, accurate, and socially acceptable by the customer. Equation GDOs initially favored by the students that excluded measurement from the problem space and tied written artifacts and column algorithm strategies to solution acceptability were supplanted over time by measurement GDO's adequate to the challenges of arithmetic as a part of shopkeeping practices.

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 characteristic of perhaps only two or three current generations in Nepali society. With respect to their own developmental histories, the shopkeepers were not becoming students in the same sense that children become students, but rather were shopkeepers learning forms of arithmetic and literacy which would be of use to them in the shop. Becoming a student was simply a means to this. It is in this sense that an activity that might otherwise be a leading activity is a non-leading activity for adults who are attending school for the first time.

These two activities, one leading and one not are defined by motives and objects that bear some relation to one another. The motives are learning to benefit an existing aspect of one's life, with learning as the object of the activity, and economic survival, with selling goods for profit as the object. This particular form of school activity allows shopkeepers to gain knowledge of some aspects of arithmetic that they see as improving the economic functioning of their shops, through record keeping and the ability to do calculations with large numbers.

Their transition from a leading to a non-leading activity involved incorporating new calculation artifacts, written numerals and equation formats, and new calculation strategies, column algorithms, into their existing repertoire of object artifacts, "mental" calculations, and reorganization and counting strategies. This was facilitated by their retention of GDOs which allowed calculation artifacts and strategies to vary depending upon the characteristics of the particular problem. In this sense the shopkeepers were expanding their flexible repertoire of arithmetic strategies and artifacts. This was done selectively, based more on their identities as shopkeepers than as students, as evidenced by their consistent "inability" to remember the signs for the four mathematical operations while mastering multidigit numbers, equation formats, and column algorithms.

The development of new knowledge of arithmetic occurred for both farmer/students becoming shopkeepers and farmer/shopkeepers becoming students. This took place through the reorganization of GDO's artifacts, and strategies into new couplings based on the continuity and discontinuity of the elements in the process of transition between school and work activities. The continuities, discontinuities, and consequent transformations as well as their arithmetic "content" could only be interpreted through individual participations in sequences of activities that are historically contingent with respect to a broader set of changes taking place in Nepali society.

<u>As a reconceptualization of transfer, how adequately do continuity, discontinuity, and transformation capture the transitions between studying and shopkeeping, at least within the domain of arithmetic?</u>

Site-to-site transfer has been reconceptualized as the continuity and discontinuity of artifacts, strategies, and goal-directed organizations across activities, and the reorganization or transformation of those elements as part of reoccurring practices in the new activity, such as an arithmetic exercise in schooling or a customer purchase in shopkeeping. This conceptualization takes the process of coming to participate in a new activity, a "process of becoming" as proposed by Dewey (Mcdermott, 1973), to be one of learning and development, not the momentary creation and recognition of isomporphs nor generalization through the use of analogical representation or reflective abstraction. In doing so it avoids the self-inflicted narrowness of what is counted as transfer by cognitive models, lending explanatory power to studies of site-to-site transfer occurring in society. It renders nonsensical distinctions such as learning at one site and the application of that learning at another, a necessary accompaniment to representational views of mind. Last, it suggests that the contradiction inherant in isomorphism and abstraction/generalization accounts, the "low and high roads to transfer" (Perkins & Solomon, 1987), can be avoided by viewing the process as one in which differential continuities and discontinuities in goal-directed organizations, strategies, and artifacts embody qualitative transformations in knowledge and skills.

At the same time this reconceptualization of transfer is not "just learning and development." The conceptualization encompasses the psychological and social import of becoming someone new through a leading activity: a student becoming a shopkeeper or a spouse becoming a parent. When there is participation in a new activity that is not leading, that participation is transformed in relation to other leading activities: a shopkeeper attending an adult education class or a professional athlete taking up golf as a hobby. In both cases of learning and development across activities, the process is part of the creation of personal identity and associated relations of status, power, and value. Lave (1995) has suggested a similar reorientation in which identity formation subsumes and organizes the acquisition of knowledge and skills.

This conceptualization of learning and development in transition between activities allowed us to look at what is learned and developed in the domain of arithmetic by individuals in transition between school and work activities, and how those activities mediated the relation of individual learning and development and societal change. It also raises a number of questions and challenges that will not be resolved in this study. Three in particular are worth mentioning here.

The concept of learning and development as a coupling between persons and activities over time, drawing on the work of Maturana and Varela (1980), takes us a potential step further in our view of continuity, discontinuity, and transformation as residing in the developing relation between person and activity, rather than in the person or in the activities. The coevolution of two systems, bees and flowers, over evolutionary time provides a wonderful metaphor for the concept of person-activity coupling.

> 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 patters 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 (Varela, Thompson, & Rosch, 1992, p. 202.)

Structural coupling is proposed as an alternative to a representational view of mind, learning, and development. No longer seen as problem solving on the basis of representations in the head or in the environment, instead, learning and development in its most expansive sense consists in the enacting or bringing forth of a world through person-activity couplings.

While still vague in its definition and usefulness as a concept in developmental psychology, it does afford a view of learning and development in transition between activities as a rearrangement of relations between personal and activity developmental systems without reducing one to the cause of the other, allows for multiple satisfactory rather than single optimal developmental resolutions, and avoids the apparent paradox of having to "peer around" one's imperfect mental representation to apprehend a truer world from which to develop ones representation.

A conscious level of organization beyond that of individual arithmetic operations, goal-directed organizations in this study, is clearly necessary for understanding how calculation artifacts and strategies come to be organized as part of a reoccurring practice, and presents a second challenge for future studies. Conscious reflection is necessary for creating, planning, and guiding calculation in the service of school- or work-based practices. Despite the utility of goal-directed organization as a construct, however, it remained difficult to define and code in this study, in part because of the explanatory tautology of defining goals based on observed data as noted by von Cranach & Kalbermatten (1982) and other action theorists. Examining the micro-formation of goal-directed organizations along with their enactment upon first participating in a preexisting social practice may go some way toward forming a non-tautological explanation of its role in learning and development.

Third, a decision was made to not constrain tasks derived from farming, schooling, and shopkeeping activities according to formal arithmetic equivalence, e.g. presenting three multiplied by fifteen as a problem embedded in a school math exercise and as embedded in a shopkeeping purchase, though this method has been successfully used to examine the effects of different contexts on calculation performance (Nunes, Schliemann, & Carraher, 1993).

Focused ethnographic work suggested that many number combinations and calculations occurred with greater frequency in one activity than another and that formal arithmetic equivalence could therefore not be assumed to hold arithmetic properties constant across activities. Furthermore, the nature of the reoccurring practices in which arithmetic occurred for the three activities varied, as did the number and complexity of the calculations involved. Achieving formal mathematical equivalence would have required eliminating that which distinguished the practices as a part of farming, schooling, and shopkeeping activities, disrupting the very learning and developmental phenomena we sought to understand.

Having opted for tracking tasks derived directly from the new activities in which the participants were operating, comparison between students becoming shopkeepers and shopkeepers becoming students was problematic in some cases, such as between a school task that involved counting the number of stacked bricks in a picture and a shopkeeping task that involved weighing out a quantity of sugar. A number of such comparisons were not included in the analyses for this reason. Future studies will need to contend with how to best derive tracking tasks from different activities while affording comparisons between the tasks that do not necessitate an extreme level of generality.

What are the benefits, shortcomings, and implications of a methodology that simulates relations between changes in Nepali society and the learning and development of Nepali villagers through school and work activities?

