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AUTHOR Cole, Michael
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ABSTRACT

This report, addressed to the broad audience of cognitive scientists, examines research on cognitive change. In the introduction, background considerations are made, previous research is reviewed, and the report itself is outlined. The first chapter, "Finding Goals Outside the Laboratory," discusses how laboratory tasks can obscure research goals and talks about different research settings. "Bases for a Theory of Learning in Interaction," the second chapter, covers the essentials of a theory that can adequately account for the appropriation process that happens in teacher-student interaction. "Misappropriating Cognitive Processes" is the topic of the third chapter, which discusses the problem of correctly coding cognitive processes in a classroom. The fourth chapter is concerned with "Learning and Assessment" and an analysis of the concept of a "zone of proximal development" for assessing children while in interaction with adults. Chapter 5, "But It's Important Data!: Making the Demands of a Cognitive Experiment Meet the Educational Imperatives of the Classroom," contains discussion with the teacher whose classroom was used for experiments; conflicts inherent in the teacher-researcher relationship are covered. Chapter 6, "Long Division of Labor: In Support of An Interactive Learning Theory," illustrates how the "zone" is actively constructed in the teacher-child interaction. The seventh chapter offers "Conclusions" and implications of the work for researchers and for educators. (CJ)

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Learning in Interaction:

Contributions to a Cognitive Science of Education

FINAL REPORT

to the National Institute of Education

of the Oceanside School Project

concerned with

The Effect of Differential Classroom Organization
on the Learning of Classroom Discourse Rules and Cognitive Content

(Grant # NIE-G-78-0159)

Michael Cole

Principal Investigator

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INTRODUCTION

This is a book about cognitive change. It is addressed to several audiences who share an interest in the processes by which human beings acquire and use knowledge. It is of special relevance to social scientists and educators who are responsible for designing educational environments that maximize the effectiveness of the learning/teaching process. It is the hope of everyone concerned with educational practice that systematic study of the processes by which education is accomplished will eventually permit us to say that each citizen is provided an optimum environment for developing his/her special abilities as an individual. But at present, educational practice labors with only dubious contributions from education-relevant social science research. By focusing directly on scientific problems that seem to coincide with difficulties in practice, we hope that we can maximize the utility of our work.

Our monograph seeks to communicate with people representing several disciplines whose ideas are supposed to bear upon education. We are particularly interested in addressing the group of scholars who have come to be identified as, cognitive scientists. At the heart of cognitive science, as thus far conceived (Norman, 1980; Simon, 1980), is the idea that it is possible to construct explicit, implementable models of complex psychological processes. This focus of attention follows from the scientific interest, articulated by Herbert Simon, in "physical symbol systems" such as the computer or more centrally the human brain. The prototype for a practical task is something like machine translation--programming a high-speed computer so it can substitute for an individual human as an input-output device.

Like other cognitive scientists we set out to "model" a complex psychological process but we did not seek to embody our model in a computer program. Rather we set out to create, in an elementary-school classroom, a series of theoretically motivated curriculum units in which we could observe the interactive process of teaching and learning. We agree with Simon's characterization of the mind as an artifact rather than as a "natural" system. This position is completely consistent with the sociohistorical theory (Vygotsky, 1978; Leont'ev, 1981) that we draw upon in our development of a theory of cognitive change. Where we differ from Simon and many of our colleagues in cognitive science is in our interest in man-made <u>systems of social activity</u> as well. A game of poker, work in a factory, a classroom lesson and a psychological experiment are all artificial systems in Simon's sense. But they are systems organized among as well as within human beings. The physical symbol systems that constitute cognition are materially present in the organization of people--in their interactions--as well as in their brains.

This extension of cognitive science beyond the analysis of stand-alone computer models is motivated by our long range goal; to provide a practical theory of the role of culturally organized experience in the development of mind. A theory with such aspirations does not give privileged status to the individual person as the object of study. Without in any way denying special structuring to the individual, we will pursue the thesis that learning is usefully understood as the <u>transformations</u> within systems of social activity and transfer of control from the social/interpersonal to the individual/intrapersonal levels of organization.

While the reader might concede that the notion of artificial intelligence can logically be extended to systems of social interaction, the fact that such extensions have not played much of a part in contemporary cognitive science naturally raises a question: why bother? Artificial cognitive systems are complex enough in machine form, where we have a great deal of control over the elements that enter into the system. When we start to consider live people engaging in joint activity we have to contend with an open system. (Bartlett, 1932) The participants' perspectives on the activity are not likely to coincide completely so there cannot be a single correct analysis or coding of either the individual's or the group's behavior. The problem of including social interaction in the arena of artificial intelligence may be too tough a nut to crack. (Simon, 1978)

As the discussion proceeds, we hope to convince the reader that it is not only possible, but very useful, to carry out extensions of cognitive science to include social interaction in activity settings. We want to argue that for the crucial issue of cognitive <u>change</u>, inclusion of the social environment is a necessity. To begin with, however, we want to summarize the steps and the practical concerns that led us to this formulation. In the "sciences of the artificial," as Simon (1981) argues, descriptions of how a system works are never far removed from questions about how to make it work better. Like other branches of cognitive science we are interested in creating a better system. But the specific problems posed to us were sufficiently different from those motivating other work in cognitive science that a narrative summary is in order as a means of motivating the discussions to follow.

Background Considerations

For a number of reasons our approach to constructing a theory of cognitive change is closely associated with questions of education. Perhaps most importantly, education is the form of culturally organized experience that is available as a tool of government policy. During the 1960's questions of cultural background and educational achievement were at the center of United States government policies aimed at eradicating poverty. While the goal may have been altered, the questions raised by the massive effort to influence young children's development are far from answered.

One focus of attention at this time was the question of how education influences the course of development. Debates about the influence of education on development are by no means new, but their reappearance in the 1960's came at a time in the history of both psychology and society which made reexamination of this issue of special interest.

In the period between the end of World War II and the present, a vast transformation has occurred in the political organization and everyday lives of millions of people around the globe known as the Third World. Formal education, which was virtually absent in many countries prior to 1945, became a universal goal of the emerging independent nations. Formal education did not come easily. It required a vast commitment of economic resources. Change has been slow, uneven and painful. In another context we might discuss the social and economic consequences of these events. Of immediate concern to the work we will discuss here is the way in which they pose difficult, unresolved problems to cognitive sciences.

<u>The Evidence from Cross-Cultural Research.</u>

A great deal of research over the last 30 years has been devoted to assessing the cognitive consequences of attending formal school. The rapid and uneven spread of schooling after 1945 provided many locales in which populations were being exposed to schooling for the first time on a relatively haphazard basis. This heterogeneity was an invitation to evaluate a logical problem that bedevils developmental research in industrialized countries; schooling, being universal, is correlated with age, making it very difficult to discriminate the influence of general experience and education on later development.

The empirical research has been nicely summarized by Rogoff (1981) who reviews various theoretical interpretations that claim to decouple education from other forces acting on development. It is our reading of this literature that it is subject to a fatal ambiguity of interpretation, arising from the formulation of the problem itself.

A simple thought experiment will help to clarify the issue. Suppose that we happened upon a society that was still in a pre-literate state where everyone tilled the fields and formal schooling was entirely absent. Suppose further that we could choose people at random in some large area and arrange for half of them to spend the workday in a specially designed environment (like a school) while their brothers and sisters continued life as before. Except during the work day, everyone spends their time just as they would have if there were no school in town. In the early mornings, evenings, and weekends, people can be found doing chores, engaging in festivals, repairing their houses, gathering crops, etc. The two groups differ only in their activity during the work/school day.