The methodology described in chapter V links the cultural- historical theory of Vygotsky and activity theory with a set of research questions about how individual learning and development relates to societal change through the mediation of historically contingent activities. This becomes operationalized in this study as the learning and development of arithmetic in transition between school and work activities in a Nepali village.

The methodology simulated societal trends that were represented in the relation between school and work activities in Bherighat through volunteers whose current participation in an activity along with their apprenticeship or enrollment in a new activity followed the societal trend, if not the personal motivation for making a particular transition to participation in a new activity. These transitions in turn induced learning and development that bore a relatively clear relation societal change.

This methodology allowed us to look at what is learned and developed in the domain of arithmetic by individuals in transition between school and work activities, and how those activities mediated the relation of individual learning and development and societal change. It also raises a number of challenges and questions. Three in particular are worth mentioning here.

First, a new aspect of the methodology emerged through its use, that of the "critical period", or those points in the history of a society when societal transformation occurs rapidly within the span of a single generation. Both forms of heterochronicity are most marked during such critical periods. Relations between sociogenesis and ontogenesis are best studied during these periods because neighboring generations of individuals often follow new paths of transition between existing activities and between existing and new activities. This in turn affords the analytic separation of individual learning and development, activity, and societal change. This form of analysis is made more difficult by times of relative societal stasis, when sociogenesis, activity, and ontogenesis appear to move together as a largely seamless whole.

Second, any methodology for studying societal change in relation to individual learning and development that does not reduce society, activity, or the individual to a singular explanation of change in one of the other historical planes is going to have massive data management and reduction problem. This was certainly the case for this study. The resulting compromise was that a detailed micro-developmental account of how continuities, discontinuities, and transformation in GDO's, artifacts, and strategies develop over real time in the process of transition is lacking. Plans are underway for one of the author's students to do such a study with a small sample Nepali of students becoming shopkeepers and shopkeepers enrolled as students.

Third, transitions from school to work activities are relatively linear; with individuals' leaving school, entering the workforce, and rarely looking back as long as employment is maintained. Learning, development, and knowledge displays a similar directionality in the transition from school to work.

However, most individuals participate in multiple activities on any given day, with learning, development, and knowledge constituted through their multiple participations. This present a far more complex methodological challenge than studying learning and development through a clear institutional transition such as that between school and work. Most research to date has resorted to linear forms of interpretation, with learning in each situation being described as affecting learning in the other (e.g. Heath, 1982; Nunes, Schliemann, & Carraher, 1993; Saxe, 1990), illustrating the lack of an adequate methodology for investigating individual learning and development as mutually constituted by participation in different activities. This is a fruitful, if challenging direction for future research. One of the author's students is currently examining children's understanding of money as it is mutually constituted by participation in the home and the school with this in mind (Reineke, Beach, & Chilcote, 1994).

Appendix A: Demographic Characteristics of the Experimental Samples

Table 1

Caste Characteristics of Informants: Experimental Samples

Caste Characteristics	Farmers n = 26		Shopkeepers n = 13		Students n = 13	
	f	%	f	%	f	%
Gurung	1	3.8	4	30.8	0	0
Magar	14	53.8	2	15.4	5	38.5
Bahaun	6	23.1	1	2.1	2	15.4
Chetri	3	11.5	2	16.4	4	30.8
Sunar	1	3.8	0	0	0	0
Sarki	0	0	1	7.7	0	0
Damai	1	3.8	0	0	0	0
Thakali	0	0	0	0	0	0
Thakuri	0	0	2	4.3	1	7.6
Newar	0	0	0	0	0	0
Kaami	0	0	0	0	1	7.6
Kumal	0	0	1	2.1	0	0
Giri	0	0	1	2.1	0	0

Table 2

Agricultural Yields of Informants' Households: Experimental Samples

Agricultural Yields	Farmers n = 26	Shopkeepers n = 13	Students n = 13
Wheat (in pathi)			
mean (sd)	106.5 (67.4)	84.6 (55.2)	138.2 (72.4)
purchase %	26.9	38.5	7.7
sell %	7.7	0	15.4
sufficient %	57.7	53.5	76.9
none %	7.7	7.7	0
Rice (in pathi)			
mean (sd)	444.6 (294.4)	325.7 (112.9)	512.3 (322.1)
purchase %	7.7	30.8	0
sell %	11.5	0	7.7
sufficient %	73.1	69.2	84.6
none %	7.7	0	0
Corn (in pathi)			
mean (sd)	91.5 (53.5)	65.6 (42.1)	119.6 (62.2)
purchase %	15.4	7.7	0
sell %	7.7	0	7.7
sufficient %	76.9	84.6	92.3
none %	0	7.7	0
Chickens			
mean (sd)	13.4 (15.7)	9.5 (11.6)	16.2 (15.3)
purchase %	11.5	30.8	7.7
sell %	23.1	7.7	23.1
sufficient %	50.0	46.2	69.2
none %	15.4	15.3	0
Goats			
mean (sd)	.9 (2.1)	.5 (2.8)	4.5 (2.8)
purchase %	7.7	30.8	0
sell %	0	0	0
sufficient %	11.5	15.4	46.2
none %	80.8	53.8	53.8

Table 2 (cont.)

Agricultural Yields of Informants' Households: Experimental Samples

Agricultural Yields	Farmers n = 26	Shopkeepers n = 13	Students n = 13
Pigs			
mean (sd)	1.3 (1.9)	1.0 (2.0)	1.0 (2.3)
purchase %	3.8	0	7.7
sell %	11.5	7.7	0
sufficient %	30.8	23.1	46.2
none %	53.8	69.2	46.2

Table 3

Types of Math Used by Informants: Experimental Samples

Activity and Type of Math Used	Percentage*		
	Farmers n = 26	Shopkeepers n = 13	Students n = 13
In Farming			
addition	100	100	100
subtraction	92.3	92.3	100
multiplication	42.3	92.3	100
division	42.3	76.9	100
counting	100	100	92.3
estimation	100	84.6	53.8
In Shopkeeping			
addition		100	
subtraction		100	
multiplication		100	
division		84.6	
counting		100	
estimation		84.6	
In Schooling			
addition			100
subtraction			100
multiplication			100
division			100
counting			92.3
estimation			15.4

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

Table 4

Informants' Familarity With Written Numerals: Experimental Samples

	Percentage		
Familiarity With Written Numerals	Farmers n = 26	Shopkeepers n = 13	Students n = 13
Can Neither Read Nor Write Numerals 1 - 9	38.5	0	0
Can Only Read Numerals 1 - 9	23.0	23.1	0
Can Read and Write Numerals 1 - 9	38.5	76.9	100

Table 5

Types of Math Mediational Devices Used: Experimental Samples

Activity and Type of Mediational Device Used	Percentage*		
	Farmers n = 26	Shopkeepers n = 13	Students n = 13
In Farming			
fingers	84.6	46.2	30.8
stones	26.9	7.7	0
tallys	19.2	7.7	0
numerals	11.5	38.5	76.9
person	80.7	76.9	15.4
mental	100	100	38.5
In Shopkeeping			
finger		61.5	
stones		7.7	
tallys		0	
numerals		46.2	
person		15.4	
mental		100	
In Schooling			
fingers			15.4
stones			0
tallys			7.7
numerals			100
person			15.4
mental			7.7