After a suitable length of time we want to assess the cognitive consequences of the experience of schooling. As an assessment device, we seek to have a sample of cognitive tasks that arise during the course of those hours of the day where people carry out their tasks together because, as good experimenters, we would want our index of change to be equally familiar to each group. Once we had found such test items and administered our assessment device, we could expect to reach some conclusion about the cognitive consequences of schooling. We could, of course, also find out something about the cognitive consequences of out-of-school activities.

This "clean" test of rival hypotheses about schooling has never been carried out. In fact, it has never been proposed. The problem is that cognitive psychology, as an experimental science, makes cognitive tasks happen. The very technology which allows the cognitive psychologist to talk technically about "cognitive consequences" stands in his way when it comes to making principled statements about cognition in environments not of his making. While we could certainly find people engaging in joint activity outside of school, it is not at all clear how to characterize such behavior at the level of cognitive processing mechanisms.

Actual cross-cultural research on the cognitive consequences of schooling has been "dirty" in a variety of ways. For one thing, there is evidence that while schooling is uneven, it is not randomly distributed across the population, giving rise to the possibility that pre-selection for schooling exists (Fahrmeier, Klein et al.). A second major difficulty arises because the structure of activity for the tasks used to assess the consequences of schooling are decidedly unlike the structure of activity constructing cognitive tasks in everyday settings. Consequently, we could not say how the cognitive demands of formal schooling differ from those of everyday life, except in common sense terms. Psychological technology seemed to be inadequate to analysis of this problem in terms adequate to claims about cognitive process.

Our own involvement in these issues (Sharp, Cole and Lave, 1978) led us to the conclusion that without some means of specifying how the tasks used as measures of cognitive change are related to the domains of activity they represented, arguments over the effects of schooling on learning and development were fatally restricted. We began to doubt our ability to identify even school-like tasks if we didn't construct them ourselves.

Discovering the Same Task in Different Settings.

We first came together to discuss these issues in the late 1970's. As a first step, Cole and his colleagues, Lois Hood, Ray McDermott, and Ken Traupmann undertook a direct investigation of whether cognitive tasks based on schooling could be identified and studied in a non-school setting. (For a fuller description see Cole, Hood, & McDermott, 1978, from which this description is derived.) They videotaped a single classroom of 18 children. They created some new settings in addition to the variety offered in school, each offering variations to permit us to see how cognitive tasks are influenced by their immediate social context. At one extreme they created a battery of tests that sampled categories of cognitive activities believed to be central to psychological functions in the everyday world as well as the school: remembering, classifying, problem solving and so on. At the other extreme responded on those rare occasions when they thought that such a problem had in fact occurred.

Perhaps their difficulties should not have come as a surprise. But in terms of the goal of building a technology whereby cognitive tasks could be discovered and their outcomes studied in non-classroom and non-test situations, they were (and we remain) in deep difficulty.

In the ensuing year they intensively studied the videotapes they had collected in order to discover the characteristics of the ways in which behavior was organized in each of the various settings. Even cursory analysis showed that they could not attribute the differences among the settings simply to the existence or non-existence of academic content. To bake a cake one needs to read recipes, measure, and keep track of what one has done. To get through a test one has to engage in coordinated social interaction with another person. All situations they studied were a mixture of "cognitive" and "social" activities. To be sure, the density of each, or perhaps the salience of each to the casual observer, was different. In the tests or in those parts of the school day where children were seen to be engaged in cognitive tasks, social interaction seemed like a part of the background. In the clubs, social interaction was <u>rarely</u> in the background.

When the researchers began to make comparisons of the children in the two settings, they had the strong impression that the children who were the class "stars" in school did not shine especially as a group during the club sessions. Nor were the class dunces readily identifiable. A little reflection will suggest that this observation poses an embarrassing paradox. Having just said that cognitive tasks could not be identified in the clubs, the researchers turned around and claim that they simultaneously discovered children who seemed to be cognitively more competent in the club than in school.

We hope that a little more reflection will reveal that once Cole and his colleagues made the judgment that some children behave more competently when facing the task of baking cake in club than doing a reading or measuring task in school, they had made contact with a central question in the present work: how do you know that you have the same task in different settings? And if you don't know how to identify "same tasks," what is the basis for your judgment that some children perform well in one version of "the" tasks and not another? When Cole and his colleagues started their earlier project, they thought they had built the answer into the structure of the activities that occurred in the three basic settings (test, school, club). The tests had initially been designed to sample school-like tasks, so they could be confident that they would appear in the classroom as they did. They chose a variety of cooking and nature activities specifically because they require reading, measurement, remembering and other cognitive skills that are the focus of the school. In fact, the reasonableness of that idea was used to convince teachers and parents that the clubs would be a good, "educational experience," for the children. Yet when they came to look at topics of the club activities, something about their social organization rendered it difficult to identify cognitive tasks in a form that we could acknowledge as cognitive psychologists.

Crudely speaking, the source of the difficulty resides in the social constraints operating on people during a social interaction, be it in school or out. The psychologist's task (classifying, paired associate learning, logical reasoning) is not a physical object in the world. It is, rather, a set of activities (perhaps involving physical objects), the goal of which is specified by the psychologist along with a set of constraints that must be honored in meeting that goal. One of our difficulties when moving from club to school to test was that the larger social context within which "the same task" was embedded placed very different constraints on the various individuals participating in the scene. As a consequence, the individuals were more or less free to change the conditions of the task, even to the point of making it go away, depending upon what social context it occurred in.

A second problem concerned the specification of goals. When we stated in the previous paragraph that the psychologist sets the goal for the subject as part of the defining characteristics of a cognitive task, we were adopting the professional shorthand. In fact, even casual analysis of a single testing situation quickly reveals that an enormous amount of "social work" goes into maintaining the psychologist's task as a focus of attention. (Mehan, 1979) Subjects often are as anxious to demonstrate their friendliness or intelligence, or simply to get-it-all-over-as-quickly-as-possible, as they are to "think hard." Test situations are designed to minimize the impact of these alternative goals, of course, and large groups of subjects are usually run on quantifiable tasks so that reliable and "valid" inferences regarding thinking can be achieved. We don't wish to question the utility of this approach here (See Cole, Hood and McDermott, 1978 for an extended discussion). What is crucial to point out, however, is that in non-test settings (including the school and the club), the multiple goals that occupy each individual at any single moment are very difficult to ignore because the settings are rarely so constrained that they prevent people from working to achieve several goals at the same time. That means that we have to deal with some difficult problems of "task analysis" in order to specify real task similarity across contexts. Only very general characteristics of task environments can be specified ahead of time in a manner analogous to the way psychologists specify their cognitive tasks.

These earlier attempts to specify how cognitive tasks and behaviors vary across social contexts convinced us that the solution would not come about through the systematic application of any established techniques of discourse or cognitive analysis. Identifying cognitive tasks outside of the laboratory would require a novel synthesis of methods.

Having concluded on the basis of our previous work that statements about children "doing the same task" better or worse in one of the settings are difficult if not impossible to , if we depend on discovery procedures, we decided in this study to make as certain as we could that the same task occurred and reoccurred in a variety of settings. In effect, we adopted the procedures for the conduct of ecologically valid research proposed several decades ago by Brunswik (1943). At the outset we knew that there would be limits to the degree of "sameness" that we could arrange. But we did not know on the basis of our earlier failures what those limits might be. We phrased our strategy as follows: lets try to make a cognitive task happen and see how different social settings pull it apart in different ways.

Building Tasks into Curriculum Units

Our current project was conducted in a school in the northern part of San Diego County. In the first year we worked in a third-fourth grade combination team taught classroom. In the second year, we worked in the fourth-grade classroom of one of the original teachers. Our data corpus involves 80 children and three teachers over the two year period. During our time in the classrooms we worked with the teachers to design seven curriculum modules, each of which was designed as a mini-experiment in creating the same task across a variety of contexts. Our topics ranged from science (e.g., electricity, animals, household chemicals) to math (long division) to social studies (Native American Indians, mapping) to a unit on memory and study skills. We refer to each curriculum module as a "cycle." In each cycle we used five different configurations of participant structures:

(a) Teacher led large group lessons: These are whole group lessons, conducted by the teacher, composed of approximately 20 students;
(b) Teacher led small group lessons: These are organized such that 5-6 children work intensively with the teacher;
(c) Child-only small group lessons: Groups of children worked together on an assigned task (often workbooks or other written materials) without direct access to a teacher;
(d) Tutorials: The teacher or a researcher works one-to-one with a child;
(e) Clubs: A member of the research staff interacts with students, either in a community setting, or at the University, about the material covered in the cycles, but in a less didactic and more recreational format.

The growth of the cycles

Each of the seven cycles was devoted to a different topic domain; we completed cycles, three the first year and four the second. This section presents a brief of the history of our work, and a summary of the successes and failures.

Throughout the project we were constrained in our choice of cycle topics by five working principles:

1) The topic and lesson plans should be known ahead of time to both researchers and teachers. We were not interested in capturing and analyzing only the teacher's ordinary classroom events as we might if this were an ethnography; nor were we interested in taking the

children into a laboratory environment as we might if this were a traditional, experimental approach. A combination of everyday practice and theory guided structure was what we needed: We knew how hard it was to locate tasks <u>post hoc</u> as they appeared in ordinary events, and we knew that methods that rely only on laboratory environments were overly confining. Our strategy dictated that we plan the content of the lessons jointly with the classroom teachers and observe the consequences of their implementation.

2) Each topic covered should be instantiated in a variety of socially organized events. The basic motivation for our work was to determine how different social organizations help or hinder performance for different children and how performance differences are related to assessment and achievement in school. Hence, we wanted teaching events of different types-- large and small groups, teacher present and child only, adult- child dyads -- and some more casual events that were outside of the ordinary school rules of institutional relations.

3) Each topic should be one which is relatively novel, so that knowledge and experience from prior exposure, in school and out, would not be so likely to intrude and differentiate among the children in ways that we had no access to in our data records.

4) Each topic should be unobtrusive as a topic to be taught children of third and fourth grade age in that school district. This follows from three aspects of our work: The teachers had a responsibility to use classroom time educating the children in a way that was coherent with what the school and parents expected; We were interested in the relevance of our work for ordinary education; We knew from our prior work that the organization of ordinary classrooms had sufficient similarity to the organization of psychological experiments so that we could use the psychological literature as a guide and critical base.

5) The topics should be ones that bring out the best in the teaching situation and still yield enough variability in child performance so that the research could succeed.

In our terms, we were creating <u>problem isomorphs</u> in seven different domains, so that the points of similarity in the different "problems" (i.e. lessons in the cycles) could act as tracer elements. These tracers would be used to investigate how one can speak of the "same task in different settings" and, hence, to understand the claim that some children perform better in some settings than in others.

Electricity and division. We describe our cycles out of chronological order so that we can highlight important issues that our research strategy was designed to stress. The first cycle was on electricity, and one of the last ones was on long division, the prototypical fourth grade task. They provide an illustration of the consequences of our commitment to the principle that the cycle topic should be known by the researcher and the teacher.

At the time that we developed the electricity cycle, we had great confidence in the power of content domain to organize activity for research and for pedagogical purposes. While the topic of electricity unified the first cycle, there was not a clearly discernible tracer element that appeared in every social configuration. We narrowed the topic to batteries and circuits, but that wasn't sufficient to give us the control we had hoped for. The lack of specificity that hindered the research use of the cycle also created problems in the teaching. All of the people on the team were liberally educated and had both a formal education and a working knowledge of electricity, in particular the structure and functioning of batteries and circuits. As recent work has shown (e.g. Heller, 1983; DiSessa, 1982), the working knowledge we have of physics topics and the metaphors that we use to talk about them do not fit well with the science that we learn in formal education. The way we talk about electricity is so confined to specific metaphors that it often fails to accommodate a new, crucial bit of physical evidence in the world. This kind of slippage happened in our planning for this cycle. Ww devised action sequences and metaphors for the children's consumption in lessons but we had problems relating our assumed knowledge to the tasks we were devising. Worse still, we had difficulty finding ways to talk about the problems. For example, one of the planners worked within the scope of a water pipe metaphor and another worked in an information processing metaphor; consequently their questions, objections and suggestions during cycle construction were incoherent to each other.

This problem is unlikely to arise in an experiment on concept learning even if similar materials are used, because in laboratory experiments, the experimenter can know a lot less about the topic than a teacher has to know. Traditional laboratory problems provide two sorts of safeguards: one is that the script usually works-- the moves, even those of the subject, can be pretty well specified in advance; a second is that unexpected moves can be ignored --they either wash out into an error term or get fixed up for later runs of the experiment, treating the problematic case as pilot work.

Even though we treated the classroom as three groups, trying out the procedures on one-third of the class as a pilot study, we couldn't get an "electricity lesson" script to work. Although we planned ideal lessons ahead of time and provided the materials to be used, we could not predict when a child's comment or question or blank stare would occur nor could we predict how the teacher's response could be designed to "save" the ideal lesson. Relying on the domain of electricity meant that we were being <u>too broad and too novel for the teachers</u>. They could not give us a good "But suppose...." objections during planning. Nor did our planning allow us to understand the teachers' online decisions about what to highlight and what to sacrifice when the unscripted events happened. As a result we had classroom discussions that were cohesive in so far as they referred to the structure and functioning of either circuits and batteries. But they arrived at their points with so many repairs and side-sequences that basic tracers are hard to locate. The teachers did online repairs and we constructed a supplementary lesson; the error of using a cycle not based on deep and broad shared understandings about electricity and goals for pupil outcomes became apparent.

In contrast, the division cycle was very well known to the teacher who worked with us and the fourth grade children during the second year of the project. Math was ceded as her specialty the year before in the team taught classroom. Her pre-service training was heavily influenced by a thoughful and innovative mathematics educator. She participated in summer workshops related to mathematics education and was active in a local mathematics teachers association. She talked with us extensively about the various constraints operating on mathematics instruction in the school we worked in: what the children had in earlier grades and what they would be expected to have in later grades. She was explicit, not only about what she was going to do but also about what alternative route she was not taking to achieve her goals. She integrated her general pedagogical interest and her sensitivity to the local constraints in her mathematics curriculum.