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

Table 6

Types of Measures Used in Schooling: Experimental Samples

Type of Measure Used	Percentage* Farmers n = 26	Shopkeepers n = 13	Students n = 13
length			
meter			100
haat			0
paila			0
distance			
kilometer			92.3
kosh			0
area			
bighaa			15.4
hectre			84.6
weight			
dharni			0
kilo			100
tolaa			0
volume			
pathi			0
kuruwa			0
litre			100
kantar			15.4
money			
rupee			100
time			
ghanta			100

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

Table 7

Types of Measures Used in Shopkeeping: Experimental Samples

Type of Measure Used	Percentage* Farmers n = 26	Shopkeepers n = 13	Students n = 13
length			
meter		84.6	
haat		61.5	
paila		0	
distance			
kilometer		0	
kosh		0	
area			
bighaa		0	
hectre		0	
weight			
dharni		61.5	
kilo		100	
tolaa		46.2	
volume			
pathi		69.2	
kuruwa		38.5	
litre		76.9	
kantar		30.7	
money			
rupee		100	
time			
ghanta		100	

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

Table 8

Types of Measures Used in Farming : Experimental Samples

Type of Measure Used	Percentages* Farmers n = 26	Shopkeepers n = 13	Students n = 13
length			
meter	3.8	46.2	61.5
haat	100	76.9	30.8
paila	46.6	61.5	15.4
distance			
kilometer	0	0	0
kosh	3.8	7.7	0
area			
bighaa	100	100	100
hectre	0	0	23.1
weight			
dharni	100	84.6	46.2
kilo	15.3	84.6	84.6
tolaa	0	7.7	0
volume			
pathi	100	100	100
kuruwa	96.2	92.3	38.5
litre	23.1	76.9	100
kantar	7.7	15.4	38.5
money			
rupee	100	100	100
time			
ghanta	100	100	100

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

Table 9

Occupations of Informants' Family Members in Addition to Agriculture: Experimental Samples

	Percentage of Families with One or More Members in Addition to the Informant Engaged in an Occupation in Addition to Farming		
Type of Occupation	Farmers n = 26	Shopkeepers n = 13	Students n = 13
shopkeeper	0	76.9	0
teacher	7.7	38.5	38.5
JTA/health worker	3.8	0	0
servant	3.8	0	0
solider	7.7	23.1	23.1
laborer	53.8	15.4	15.4
carpenter	0	0	7.7
porter	19.2	0	7.7
office clerk	0	0	0
blacksmith	7.7	0	0
tailor	0	0	0
goldsmith	0	0	7.7
leather worker	0	7.7	0

Table 10

Income Level of Shops: Shopkeeping Experimental

Sample (n = 13)

Income in Rupees*	Frequency	Percentage
less than 1000 rupees	2	15.3
1000 to 2000 rupees	3	23.1
2001 to 3000 rupees	3	23.1
3001 to 4000 rupees	0	0
4001 to 5000 rupe	0	0
5001 to 6000 rupees	1	7.7
6001 to 7000 rupees	0	0
7001 to 8000 rupees	1	7.7
8001 to 9000 rupees	0	0
9001 to 10,000 rupees	1	7.7
10,001 to 15,000 rupees	1	7.7
above 15,000 rupees	1	7.7

* Approximately 26 rupees were equivalent to one US dollar at the time of the survey

Table 11

Types of Shops: Shopkeeping Experimental Sample

(n = 13)

Type	Frequency	Percentage
general shop	8	61.5
general/tea shop	2	15.4
general/cloth shop	1	7.7
cloth shop	2	15.4
medical hall	0	0
repair shop	0	0
tea shop	0	0

Table 12

Location of Wholesale Sources for Shops: Shopkeeping Experimental Sample (n = 13)

Location of Source	Frequency	Percentage*
Local	5	38.5
Lekh Pharsa (1 kilometer)	2	15.4
Chinchhu (8 kilometers)	10	76.9
Birendranagar (25 kilometers)	7	53.8
Nepalganj (30 Kilometers)	5	38.5
India (31 kilometers)	1	7.7
Kathmandu (250 kilometers)	2	15.4

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

Table 13

Most Common* Items Found in Shops: Shopkeeping

Experimental Sample** (n = 13)

Item	Frequency	Percentage
Red Rose Tea	8	61.5
Matches	13	100
Yak Cigarettes	8	61.5
Gaida Cigarettes	13	100
Deaurali Cigarettes	13	100
Candy	13	100
Supari	10	76.9
Hair Ribbons	9	69.2
Mhaduri Soap	7	53.8
Myalu Soap	11	84.6
Myalu Biscuts	12	92.3
Glucose Biscuts	13	100
Pineapple Biscuts	6	46.2
Razor Blades	9	69.2
Chewing Tobacco	13	100
Notebooks	12	92.3
Pencils	9	69.2
Ballpoint Pens	12	92.3
Fountain Pens	11	84.6
Ink	12	92.3
Rara Noodles	13	100

* Only those items found in 75 percent or more of the shops in the demographic sample are included.

** More than one category of response per informant was permitted. Percentages may therefore total more than 100.

Table 14

Relationship of Principal Shop Assistants to Shopkeepers: Shopkeeping Experimental Sample (n = 13)

Assistant	Frequency	Percentage
none	5	38.5
wife	1	7.7
son	3	23.1
brother	1	7.7
brother-in-law	1	7.7
uncle	0	0
father	2	15.3
nephew	0	0
student	0	0

Table 15

Number of Years Failed by Students: Schooling Experimental Sample (n = 13)*

Number of Years Failed	Frequency	Percentage
none	5	38.5
one	8	61.5
two	0	0
three	0	0

* Students in the experimental sample failed a mean of .62 years of school with a standard deviation of .51 years

Table 16

Certainty of Passing the School Leaving Certificate Examinations Expressed by Students: Schooling Experimental Sample (n = 13)*

Certainity of Passing	Frequency	Percentage
0 percent	0	0
1 to 20 percent	0	0
21 to 40 percent	1	7.7
41 to 60 percent	7	53.8
61 to 80 percent	3	23.1
81 to 100 percent	2	15.4

* Students in the experimental sample expressed a mean percent certainty that they would pass of 71.2 with a standard deviation of 42.8.

Table 17

What Students Believe They Will Pursue if They Pass the School Leaving Certificate Examinations: Schooling Experimental Sample (n = 13)

Pursuit	Frequency	Percentage
teaching	2	15.4
military	0	0
higher education	9	69.2
junior technical assistant	1	7.7
agriculture	0	0
shopkeeping	0	0
other	1	7.7

Table 18

What Students Believe They Will Pursue if They Fail the School Leaving Certificate Examinations: Schooling Experimental Sample (n = 13)

Pursuit	Frequency	Percentage
agriculture	3	23.1
shopkeeping	4	30.8
military	0	0
take exam again	6	46.2

Table 19

Characteristics of Mathematics as a Subject For

Students: Schooling Experimental Sample (n = 13)*

Mathematics as a Subject	Frequency	Percentage
Sudent's best subject in terms of marks	0	0
student's worst subject in terms of marks	4	30.8
student's favorite subject	2	15.4
student's least favorite subject	7	53.8

* The mean annual math test score for a student out of a possible 100 is 29.2 with a standard deviation of 14.9. A score of 32 or above is generally considered a passing in the school.

Table 20

Students' Chores After School: Schooling Experimental

Sample (n = 13)

Chores	Frequency	Percentage*
carrying water	2	15.4
planting	1	7.7
plowing	10	76.9
cutting foder	0	0
grazing animals	4	30.7
cutting wood	1	7.7
studying	12	92.3
helping others study	3	23.1
watering animals	2	15.4
dumping garbage	1	7.7
carrying wood	0	0

* More than one category of response per informant was permitted. Percentages may therefore total more than 100.