We wanted a mathematics cycle because it is such a nicely constrained domain. The work of Judah Shwartz and others at Project Torque and the work of John Seeley Brown at Xerox provided an analytic edge for us. The talk, the black board, and the paper and pencil products of instruction, were all amenable to rich analysis. Furthermore, division is clearly a novel topic for the children in this class: Everyone in our culture knows of the fourth grade introduction to long division and this school was no different.[1] A long

1. The New Yorker magazine used as a column filler a headline "Pope Seeks to End Long Division" with the comment appended, "Fourth graders of the world rejoice!"

division cycle met all of our constraints and this teacher provided us with a bonus. Our work was merely to get her to explicate her practices, justify her plans, and provide us with the openings to make some small suggestions. We were essentially prospective documentarians. There was no doubt of her knowledge of this domain, there was no doubt about the tracer: the "bring-down" algorithm. Her script worked; there was a normal procedure that could be re-located from analysis of the tapes. As a result, we are able to note variation related to ability grouping and to examine how a complex matter gets taught (see Chapter 6, below).

Between electricity and long division were 5 cycles that applied our approach to cases that tested one or more aspect of the teaching/learning process.

Restricted domains: referent tracers. Reacting to the unwieldiness of the electricity cycle, we developed two quite different cycles the first year. Each was an important step in our ability to take advantage of the teacher's knowledge. In two series of lesson obtaining adequate tracers we focussed on three categories of information about six Native American groups as they lived just prior to extensive white contact. For the third cycle we focussed on the variations in two categories of properties of animals. We arrived at very specific tracer elements that served three purposes:

(1) coordinated interactions in lessons between teachers and children;
(2) coordinated planning interactions between teachers and researchers;
(3) allowed us to relocate the tasks in the data records of the various problem isomorphs.

We elicited extensive help from the research community --libraries, museums, anthropologists and biologists. We generated an extensive curriculum for each cycle, providing a wide range of background information for all the possible activities. We had the luxury of choosing among a variety of sub-topics; teacher familiarity with the sub-topic and the teachers' gauge of possible child responses were easy to accommodate as we narrowed down our plans. The tracer element in each cycle was a filled in chart that associated the groups of people or the animals with the appropriate variables of the categories being focussed on.

The materials and procedures developed to teach the categories and the variables were creative and quite lovely, ranging from guided discovery to role-playing to problem solving to use of written materials. The teachers were particularly interested in more or less recapitulating the abstract structure of the Native American cycle in another cycle because they were struck by what they noticed about the weaknesses some of the children had in organizing domains of knowledge. One of the children, grasping the important point of the Native American lesson, gave us a wonderful quotation: "They're all the same in their own way!" From the point of view of the attitudinal outcome for a social studies unit this was rewarding: Gone was the undifferentiated feathers and horses image from cowboy movies and here was an entry into understanding human universality and cultural specificity. From the point of view of the importance of understanding categories and variables, the child's comment was also important.

As our work progressed, modifying the conceptual apparatus and creating new cycles, we developed a deeper understanding of the non-trivial relation of our work to contemporary education and a theoretical explication of how the specific examples and domains relate to basic research issues.

While memory, especially meta-memory, is not an ordinary topic in a fourth grade classroom, our team agreed that it could be defended as educationally relevant. As we developed plans for the cycle on memory, what we gave up by and large was the teacher. Since meta-memory was the content domain, we had psychology graduate students who were experienced and interested in working with the children to help out. Since it was, in a sense, memory "tricks" that we were discussing, we took advantage of the presence of a professional mnenonist who taught in an entertaining manner.

We picked one of the mnemonist's devices, unusual sentence elaboration, traced it across several problem isomorphs. One problem with two facets became apparent: It was very difficult to initiate the tracer task, outside of the situation where someone was told to remember a list. We had a good specification from the literature about this meta-memory technique but we had difficulty planning school or club tasks that would truly motivate its use. It wasn't hard to think of lots of variations on the task (it is a cognitive psychological mainstay). It was hard to find a place in the children's lives where they were called upon to remember lists of unassociated items. The children weren't learning vocabulary in a foreign language; that was the only educational activity that was suggested as motivation for this memory strategy.

In addition to the practical difficulty of getting enough interesting problem isomorphs where the tracer task might be "discovered" by the children as they went about some other nominal task, we found a related difficulty in the literature. In spite of the extensive experimental work on meta-memory, the research community had little to offer about how people outside of an experiment chose to use any particular strategy they might have in their repertory of meta-memory aids. A colleague working on assessing and developing the range of memory strategies that mentally retarded individuals display claims that the work on this "executive" level is years away from being informative.

The solution of course would be to again teach a specific domain, again downplaying the meta- memory aspect. This dilemma, along with the startling absence of the teacher and the rationalized educational relevance combined to make the execution and analysis of this cycle less interesting to us, especially as it contrasted with the division and chemicals cycles of the second year. Overall, the children were able to learn the strategy and appeared to use it across situations. To make more of a claim and to make it about meta-memory, we now understand we would have to examine many specific domain cycles, finding a range of activities like those that Neisser (19XX) has arranged for analytic comparison.

These considerations produced a mapping cycle. The mapping cycle arose as a way to combine two aspects of the school curriculum with a current research topic. Drawing and mathematical proportions were both involved in maps. How children varied and changed in the way they represented their world in maps was a topic of interest. The tracer element was the representation of three-dimensional structures on paper, some mapmaking and some map reading activities were designed. Although we had little research and teaching time to devote to the unit, we ran a mini-cycle.

Unfortunately, the timing of the cycle was such that it overlapped with other cycles and continuity among the events in the cycle was lost. The division cycle had the first claim on timing because it had to fit into the year long mathematics curriculum. The memory cycle timing had to be coordinated with our outside experts as teachers. Mapping lessons fell in between and got rescheduled, and even abandoned. We did not succeed in executing enough of the problem isomorphs to allow us the analytical edge that we needed. It was clearly the case that there was educational relevance for this cycle, and, judging from the children's products, the mapping task was not something they had encountered before. The timing problem disabled our efforts to get the needed variety of the situations for adequate analysis for this project.

The Clubs. During the first year, we designed the club activity as a part of each cycle. We relaxed institutional constraints on discourse, mixed the child groups in ways that didn't appear in the classroom, changed the location (once in a special resource room, once at the university, once in a part of the classroom that had had its furniture moved), and we introduced outsiders rather than teachers as the adult resources. There's fun in the tapes. The children made a blinking Christmas tree, visited a mini-version of the Lawrence Hall of Science (courtesy of a consultant from the Hall and local pet stores), hunted and gathered wild lettuce and played an anthropology computer game at the University. However, there was no sense in which the children were electing to participate nor were they co-members in a continuing endeavor. And the clubs were held during regular school time.

The second year, we made real clubs. Eliciting help from our colleagues who had interesting hobbies, we offered the children a choice of clubs and a choice of times outside of school that they could meet. We spent time arranging for the children to negotiate interest and friendship groups. We spent time arranging to embed tracer tasks for our second year units in the club activities that would be going on anyway.

Three clubs resulted: a Saturday morning Back Pack Bears club, devoted to camping and hiking interests, and two Computer Capers clubs, one on Saturday morning and one after school on Monday. The first task we tried to embed in the clubs was a Piagetian combinations task. The Back Pack Bears combined elements of freeze-dried meals to plan for a healthy and interesting menu on a long hike. The Computer Capers children were supposed to arrange a combinations of children for a tournament of computer games, but the task had trouble getting initiated with the children who were experiencing their first hands-on computer time in a relaxed atmosphere. The Back Pack Bears mapped in relation to the mapping cycle, but the Computer children didn't. Both groups did some relevant division and memory work.