Appendix B: Narrative Questions in Structured Interview

1A. Would you have gone to school if you had had the chance? (farm and shop groups)
   1a. (if yes) Why didn't you have the chance?
   1b. (if yes) Are there any other reasons why you didn't have the chance?
   2a. (if no) Why wouldn't you have gone if you had had the chance?
   2b. (if no) Are there any other reasons why you wouldn't have gone if you had had the chance?

1B. Would you have opened a shop if you had had the chance? (farm and school groups)
   1a. (if yes) Why didn't you have the chance?
   1b. (if yes) Are there any other reasons why you didn't have the chance?
   2a. (if no) Why wouldn't you have gone if you had had the chance?
   2b. (if no) Are there any other reasons why you wouldn't have gone if you had had the chance?

2A. What advantages do you gain from doing farming? (all groups) Are there any other advantages do you gain form doing farming? What are they?

2B. What advantages do you gain from doing shopkeeping? (shop group) Are there any other advantages do you gain form doing shopkeeping? What are they?

2C. What advantages do you gain from studying in school? (school group) Are there any other advantages do you gain form studying in school? What are they?

3A. Tell me all of the places where you do farming. (all groups) Are there any other places where you do farming? Where are they?

3B. Tell me all of the places where you do shopkeeping.
(shop group) Are there any other places where you do shopkeeping? Where are they?

3C. Tell me all of the places where you do studying.
(school group) Are there any other places where you do studying? Where are they?

4A. Tell me all of the times when you do farming.
(all groups) Are there any other times when you do farming? When are they?

4B. Tell me all of the times when you do shopkeeping.
(shop group) Are there any other times when you do shopkeeping? When are they?

4C. Tell me all of the times when you do studying.
(school group) Are there any other times when you do studying? When are they?

5A. Tell me all the types of people you work with when you do farming.(all groups) Are there any other types of people you work with when you do farming? What are they?

5B. Tell me all the types of people you work with when you do shopkeeping.(shop group) Are there any other types of people you work with when you do shopkeeping? What are they?

5C. Tell me all the types of people you study with.
(school group). Are there any other types of people you study with? What are they?

6A. Tell me all the things you use to do farming.
(all groups) Are there any other things you use to do farming? What are they?

6B. Tell me all the things you use to do shopkeeping.
(shop group) Are there any other things you use to do shopkeeping? What are they?

6C. Tell me all the things you use to study.
(school group) Are there any other things you use to study? What are they?

7A. Tell me all the types of knowledge you need to do farming.
(all groups) Are there any other types of knowledge you need to do farming? What are they?

7B. Tell me all the types of knowledge you need to do shopkeeping.(shop group) Are there any other types of knowledge you need to do shopkeeping? What are they?
7C. Tell me all the types of knowledge you need to do studying. (school group) Are there any other types of knowledge you need to do studying? What are they?

8A. Tell me all the things you do when you do farming? (all groups) Are there other things you do when you do farming? What are they?
8B. Tell me all the things you do when you do shopkeeping? (shop group) Are there other things you do when you do shopkeeping? What are they?
8C. Tell me all the things you do when you do studying? (school group) Are there other things you do when you do studying? What are they?

9A. I am interested in how you learned to become a farmer. Remember back to the first thing you learned about farming. What was it? (all groups) How did you learn about it?
9B. I am interested in how you learned to become a shopkeeper. Remember back to the first thing you learned about shopkeeping. What was it? (shop group) How did you learn about it?
9C. I am interested in what you learned in school. Remember back to the first thing you learned in school. What was it? (school group) How did you learn about it?

10A. What was the second thing you learned about farming? (all groups) How did you learn about it?
10B. What was the second thing you learned about shopkeeping? (shop group) How did you learn about it?
10C. What was the second thing you learned in school? (school group) How did you learn about it?

11A. What was the third thing you learned about farming? (all groups) How did you learn about it?
11B. What was the third thing you learned about shopkeeping? (shop group) How did you learn about it?
11C. What was the third thing you learned in school? (school group) How did you learn about it?

12A. What was the fourth thing you learned about farming?
(all groups) How did you learn about it?
12B. What was the fourth thing you learned about shopkeeping?
(shop group) How did you learn about it?
12C. What was the fourth thing you learned in school?
(school group) How did you learn about it?

13A. What was the fifth thing you learned about farming?
(all groups) How did you learn about it?
13B. What was the fifth thing you learned about shopkeeping?
(shop group)How did you learn about it?
13C. What was the fifth thing you learned in school?
(school group) How did you learn about it?

14A. Are there other things you learned about farming? What are they?(all groups) How did you learn about them?
14B. Are there other things you learned about shopkeeping? What are they? (shop group) How did you learn about them?
14C. Are there other things you learned in school? What are they? (school group) How did you learn about them?

15. I am interested in how you learned to use numbers. Remember back to the first thing you learned about numbers. What was it? (all groups) How did you learn about it?

16. What was the second thing you learned about numbers? (all groups) How did you learn about it?

17. What was the third thing you learned about numbers? (all groups) How did you learn about it?

18. What was the fourth thing you learned about numbers? (all groups) How did you learn about it?

19. What was the fifth thing you learned about numbers? (all groups) How did you learn about it?

20. Are there other things you learned about numbers? What are they? (all groups) How did you learn about them?

21A. Can do things with numbers using your fingers? (all groups) (if yes) How did you learn this?
21B. Do you ever actually do things with numbers using your fingers? (if yes) In what types of situations do you do things with numbers using your fingers?

22A. Can do things with numbers using seeds or stones? (all groups) (if yes) How did you learn this?
22B. Do you ever actually do things with numbers using seeds or stones? (if yes) In what types of situations do you do things with numbers using seeds or stones?

23A. Can do things with numbers using tallys? (all groups) (if yes) How did you learn this?
23B. Do you ever actually do things with numbers using tallys? (if yes) In what types of situations do you do things with numbers using tallys?

24A. Can do things with written numbers using paper and pencil? (all groups) (if yes) How did you learn this?
24B. (if yes) Do you ever actually do things with written numbers using paper and pencil? (if yes) In what types of situations do you do things with written numbers using paper and pencil?

25A. Can do things with numbers in your mind? (all groups) (if yes) How did you learn this?
25B. (if yes) Do you ever actually do things with numbers in your mind? (if yes) In what types of situations do you do things with numbers in your mind?

26A. Do you ever have to do things with numbers, but can not seem to come up with the right answer or do not know how to get the answer? (all groups) (if yes) In what sorts of situations does this happen? What do you do when this happens?
26B. Do other people ever help you get the right answer? What types of people usually help you get the right answer?

27. I am interested in how you learned to measure things. Remember back to the first thing you learned about how to measure things. What was it? How did you learn about it?

28. What was the second thing you learned about how to measure things? (all groups) How did you learn about it?

29. What was the third thing you learned about how to measure things? (all groups) How did you learn about it?

30. What was the fourth thing you learned about how to measure things? (all groups) How did you learn about it?

31. What was the fifth thing you learned about how to measure things? (all groups) How did you learn about it?

32. Are there other things you learned about how to measure things? What are they? (all groups) How did you learn about them?

33. What is the largest number that you can count up to from 1? (all groups) Can you count to (increment participant's number by one three) (if yes) Then what is the largest number you can count up to? (repeatuntil they reply they cannot or don't know the name of the next number).

34A. Do you ever "add" things while you are farming? (all groups) (if yes) Give me an example of how you "add" things when you are farming.
34B. Do you ever "add" things while you are shopkeeping? (shop group) (if yes) Give me an example of how you "add" things when you are shopkeeping.
34C. Do you ever "add" things while you are studying? (school group) (if yes) Give me an example of how you "add" things when you are studying.

35A. Do you ever "subtract" things while you are farming? (all groups) (if yes) Give me an example of how you "subtract" things when you are farming.
35B. Do you ever "subtract" things while you are shopkeeping? (shop group) (if yes) Give me an example of how you "subtract" things when you are shopkeeping.
35C. Do you ever "subtract" things while you are studying? (school group) (if yes) Give me an example of how you "subtract"things when you are studying.

36A. Do you ever "multiply" things while you are farming? (all groups) (if yes) Give me an example of how you "multiply" things when you are farming.
36B. Do you ever "multiply" things while you are shopkeeping? (shop group) (if yes) Give me an example of how you "multiply" things when you are shopkeeping.
36C. Do you ever "multiply" things while you are studying? (school group) (if yes) Give me an example of how you "multiply" things when you are studying.

37A. Do you ever "divide" things while you are farming? (all groups) (if yes) Give me an example of how you "divide" things when you are farming.
37B. Do you ever "divide" things while you are shopkeeping? (shop group) (if yes) Give me an example of how you "divide" things when you are shopkeeping.
37C. Do you ever "divide" things while you are studying? (school group) (if yes) Give me an example of how you "divide" things when you are studying.

38A. Do you ever "count" things while you are farming? (all groups) (if yes) Give me an example of how you "count" things when you are farming.
38B. Do you ever "count" things while you are shopkeeping? (shop group) (if yes) Give me an example of how you "count" things when you are shopkeeping.
38C. Do you ever "count" things while you are studying? (school group) (if yes) Give me an example of how you "count" things when you are studying.

39A. Do you ever "estimate" things while you are farming? (all groups) (if yes) Give me an example of how you "estimate" things when you are farming.
39B. Do you ever "estimate" things while you are shopkeeping? (shop group) (if yes) Give me an example of how you "estimate" things when you are shopkeeping.
39C. Do you ever "estimate" things while you are studying? (school group) (if yes) Give me an example of how you "estimate" things when you are studying.

40A. Does how well you can do things with numbers affect how well you do farming? (all groups) (if yes) How does it affect how well you do farming?

40B. Does how well you can do things with numbers affect how well you do shopkeeping? (shop group) (if yes) How does it affect how well you do shopkeeping?

40C. Does how well you can do things with numbers affect how well you study? (school group) (if yes) How does it affect how well you study?

41A. Do you use more math when you are farming, or when you are shopkeeping? (shop group)

41B. Do you use more math when you are farming, or when you are studying? (school group)

Appendix C: Tasks on Current Knowledge of Calculation, Artifacts, and Measurement

Addition, Subtraction, Multiplication, and Division Problems Presented in Math Facts Instrument

Addition

1. 24 + 48 = 72
2. 49 + 7 = 56
3. 50 + 8 = 58
4. 4 + 2 = 6
5. 4 + 8 = 12
6. 3 + 60 = 63
7. 7 + 49 = 56
8. 7 + 74 = 81
9. 45 + 26 = 71
10. 74 + 7 = 81
11. 32 + 4 = 36
12. 30 + 15 = 45
13. 60 + 3 = 63
14. 15 + 30 = 45
15 9 + 0 = 9
16. 5 + 2 = 7
17. 8 + 4 = 12
18. 34 + 20 = 54
19. 8 + 50 = 58
20. 26 + 45 = 71
21. 0 + 9 = 9
22. 12 + 11 = 23
23. 2 + 4 = 6
24. 11 + 12 = 23
25. 7 + 6 = 13
26. 42 + 21 = 63
27. 20 + 34 = 54
28. 6 + 62 = 68
29. 4 + 32 = 36
30. 62 + 6 = 68
31. 21 + 42 = 63
32. 48 + 24 = 72
33. 6 + 7 = 13
34. 5 + 2 = 7

Subtraction

1. 23 - 12 = 11
2. 76 - 0 = 76
3. 13 - 6 = 7
4. 63 - 3 = 60
5. 80 - 16 = 64
6. 15 - 0 = 15
7. 70 - 14 = 56
8. 45 - 15 = 30
9. 68 - 6 = 62
10. 50 - 10 = 40
11. 63 - 42 = 21
12. 72 - 24 = 48
13. 9 - 0 = 9
14. 34 - 4 = 30
15. 63 - 21 = 42
16. 10 - 6 = 4
17. 6 - 2 = 4
18. 12 - 4 = 8
19. 50 - 40 = 10
20. 7 - 2 = 5
21. 72 - 48 = 24
22. 51 - 34 = 17
23. 6 - 0 = 6
24. 10 - 2 = 8
25. 58 - 8 = 50
26. 56 - 7 = 49
27. 13 - 7 = 6
28. 8 - 5 = 3
29. 70 - 56 = 14
30. 23 - 11 - 12
31. 10 - 8 = 2
32. 80 - 64 = 16
34. 10 - 4 = 6
35. 45 - 30 = 15
36. 51 - 17 = 34

Multiplication

1. 11 x 3 = 33
2. 4 x 15 = 60
3. 5 x 10 = 50
4. 13 x 26 = 338
5. 3 x 20 = 60
6. 42 x 14 = 588
7. 13 x 11 = 143
8. 2 x 3 = 6
9. 6 x 12 = 72
10. 6 x 1 = 6
11. 12 x 11 = 132
12. 4 x 7 = 28
13. 3 x 2 = 6
14. 5 x 0 = 0
15. 20 x 3 = 60
16. 12 x 4 = 48
17. 3 x 11 = 33
18. 10 x 14 = 140
19. 26 x 13 = 338
20. 4 x 12 = 48
21. 14 x 42 = 588
22. 6 x 3 = 18
23. 30 x 15 = 450
24. 11 x 12 = 132
25. 15 x 30 = 450
26. 11 x 13 = 143
27. 14 x 10 = 140
28. 15 x 4 = 60
29. 7 x 4 = 28
30. 1 x 6 = 6
31. 10 x 5 = 50
32. 3 x 6 = 18
33. 12 x 6 = 72
34. 0 x 5 = 0

Division

1. 72 / 6 = 12
2. 6 / 2 = 3
3. 60 / 3 = 20
4. 84 / 7 = 12
5. 60 / 15 = 4
6. 18 / 6 = 3
7. 0 / 5 = null
8. 50 / 2 = 25
9. 50 / 5 = 10
10. 6 / 3 = 2
11. 5 / 0 = 5
12. 60 / 4 = 15
13. 50 / 10 = 5
14. 18 / 3 = 6
15. 72 / 12 = 6
16. 48 / 12 = 4

Numeral/Sign/Equation Reading and Writing Tasks

1. 6
2. 1
3. 5
4. 6
5. 7
6. 0
7. 4
8. 8
9. 2
10. 4
11. 9
12. 3
13. 4,249,378
14. 40
15. 3,333,333
16. 1,000
17. 40,079
18. 10
19. 407
20. 5,555,555
21. 22,222,222
22. 44,444
23. 100
24. 10,000,000
25. 9,999
26. 832,415
27. 2,483
28. 593
29. 5,285
30. 34,299,173
31. 120,026
32. 88
33. 1,000,000
34. 3,008
35. 100,000
36. 42
37. 340,029
38. 10,000
39. 666
40. 63,002,491
41. -
42. ÷
43. x
44. =
45. -
46. +
47. 10 - 4 =
48. 5 ÷ 50 =
49. 33
- 5
50. 8 + 42 =
51. 5
- 32
52. 12
x 6
53. 18 x 2 =
54. 4 - 10 =
55. 6| 12
56. 42 + 8 =
57. 7
+ 89
58. 2 X 18 =
59. 12 | 6
60. 19
+ 7