The child-only small group sessions in the classroom gave us some analytical insights (see Chapter 2) for further analysis of this part of the corpus. Of particular interest for further work is an examination of these situations in terms of goal-formation. The difficulty of getting a task inititated is not found as often in teacher led groups, but this very difficulty in clubs make them an interesting locus for investigating how children come upon a problem and identify it as one where a school learned skill could be useful. The child-only problem isomorphs instituted in the classrooms during the cycle provide for a sort of "near transfer," while the clubs provide for a "far transfer" test of the learning that takes place during the classroom parts of the cycle. Even in the child-only settings in the classroom, the discovery of the task that we had embedded was not always made. For some children, for some cycles, the tracer only came in when the teacher brought it in. In the far transfer to the different materials and social setting of the clubs, task discovery is even more complex and variable in its appearance. Hence, club settings appear to be very promising for well constrained analyses addressing the problem of how educational activity gets transferred to every-day life situations.

Chemicals cycle. In this remainder of this report, much attention is paid to the Chemicals cycle that we ran in the second year of the project. Like the division cycle, it is a good example of the five working principles that we started with. In addition, the chemicals cycle provides an illustration of how the joint planning can be marshalled to produce and present work that can be seen as non-trivial from either the point of view of educational relevance or the research community.

The researchers searched for some tracer that

(1) they knew well from the research literature;
(2) they knew had been studied using different sorts of materials and with different configurations of social organization;
(3) they knew was an unlikely part of the children's prior experience;
(4) they knew had been used in training experiments that might guide teaching suggestions;
(5) they expected to produce variable performance by fourth-graders.

Tasks related to the Piagetian theory of operational stages fit the bill.

Given both the historical relation of Piagetian tasks to education and the current emphasis on Piaget's work in discussions about education, it seemed likely that we could find educationally relevant and important domains within which to instantiate a Piagetian formal operational task.

We did not make the mistake that we had in the meta-memory planning: We knew we needed a specific domain to map the problem isomorphs in the school lessons onto. While the tasks may be viewed as general in the Piagetian theory, we had theoretical reason to suspect that domain specificity was important to investigate (LCHC, 1982; Piattelli-Palmarini, 1980; Feldman, 1980). Furthermore, to get the practical work done in the classroom, domain specificity provided coordinates for the planning and the teaching. We didn't want to repeat the problems of the electricity cycle, this time allowing confusions about epistemics to disable our interactions. We also did not make the other mistake that appeared in the meta-memory and the mapping cycle: we didn't just create educational relevance, either by rationalization or by developing some integrated curriculum that the teacher could not rely on as a motivation to guarantee that the lessons be taught regardless of the other demands of the school year and school days.

The teacher, working on a curriculum committee over the summer as well as with our planning team, brought news about curriculum topics that the district was interested in introducing into the schools. Together we examined the existing curricula and the new topics, trying to find some in which Piagetian tasks could be embedded. Household chemicals became the focus of our attentions, and the Piagetian task of "making all the pairs you can and no duplicates" (the intersection procedure) emerged as the tracer element. As was the case with the successful first year cycles, we were able to develop enough activities and enough mutual understanding of the domain and the tracer that we could choose among possible sub-topics and gauge well the children's responses. The on-line repairs and the supplementary lesson planning done during the execution of the cycle could rely on the well-understood problem that we were coordinated around.

The richness of the educational experience was noticeable: The children dealt with the uses and dangers of common household chemicals (like cleaning agents). They had access to the reasons that the products worked, what certain ones had in common, and how the ingredients acted in combination to accomplish their function. They developed consumer awareness as they dealt with labels and with homemade chemicals. In addition they learned a bit about scientific methods, a procedure for epistemically arriving at all the possible combinations of pairs of objects, and how records could be kept to aid in an investigation. Several chapters of this report are devoted to this cycle because of its richness in illuminating several of our key issues at once.

Cycles and models.

From the problems that we ran into we learned to define what it means to build artificial educational models. is what building artificial models is all about. We knew from the start that there would be a blurry line between the task and the social organization in which it appeared. Our model would have to handle this blurry line: it would have to embody strategies for treating what other models or theories call the cognitive *versus* the social aspects. We took ideal cognitive tasks, our tracers, and tried forcing them into a variety of social configurations. Our major effort was to do enough work with the varying social situations so that we could specify how it was the case that tasks appeared or disappeared or became mutilated or transformed. As soon as we could do that, our model would be a model of cognitive change: the persons in the situations are the ones who have to carry out the tasks, who make them appear or fail to, who transform them into easier or harder or very different versions of what might have been there.

The analysis of the research problem that we started with developed, of course, as a result of our confrontation with the reality of the classroom. We came to view our work as one example of a "formative") experiment. It is also a concrete example of the principles we discovered about cognitive change, now applied to ourselves. First, our learning was the result of carrying out a joint activity with others who had a different analysis of our shared situation (i.e., practicing teachers); second, there were concrete constraints from the specific domain we were all working in that increased the chances of shared understanding and decreased the chances of the task disintegrating; third, we were not subjected to direct instruction (which in any case we would not have understood at the outset!), fourth, our new formulation of answers to the questions we posed was first worked out inter-personally in the interactions we had with the teachers, with our colleagues and among ourselves before any one of us felt individually (intra-personally) that we had a firm grasp of our current analysis.

These features of our learning experience are familiar to most researchers who have tried to collaborate with others. These features are generally absent, however, from most current accounts of cognitive change. As we hope we can show, this pattern of mutual disinterest is not accidental. There are systematic reasons for the psychological assumption of the individual as a unit of analysis which have been extremely important in shaping educationally-focused research. Our goal in this report is to provide an alternative system based on, and illustrated by, the interactions we observed during our work in the classroom to provide teachers and policy makers with the means to deal with the pressing issues they face daily.

At the end of this report we will return to summarize our conclusions.

The Plan for this Report

The first Chapter makes the case that laboratory tasks systematically obscure the process by which the subject comes to have the goal of the task. The task is the task as understood by the researcher and the goal is already prepared by the researcher as a condition for obtaining sufficient control over the experimental situation. The fact that a subject, especially a child subject, may have an alternative analysis of the task is either corrected during the instruction phase or is made invisible by the coding scheme by which the subject's performance is measured. By comparing laboratory and peer activity versions of the "same task" we can clearly see this limitation on the laboratory setting. In the peer activity the children's alternative analysis in many cases led them to carry out a different task from the one they all carried out under the constraints of the laboratory. But we can also see that, in principle, the researcher is not much different from the teacher. In both cases we must appropriate the child's actions into our own system of activity. The teacher creates interpretations of the child's actions that organize the interaction between the teacher and the child. To a large extent, this process of appropriation can go on irrespective of the child's prior system of activity. A version of this chapter will appear in an edited volume concerned with the development of everyday cognition (Newman, Griffin & Cole, in press)

The second chapter sets out the essentials of a theory that can adequately account for the process of appropriation that we see happening in teacher-child interaction. We find in Vygotsky's sociohistorical theory and Leont'ev's theory of activity concepts of enormous usefulness which have been largely overlooked in American cognitive psychology. These approaches provide a strong base for a theory of learning in interaction because they treat social interaction in a principled way as a source of change. The concept of appropriation in fact can be found in Leont'ev's theory where he speaks of the child actively appropriating the tools of a culture. Our usage includes the reciprocal: the culture appropriates the child's actions as a way of giving them meaning. We also discuss Vygotsky's important concept of the "zone of proximal development" which for us refers to the organization of teacher-child (or more generally, expert-novice) interaction. We find that a full account of the appropriation process requires that we consider the ways that the child can internalize the organization of that interaction. That is, the child gradually takes over the interpretations of his actions that are supported in the interactive "zone" by the teacher. We explain how such a view of cognitive change requires a theory in which abstract schemata can have an interpersonal as well as intrapersonal existence and in which behavior is not uniquely interpretable. Among the benefits of this theory is an account of how more powerful structures can develop in the child. Higher-level structures are appropriated by the child from the interaction between himself and the teacher. This chapter is based on a paper presented at the biennial meetings of the International Society for the Study of Behavioral Development (Griffin, Newman & Cole, 1981).