61.

$$\begin{array}{r} 6 \\ \underline{\times\ 12} \end{array}$$

62. 50 ÷ 5 =

Finger Counting Tasks

1. 4 + 9 =
2. 13 - 6 =
3. 3 x 4 =
4. 14 / 7 =

Problem-Solving Tasks

1. 8 + 7 =
2. 16 + 2 =
3. 2 + 16 =
4. 16 + 13 =
5. 8 + 8 + 8 + 8 =
6. 17 + 15 =
7. 15 + 6 =
8. 10 + 14 =
9. 21 - 10 =
10. 35 - 17 =
11. 7 - 4 =
12. 7 - 3 =
13. 18 - 5 =
14. 12 - 8 =
15. 4 x 8 =
16. 8 x 4 =
17. 10 x 14 =
18. 6 x 12 =
19. 10 x 4 =
20. 15 x 13 =
21. 3 x 5 =
22. 36 / 2 =
23. 18 / 6 =
24. 18 / 3 =
25. 40 / 10 =
26. 132 / 11 =
27. 6 / 2 =

Measurement Conversion Tasks

1. one minute = ? seconds
2. ghanta = ? minutes
3. ghanta = ? seconds
4. din = ? minutes
5. foot = ? inches
6. gaz = ? feet
7. meter = ? centimeter
8. bittha = ? aaula
9. haat = ? bittha
10. haat = ? kadam
11. paila = ? kadam
12. haat = ? aaula
13. kadam = ? bittha
14. meter = ? haat
15. paila = ? feet
16. foot = ? aaula
17. meter = ? foot
18. katha = ? meter
19. dhur = ? paila
20. tolaa = ? lal
21. tolaa = ? aathanni
22. aathain = ? chawanni
23. dharni = ? bisoli
24. bisoli = ? ser
25. kilo = ? grams
26. dharni = ? ser
27. chawanii = ? lal
28. dharni = ? kilo
29. tolaa = ? grams
30. dharni = ? tolaa
31. bisoli = ? kilo
32. pathi(rice) = ? kilo
33. kilo(rice) = ? maana
34. bighaa = ? kattha
35. kattha = ? dhur
36. ropani = ? anna
37. anna = ? paisa
38. bighaa = ? dhur
39. ropani = ? paisa
40. bighaa = ? ropani
41. ropani = ? kattha
42. bighaa = ? paisa
43. ropani = ? dhur
44. rupee = ? mohor
45. mohor = ? sukha
46. sukha = ? paisa
47. rupee = ? paisa
48. litre = ? Mililitre
49. pathi = ? maana
50. muri = ? pathi
51. kantar = ? litre
52. chauthai = ? hap
53. muri = ? maana
54. kantar = ? hap
55. kantar = ? liter
56. litre = ? kuruwa
57. pathi= ? litre
58. hap = ? kuruwa
59. ropani = ? muri
60. kattha = ? muri

Appendix D: <u>Initial Problem-Solving Assessments</u>

<u>Farming Tasks</u>

1. How much rice do you estimate is in this pile (show pile of 11.5 pathi of unhusked rice)? Here are *dalo, doko, pathi, and maana* measure containers. Please find out exactly how much rice is in this pile by measuring it into this bag.

2. How much (rice, wheat, corn) do you think the area marked by the four red flags (220^2 meters) yield? How can you tell? How much seed would you use to plant it? How do you know this?

3. How much (rice, wheat, corn) do you think the area marked by the four red flags (220^2 meters) yield if it was located at the edge of the Bheri River? How can you tell? How much seed would you use to plant it? How do you know this?

4. Suppose that these bags are goat meat. If you had to give this amount of meat (5 dharni and 5 bisauli) evenly to 5 people who bought into the goat, how much would you give each person? Use the *thulo* to weight the meat. (point out dharni, bisauli, ser, and pau markings on single-pan scale)

5. Suppose that these bags are goat meat. If you had to give this amount of meat (6 bisauli and 12 ser) evenly to 6 people who bought into the goat, how much would you give each person? Use the *thulo* to weight the meat. (point out dharni, bisauli, ser, and pau markings on single-pan scale)

6. If this year you had 17 muri extra rice to sell and last year you had 6 muri extra rice to sell, how much extra rice were you able to sell over these two years?

7. If you had a field that yielded 5 muri of rice the first year and only 2 muri the next year because there was not enough water, what would be your total yield for the two years?

8. If your field yielded 15 muri of rice this year and 8 muri last year, how much of an increase in yield did you have from last year to this year?

9. If your field yielded 11 muri of rice this year and 25 muri last year, how much did you yield decrease by from last year to this year?

10. If you had to pay 15 rupees for a day's work to each of 3 field workers, how much money would you need to pay out total for one day's work?

11. If you had to pay 12 rupees for a days work to each of 3 field workers, how much would you have to pay out total for one day's work for 5 people?

12. If you gave 40 rupees total evenly to 20 people for some work they did carrying one load of stones from the Bheri River, how mch would you have to pay each person?

13. If you had to give 20 rupees evenly to three people working in your fields as a team for one day, how much would you pay each person?

14. Here is a plow. Suppose that you had asked someone to make this plow for you to use in your fields. Would you be happy with it, or not? Why not? Which measurements are wrong, how can you tell, and what should they be?

<u>Shopkeeping Tasks</u>

1. If the amount of khani in this tin sells for 24 rupees, figure out how much khaini you would sell for 2 rupees.

2. This bag contains sugar. Pour out and weigh out (1 kilo, 350 grams, 400 grams) of sugar using the two-pan scale.

3. These bags contain sugar. Find out how much each of these bags weigh (1.5 kilo, 375 grams, 225 grams).

4. I am going to tell you the prices of these things. Later I am going to ask you to tell me what the prices of these things are (use actual objects, point to each object, name, and state name and price slowly). (at end of session) Please tell me the prices of these items.

5. Suppose that I want to buy 4 haat of this cloth (show white cloth). The price of the cloth is 20 rupees a meter. How much will you sell me the 4 haat of cloth for?

6. If you bought sugar for 8 rupees a kilo in Nepalganj and sold it for 15 rupees a kilo in Bherighat, how much money would you make or loose for every kilo you sold?

7. If you buy 12 notebooks from another shopkeeper for 78 paisa and sold them in your shop for 75 paisa each, how much money would you make a loose by selling all of the notebooks?

8. If you bought a pair of sandles for 17 rupees and wanted to make a 6 rupee profit, how much would you have to sell them for?

9. If you bought 20 tins of kaini in Surkhet for a total of 80 rupees and paid 20 rupees to have them carried to your shop in Bherighat, how much would you have to sell each tin for to make a 2 rupee profit on each?

10. If you bought some pens for 5 rupees each and wanted to make a 10 percent profit, how much would you have to sell each pen for?

11. I want to buy a pair of sandles for 18/50, two packs of yak cigarettes for 10 rupees each, and three packs of matches at 50 paisa each. How much money do I need to give you? (give person a 100 rupee note) Please give me my change.

12. I want three Tulsi soaps at 5/50 each, two notebooks for a rupee each, and one pen for 2/75. How much money do I need to give you? (give person two 20 rupee notes) Please give me my change.