The following four chapters return to data from our classroom corpus expanding on issues that follow from the above theoretical considerations.

The third chapter takes up the problem of coding cognitive processes in a classroom. We point to the possible misappropriation of children's behavior by classroom researchers. Two standard schemes are applied to a small group lesson. We find that the schemes work only for children who are engaged in the task as understood by the teacher. A shorter version of this chapter appeared in the journal, Discourse Processes (Griffin, Cole & Newman, 1982).

In the fourth chapter we discuss how Vygotsky's concept of the "zone of proximal development" provides a method for assessing children while in interaction with adults. Our attempts to use this method indicates crucial limitations that arise when the "observer's" task is teaching rather than research. This chapter is based on a paper presented at the annual meetings of the American Educational Research Association (Newman & Broyles, 1982) and has been submitted for publication.

In the fifth chapter, the teacher whose classroom was the setting for our experiments, discusses the conflicts inherent in the teacher-researcher relationship. Her observations are a powerful illustration of how classrooms and laboratories differ as contexts for conducting research. This chapter appeared originally as an article in The Quarterly Newsletter of the Laboratory of Comparative Human Cognition (Quinsaat, 1980).

In the sixth chapter we show how the "zone" is actively constructed in the teacher-child interaction and how it becomes organized differently when the teacher interacts with children with different entering skills. The analysis is based on data from a set of lessons designed by the teacher to teach long division. We find that the learning of a crucial step in the algorithm was neither taught directly nor invented by the children. Rather, it emerged in the interaction as the teacher appropriated the trial and error attempts of the children and used them to instantiate the expert strategy. Differences in ability groups led to differences in this interactive process such that the lower ability groups were unable to move beyond the teacher's explicit instructions. A version of this chapter has been recommended for publication in the journal, Cognition and Instruction.

We conclude by specifying the implications of our work for researchers in the cognitive sciences and for educators and others concerned with improving the quality of education.

CHAPTER 1:

FINDING GOALS OUTSIDE THE LABORATORY

Our point of departure is the psychological laboratory. Here the investigator constructs a model system within which it becomes possible to make principled, but limited, claims about hypothetical processes (currently referred to as cognitive processes) that can be said to mediate between states of the artificially created environment and behaviors of the subject.

The key to making claims in the laboratory is the psychologist's control over the task and the conditions under which the subjects undertake the task. In terms of experimental methodology, two kinds of control are necessary. One is obtained by carefully contrasting particular conditions in the model system and by having a sufficiently large number of subjects undertake the same task under the same conditions. This is referred to as experimental design. These design controls presume a practical control over the task e.g., the goals of the subject's behavior and the conditions the subject is subjected to. The experimenter must be sure, for example, that subjects are actually working on the task they are expected to be working on and that it is the subject's behavior, not somebody else's, that is being recorded.

Whether we use laboratory settings for testing cognitive theories or for administering psychological tests, we like to believe that the cognitive processes we model, and the cognitive accomplishments that we test for, represent more than esoteric games. There is no doubt that performance in these games count. Cognitive tests not only predict school success, they are used for a wide variety of decisions that influence economic fates. But as many commentators have noted, the constraints on activity used to create model systems render them systematically dissimilar to the systems of activity created in the society for other purposes (Bartlett, 1958; Cole, Hood & McDermott, 1978; Lave, 1980). As a consequence, our cognitive theories are weak in just those areas where they relate most closely to practice--to those "everyday" cognitive tasks that are significant contexts in our lives.

This chapter is directed to the question of how behavior occurring in one kind of setting (defined in terms of its social organization, participant goals, etc.) can be compared with behavior in another kind of setting in ways that are productive for cognitive theory and that contribute to educational practice.

We will discuss examples from our data in which children confront the "same task" in two different settings. These data allow us directly to compare children's performance in a rather standard, laboratory-derived task with behavior in a loosely supervised science activity. On the basis of our analysis of the way the children confront and are confronted by these tasks, we will argue that the standard "division of labor" between researcher and subject in laboratory settings tends to obscure an important feature of cognition. When experimenters present a well defined task to the subject, in a standardized way, they have little chance to observe the formation of new goals by the subject or his/her application of a procedure to new situations.

In making these comparisons, we do not assume one setting to be more valid than another for the characterization of cognition. Rather we argue that both kinds of settings make available for analysis important, and different, aspects of cognitive activity. We believe that the integration of analyses from these different settings will be required if we are to construct a cognitive science that is relevant to a general range of human environments for learning and thinking.

Making the "Same Task" Happen in Different Settings

In the early stages of this work, Cole and his colleagues set out to locate psychological test-like behaviors occurring in classrooms and after-school clubs. The idea was to analyze the nature of known cognitive tasks when they arise in these nonlaboratory settings.

In the subsequent phase of our work, we have, in a sense, reversed the earlier strategy. Instead of waiting around for something recognizable as a cognitive task to appear, we set out deliberately to find ways to make hypothetical "same tasks" happen in several settings inhabited by the same children. We worked closely with teachers and club leaders to construct a set of activities (one-to-one tutorials, small group lessons, child-guided work groups) all of which had a particular problem structure embedded within them. We went a step further. We put into those various settings what we call "tracers". The tracer was some bit of knowledge or some procedure which we taught the children in one of the settings and which would be potentially useful if they recognized that they had been confronted with what they considered the same task in the new setting. This set of constraints greatly increased the probability of finding good candidates for analysis and of uncovering how the "same task" is transformed, made easier or more difficult or avoided entirely under the different organizational conditions.

When is a Task the Same?

We put the term "same task" in quotes because the sense in which two tasks can ever be considered the same is a central question for this analysis. It must be said at the outset that we had no illusions that a cognitive task could be specified independent of its social context. Our orientation was quite the opposite. From our perspective, cognitive tasks are always social constructions. Transformations of the social organization of the tasks that we studied drastically changed the constraints on behavior, thereby rendering the tasks instantly different according to widely shared ideas of what constitutes a task in cognitive psychology. It was our hope that by highlighting the way in which our efforts failed to make the "same task" occur in different settings, we could arrive at a clearer specification of the class of social constructions represented by such activities as tests and experiments. (See LCHC, 1978, 1979 for a discussion of the history of the viewpoint in our collaborative work).