13. I want to buy one pair of Geep batteries at 14 rupees, three pineapple biscut at 5/50 each, and one pen at 2/75. How much money do I need to give you? (give person four 10 rupee notes) Please give me my change.

14. I want to buy 5 orange candies for 25 paisa each, one pen for 2/75, and one hair rope for 15 rupees. How much money do I need to give you? (give person one 20 and one 5 rupee note) Please give me my change.

15. This single pack of matches sells for 50 paisa. How much would you sell this large packet (4 x 6 packs) for?

16. If you sell five of the orange candies for 25 paisa, how much would you sell this bag of candy for? (give person bag with 15 candies)

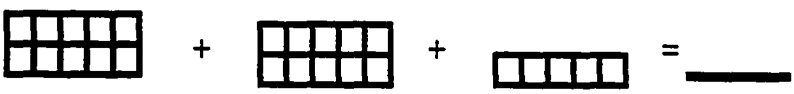
17. Suppose you would sell a pack of Yak cigarettes for 20 rupees. How much would you sell be one cigarette for?

18. Suppose you sell a packet of Deurali cigarettes for 3 rupees, how much would you sell me 3 cigarettes for?

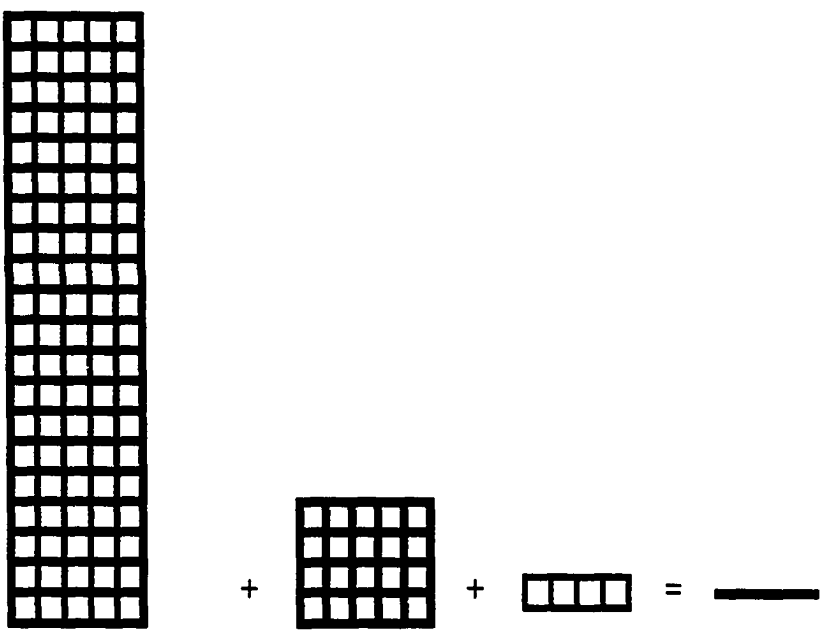
<u>School Tasks</u>

1.

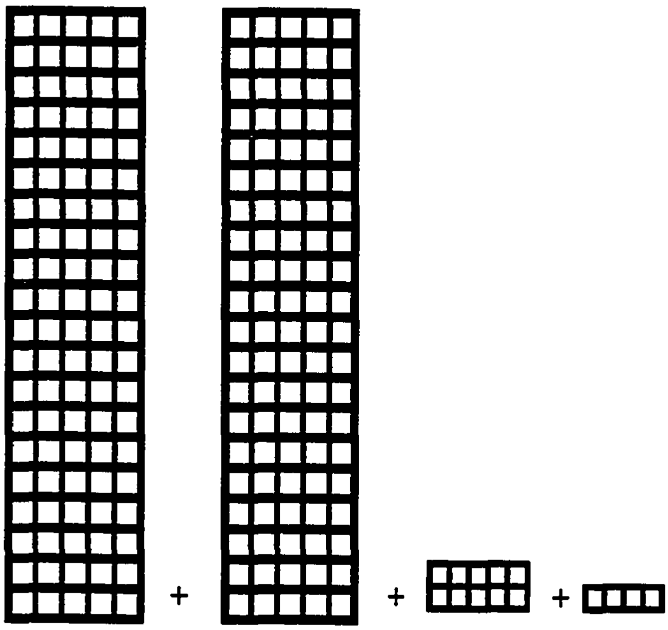
2.



3.

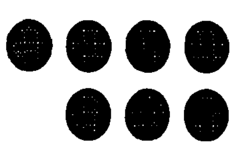


4.



= ____

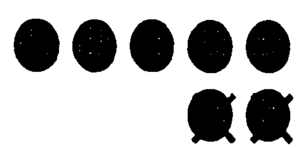
5.



4
+ 3

____

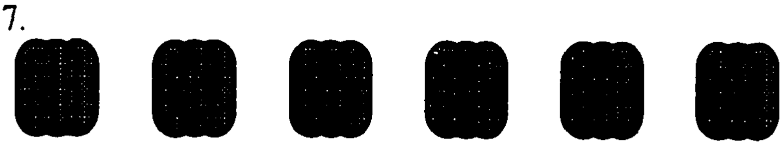
6.



5
- 2

____

7.

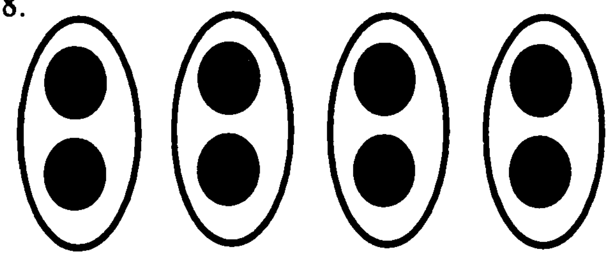


= ____

3 + 3 + 3 + 3 + 3 + 3 = ____

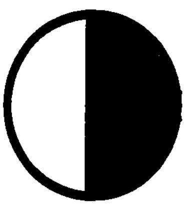
3 x 6 = ____

8.



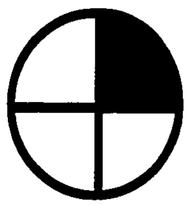
8 ÷ 2 = ______

9.



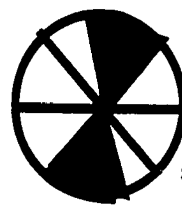
=

10.



=

11.



=

12.

15
+ 2

13.

17
+ 3

14.

27
+ 12

15.

17
- 4

16.

15
- 8

17.

25
- 19

18.

12
x 3

19.

15
x 3

20.

40 ÷ 20 =

21.

20 ÷ 2 =

22. If one meter equals one hundred centimeters, how many centimeters are there in half a meter?

23. If one litre equals one thousand mililitres, how many mililiters are there in half a litre?

24. If one kilo equals one thousand grams, how many grams are there in a quarter of a kilo?

Appendix E: Tracking Tasks

Tracking Tasks for Shopkeeping Apprenticeship

	Purchase	Total/Change (2)	
Day 8	1 pen	2/50	
	1 tulsi soap	5/50	
	1 pineapple biscut	4/25	two 10 ru. notes given
	3 ganga soaps	4/50 ea.	
	5 candies	-/25 ea.	
	1 notebook	1/50	one 20 ru. note given
Day 16	1 pack topaz blades	5/-	
	1 large notebook	6/75	
	1 pineapple biscut	4/50	four 5 ru. notes given
	5 tulsi soaps	5/50 ea.	
	6 candies	-/75 ea.	
	1 hair ribbon	5/25	one 100 ru. note given
Day 24	1 shirt	23/50	
	1 red cloth	10/75	
	1 pr. sandles	21/50	one 100 ru. note given
	3 kaini	2/75 ea.	
	1 pr. batteries	14/-	
	1 pen	2/50	one 20 ru. and one 10 ru. note given
Day 32	1 Chinese pen	8/-	
	1 pack tea dust	6/75	
	1 pr. underwear	18/50	two 20 ru. notes given
	1 pen	2/75	
	4 chow-chow noodles	6/50 ea.	
	1 handkerchief	15/75	one 50 ru. note given

Cloth Measure Conversion (1)

Day 8 If the price of one meter of this cloth is 10 rupees and I would like 2 haat of cloth, then how much will the cloth cost me?