When we set out to make "same tasks" happen our idea was to create a set of what are called "problem isomorphs" in cognitive psychology. Problem isomorphs are a set of problems which share an abstract structure but differ in concrete content (e.g., Reed, Ernst & Banerji, 1974; Gick & Holyoak, 1980). In the cases we will be discussing, children were asked at one time to make all the possible pairs from four stacks of differently colored cards and at another time to make all the possible pairwise mixtures from a set of four chemicals. In cognitive psychological studies (where problem isomorphs are used to study the effects on a subject's performance after experience with a problem "of the same kind") every effort is made to change only the content of the problem leaving the abstract form of the procedures, initial conditions, legal moves, and goal unchanged. So, in our example, the content clearly differed but the abstractly defined goal of "finding all the pairs" remained the same.

The "problem isomorph" formulation for what we were trying to do might have worked out fine except that we changed a feature of the task environment which is almost never altered in cognitive psychological research. In the chemicals activity we departed from the one-to-one social organization of the standard laboratory setting; we had groups of children working together. This change in social organization not only increased the social resources available for solving the problem (thereby making it hard to say who did what). It also changed the <u>source</u> of the problem and thereby the nature of the task. In the one-to-one situation the tutor motivated the problem as the one to be done, i.e., the children were <u>presented</u> with the task of finding all the pairs of problem elements. In the chemicals situation, the children had to formulate the problem for themselves as they began to run out of pairs to mix. This shift in the origin of the task clearly changes the nature of the task such that one would hesitate to call the two versions "isomorphs".

Because task in cognitive psychology is a goal plus constraints on reaching the goal presented by the researcher to the subject, the researcher does a lot of work to formulate a clear task. In everyday situations people do not always have the "advantage" of this kind of help--they often have to figure out what the problem is, what the constraints are, what resources are available as well as to solve the problem once it is formulated. In everyday situations people are confronted with the "whole" task, not just the solution part.

Armed with this broader conception of the "whole task" we have some hope of analyzing the transformation of a task when it is embedded in different social settings. When we look for the "same task" happening outside of the laboratory we have to look for how the work of formulating the task (which is done by the experimenter in the laboratory) is getting done and who is doing it. This analysis will provide us with the basis for arguing that the practical methods of maintaining control in the laboratory lead us to ignore the crucial processes of formulating the task and forming the goal which are often the responsibilities of people in everyday settings.

We can now turn to the concrete details of how we tried to make the "same task" happen in different settings and to the analyses that our efforts made possible.

The Combinations Task

To create examples of the "same task" in two different settings we needed a task that would have as a solution an easily analyzable and recognizable procedure that the children would not already know. This solution was our tracer. We found an appropriately simple but exotic task among a set that Piaget and Inhelder (1975) used in their studies of combinations and permutations.[2] One of these tasks was aimed at the ability to generate all possible pairs from a set of items (they used stacks of differently colored chips). There is an accepted "formal operational" procedure for the systematic solution of this combinations problem which we thought was both elegant and probably beyond the capacity of our fourth graders' as individual inventions. For us, the combinations task was also useful because Inhelder and Piaget (1958) studied another version of it which involved combinations of chemicals. Since the classroom teacher was already planning a unit on "household chemicals," we had an opportunity to embed this well analyzed cognitive task into the ordinary course of classroom activities.

"Laboratory" version of the task. In our one-to-one tutorial situation, each child was invited into the library corner of the classroom by a researcher and was presented with stacks of little cards. Each stack of cards was of a different color and bore the picture of a different TV or movie star. Starting with four stacks, the child was asked to find all the ways that pairs of stars could be friends. Specifically, the child was asked to make all the pairs of stars and none that were the same. The child then usually went about choosing pairs of cards from the stacks and placing them in a column.

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2. We were not concerned with testing Piaget's theory or testing the children's "operational level"; we chose the task for its usefulness as a tracer in our design. While we occasionally make use of Piagetian analyses, we are essentially taking the task outside of the theory which generated it. But for a discussion of Piaget's theory in relation to our approach see Newman, Riel & Martin (1983).

When the child had done as many pairs as s/he could, the researcher instituted a short tutorial before doing another trial of pair making. She asked the child to check to see if s/he had made all the pairs. If the child did not invent a systematic procedure for checking, the tutor suggested one. She would ask "Do you have all the pairs with Mork" (if Mork were the first star on the left). Then she would ask about the next star to the right. With these hints, we wanted to give the child the idea of systematically pairing each star with every other star. We could then see whether this systematic procedure carried over to the next trial at making combinations.

When the checking was finished, the stars were put back in their piles and a fifth star was chosen. Again the child was asked to make all the possible pairs and none more than once. At this point, many of the children began by making all the pairs with the left most star. This star was combined with each to his/her right. Then the second star (from the left) was combined with each to his/her right and so on until all the combinations were made. For children who did not arrive at this particular system of producing pairs, the checking procedure was repeated. But this time the tutor gave as explicit instructions as were necessary to get the child step by step through an entire check. That is, the tutor would ask about each star and his/her pairing with every other star in a systematic left to right manner. In the final trial, the child chose a sixth star and attempted to make all the possible pairs with six.

The "tracer" procedure. The tutorial accomplished two things. First, it acted as a pretest, we tested each child in a typical laboratory setting on one version of the combinations task. Second, it taught each child a procedure for determining that he has all the pairs.[3] The procedure of combining each item with each other item could then act as a tracer in a later task with a different social organization. If the children later used the particular procedure we taught (and if it were reasonable to assume that the procedure would not be used except for the goal of finding all pairs) then we could say that the children's use of the procedure would be evidence that the child-participants had identified the "same task".

Piaget's analysis of this procedure is useful to consider because it is abstract enough to be considered to apply to combinations problems presented in other modes. He referred to the procedure as "intersection." As he conceived of it, the child is coordinating several series of correspondences. This can be understood as treating the single array (of four stars, for example) as if there were two dimensions which intersect. Each item on one dimension is paired with the items on the other dimension in the manner of a matrix like that shown in Figure 1. With this matrix conception, choosing pairs follows planfully from beginning to end. All the child has to do is work through the matrix.[4] In contrast, a child without the conceptual matrix will typically make pairs without an orderly pattern or will make patterns such as 1&2, 3&4, 2&3, 1&4. Without the matrix concept, the child will not be certain he has all the pairs; "he just can't think of" any more patterns. This endpoint lacks the certainty or sense of necessity that is found in the intersection

3. The task as formulated by the researcher was to make all the pairs and no duplicates. We will concentrate our discussion on the goal of getting all the pairs which was the primary focus of the checking procedure.

4. If the child is just checking if all the pairs are done, it is often just as easy to go, say, row by row even though checks are duplicated. In the production of pairs where duplication is not allowed, the system of dropouts is usually used so that only, say, the top half is produced.

	1	2	3	4
1		1 and 2	1 and 3	1 and 4
2	2 and 1		2 and 3	2 and 4
3	3 and 1	3 and 2		3 and 4
4	4 and 1	4 and 2	4 and 3	

Figure 1. The intersection procedure "schema"

procedure.

We can consider the intersection procedure to be potentially general enough to apply to any number of or any kind of items should the structure of the activity make it useful. In cognitive psychology, such an abstract and general structure would usually be called a "schema" and would be considered to be a feature of a subject's internal conceptualization (cf. Abelson, 1981, Rumelhart 1980). We will be looking for this "schema" outside of the laboratory, and we have to be careful not to give it an exclusively mental status. In looking for this schema in the peer interaction setting which we set up later, we had to allow that it would be found as much to be mediating social interactions as to be mediating an individual's actions. Even using this tracer as a frame for comparison between the two settings, our attempt to locate the "same task" would be far from straightforward.