Day 16 If the price of one meter of this cloth is 30 rupees and I would like 3 haat of cloth, then how much will the cloth cost me?

Day 24 If the price of one meter of this cloth is 50 rupees and I would like 1 haat of cloth, then how much will the cloth cost me?

Day 32 If the price of one meter of this cloth is 40 rupees and I would like 2 haat of cloth, then how much will the cloth cost me?

Profit/Loss (1)

Day 8 You bought these 25 packets of glucose biscuts for 75 rupees in Chinchu and paid 10 rupees to have them carried to your shop. How much will you have to sell each packet of biscuts for if you want to make a 60 paisa profit on each?

Day 16 You bought 14 Ganga soaps for 60 rupees in Nepalganj and pay 17 rupees to have them brought to your shop. How much do you have to sell each soap for to make a 50 paisa profit on each?

Day 24 You bought these 12 pens for 30 rupees in Shrkhet and paid 6 rupees to have them carried to your shop. How much will you have to sell each pen for if you want to make a 50 paisa profit on each?

Day 32 You bought 8 packs of incense for 44 rupees in Nepalganj and paid 12 rupees to have them carried to your shop. How much will you have to sell each pack of incense for if you want to make a 2 rupee profit on each?

Weighing/Pricing (1)

Day 8 I want to buy this piece of iron (450 grams). If you are selling iron for 10 rupees per kilo, how much money do I have to give you for this piece of iron?

Day 16 I want to buy this piece of iron (400 grams). If you are selling iron for 10 rupees per kilo, how much money do I have to give you for this piece of iron?

Day 24 I want to buy this piece of iron (75 grams). If you are selling iron for 10 rupees per kilo, how much money do I have to give you for this piece of iron?

Day 32 I want to buy this piece of iron (270 grams). If you are selling iron for 10 rupees per kilo, how much money do I have to give you for this piece of iron?

Creating a Measurement Standard (1)

Day 8 You sell this bag of cumin for 14 rupees (14 kaini containers worth). I want 2 rupees of cumin. How much cumin will you give me for 2 rupees?

Day 16 You sell this bag of cumin for 30 rupees (15 kaini containers worth). I want 5 rupees of cumin. How much cumin will you give me for 5 rupees?

Day 24 You sell this bag of cumin for 32 rupees (16 kaini containers worth). I want 4 rupees of cumin. How much cumin will you give me for 4 rupees?

Day 32 You sell this bag of cumin for 36 rupees (9 kaini containers worth). I want 12 rupees of cumin. How much cumin will you give me for 12 rupees?

Metric Weight Estimation (1)

Day 8 How much sugar do you estimate is in this bag (500 grams)?

Day 16 How much sugar do you estimate is in this bag (750 grams)?

Day 24 How much sugar do you estimate is in this bag (600 grams)?

Day 32 How much sugar do you estimate is in this bag (200 grams)?

Counting 3-D Array of Items (1)

Day 8 How many pack of Deurali cigarettes are there here (2x3x3=18)?

Day 16 How many pack of Deurali cigarettes are there here (2x4x4=32)?

Day 24 How many pack of glucose biscuts are there here (2x2x4=16)?

Day 32 How many pack of Yak cigarettes are there here (2x2x6=24)?

Tracking Tasks for Studying in School

Quantifying Bricks (1)

Day 8 3x18 array + 3x18 array + 3x8 array + 4x5 array

Day 16 4x8 array + 4x8 array + 3x5 array + 2x3 array

Day 24 5x7 array + 5x7 array + 3x10 array + 3x4 array

Day 32 5x10 array + 5x10 array + 4x6 array + 3x5 array

Addition, Subtraction, Multiplication, and Division Problems (8)

Day 8

$$\begin{array}{r} 48 \\ +\ 24 \\ \hline \end{array} \qquad 14 + 7 =$$

$$\begin{array}{r} 53 \\ -\ 17 \\ \hline \end{array} \qquad 15 - 6 =$$

$$\begin{array}{r} 14 \\ \times\ 13 \\ \hline \end{array} \qquad 14 \times 6 =$$

$$3\overline{)\,78} \qquad 4\overline{)\,21}$$

Day 16

$$\begin{array}{r} 35 \\ +\ 27 \\ \hline \end{array} \qquad 18 + 5 =$$

$$\begin{array}{r} 63 \\ -\ 15 \\ \hline \end{array} \qquad 13 - 5 =$$

$$\begin{array}{r} 16 \\ \times\ 12 \\ \hline \end{array} \qquad 13 \times 4 =$$

	7) 84	5) 17
Day 24	27 + 28	16 + 7 =
	38 - 19	16 - 8 =
	18 X 15	12 x 6 =
	5) 65	3) 23
Day 32	35 + 17	17 + 9 =
	47 - 29	14 - 6 =
	17 X 13	16 x 8 =
	7) 99	6) 25

Numeral Writing, Recognition, and Place Value (15)

Day 8 24, 1, 5, 3, 20,405, 92, 6, 4, 7, 105, 2, 3,005,10, 9, 10,206, 8, 1,008, 0, 209

Day 16 206, 1, 10, 0, 5, 7, 82, 9, 28, 4, 2, 3, 6, 2,005, 3,005, 20,304, 20,403, 8, 402

Day 24 2, 9, 30,807, 0, 4, 304, 8, 1,006, 2,004, 35, 103, 30,906, 6, 3, 1, 10, 34, 7, 5

Day 32 26, 3, 602, 8, 10, 10,504, 0, 5, 306, 32, 6, 3,009, 3,001, 7, 10,405, 1, 9, 4, 2

Appendix F: Nepali Counting Words

1	- ek
2	- dui
3	- tin
4	- charr
5	- pach
6	- chha
7	- saat
8	- aath
9	- nau
10	- das
11	- eghaara
12	- baara
13	- terha
14	- chauda
15	- pandhra
16	- sorha
17	- satra
18	- athaara
19	- unnaais, unis
20	- bis
21	- ekkaais
22	- baais
23	- teis
24	- chaubis
25	- pachchis
26	- chhabbis
27	- sattaais
28	- athtaais
29	- unantis, untis
30	- tis
31	- ektis
32	- battis
33	- tettis
34	- chautis
35	- paitis
36	- chhattis
37	- saitis
38	- athtis
39	- unanchaalis
40	- chaalis
41	- ekchaalis
42	- bayaalis
43	- trichaalis
44	- chawaalis
45	- paitaalis
46	- chayaalis
47	- satchaalis
48	- athchaalis
49	- unanchaas
50	- pachaas
60	- saathi
70	- sattari
80	- asi
90	- nabbe
100	- sae, saya
1,000	- hajaar
10,000	- das hajar
100,000	- laakh
1,000,000	- das laakh
10,000,000	- carod

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