The chemicals task. The second setting in which we attempted to locate our tracer looked very different from the movie star tutorial. We developed, in collaboration with the classroom teacher, a unit on household chemicals. A series of lessons and activities lead up to the second version of the combinations problem. It was presented as a special work-table activity. Groups of two and three children went to the back of the room where the teacher supervised some science activities one of which involved making combinations of chemicals.[5] Each group of children was given four beakers of colorless solutions which were numbered for easy reference, a rack of test tubes and a sheet

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5. The children did two versions of the combinations of chemicals task a few days apart. A second version closely resembled the original Inhelder and Piaget procedure, but the one we will discuss here was slightly simpler and its goal more closely matched the combinations-of-movie-stars task.

of paper with two columns marked off on which to record "CHEMICALS" and "WHAT HAPPENED." The four chemicals had been chosen (with the help of UCSD chemist, Dr. C. Perrin) such that each pair would have a distinctive reaction.

The written worksheet instructed the children to find out as much as they could about the chemicals by making all the combinations of two and recording the results. After getting a child to read aloud the instructions, the teacher reiterated some safety precautions and directed the children to make all the possible pairs without duplicates. The teacher then sat down at the end of the table and busied herself with paperwork so that she could observe the children without directly supervising them. She intervened on occasion when children ran into difficulty or asked for help, but, for the most part, the pairs of children worked on their own. It was thus more markedly like a peer group activity with fewer laboratory-like constraints on what was to be done or how to do it than we typically observe in cognitive experiments.

How We Tried to Make the "Same Task" Happen.

We went to considerable effort to give the task a good chance of happening in the two settings. Most notably, in both cases the researcher or teacher stated the goal of making all the pairs at the initiation of the problem. These instructions were not always sufficient to make the task happen, a failure of instruction that enables some of the central claims we want to make.

We anticipated some difficulties in getting the task to happen in the chemicals setting. The movie star activity posed far fewer practical problems. The movie star cards were just the right size for placing one pair under another in a neat and accessible column (on the mat next to the child). Once a column was constructed, it was easily scanned and checked (the cards were brightly colored and the pictures were distinctive). The chemicals were much harder to manage. They had to be transferred from beakers to test tubes and once a pair was in the tube there was no automatically available visual record of which ones had been put in.

If the children were unable to mix and keep track of the chemicals we could hardly expect them to attend to the task of getting <u>all</u> the combinations. Our solution was to set up an earlier lesson in which the children had to place a solution from a beaker into a test tube and record the results on a form which was to be used later in the combinations of chemicals task. The recording paper (and the previous instruction and practice on using it) provided not only an "external memory" for each child but also a common reference for the groups who were (expected to be) working together.

There is, of course, no way of measuring precisely the relative difficulty of the two situations. But such comparability is not crucial to our analysis. In spite of the long list of differences between the two situations, there was still an important way in which they were the same. They were both settings in which the intersection procedure--our tracer--is potentially useful if the children accept <u>our</u> notion of the task. However, the nature of our enterprise required that we take some chances. In the chemicals activity we could not direct the children to use the tracer or force the task to happen. The lack of teacher/researcher direction was the crucial difference we wanted to maintain. If, despite that difference, we were still able to locate the tracer we would have an anchor point for which to begin an analysis of the "same task" in two different settings.

Comparing the Two Settings

We started out assuming that we had problem isomorphs in the ordinary sense. We suspected that this assumption would not ultimately be warranted but we wanted to push a standard approach as far as it would go, to discover how it broke down. The problems this approach ran into forced the alternative analysis which we will describe below.

Our Initial Attempt to Code Performance

Once the videotapes were collected, we started out somewhat naively to code the events for occurrences of our tracer. Once coded, we could simply run a statistical test to see if performance on the two tasks was correlated. If a child uses the intersection procedure in the movie star task is he likely to use it in the chemicals task? Or is it the case that different children used it in one setting or the other?

In coding both tasks we were looking for any instance of a child going through a sequence like 1&2, 1&3, 1&4 2&3 and so on, i.e., a sequence in which each item is paired with every other item in a systematic way we could recognize. (The sequence could contain duplicates). The sequence could be either a complete run through of the procedure or a fragment of the procedure (e.g., all the 2's: 2&1 2&3 2&4). We used a three point scale where "1" meant no fragments of the procedure were found, "2" meant that some fragments of the procedure were found, and "3" meant that the child produced at least one complete run through of the procedure.

In the move star task, only 3 children (out of 27) started out in the first trial using the intersection procedure. But after the checking tutorial, 17 children used a complete run through of the procedure (and 4 others used it partially) in the second or third trial. In the chemicals task, the coding credited only 4 children with a complete run through of the procedure although 8 others did at least one set (e.g., all the 4's). In statistical terms, the conclusion from such a coding approach is a low correlation between performance in the two settings (Kendall's tau is .37; with 1 child doing a full run through in the chemicals but producing only a fragment in the last trial of the movie stars and 5 children using it in the movie stars but not at all in the chemicals).

We might also take these results to indicate that, in some sense, the movie star task was easier, confirming our suspicion that the chemical materials were difficult and unfamiliar. The result was also not surprising given that we taught the intersection procedure just before the second movie star task, a lesson that came months before the chemicals task.

But, for the current discussion, there is a more important sense in which the movie star task was easier. It was far easier to code. For one thing, we knew exactly where to code. We were interested in just the testing trials where the child was put on his own to produce the pairs from 4, 5, or 6 stacks of stars. In contrast, in the chemicals activity the intersection sequences were located at various points in the episode in the children's talk about what pairs had, or had not, been done. Also, children were not isolated from sources of help. The intersection sequences which appeared during the chemical task were often collaborative productions which were difficult to code in anything but an ad hoc way.

These differences provide us with crucial points of comparison. The coder's problems are symptomatic of differences for the participants (including the teacher and researcher) in what the task is and how the work gets done.

Locating the Tracer in the Chemicals Activity.

The chemicals activity presented us with difficulties from the beginning. We can gloss these as problems in locating our tracer i.e., the intersection procedure. There were two kinds of difficulty: a) knowing where to find the tracer in the course of the children's activity, and b) knowing to whom we should attribute the procedure.

Finding the tracer. We thought that the children would use the procedure (our tracer) to produce the pairs of chemicals as they had produced the pairs of movie stars in the tutorial. We thought that some of the children would start out with, say, 1&2 and proceed to do all the pairs with 1 and so on through the six possible pairs. This never happened. Instead, the groups of children started with whatever pair was most convenient or was "thought of first" (for lack of a better description). The sequence of pairs either manifested no pattern at all or took on patterns such as, for example, doing the middle then the ends. These patterns were not usually produced as part of a single, coherent sequence by the children. For example, one common pattern started with 1&2 then 3&4 when the two children who were part of the group but working independently, each took the two beakers closest to him or herself. When it appeared, the intersection procedure arose in the talk among the children. When the children could not think up another pair that had not yet been done they would discuss the written record or would consult one another's memory.

A group composed of Thomas, Candy and Elvia provide a good example of this process. At the beginning of the task they settled on a turn-taking order which they maintained throughout. During a turn, one child would both mix the chemicals and record the results. (This is not to say the children were working alone; many of the decisions about what to mix and how to describe the result were made after extensive discussion.) At each new turn, one child would choose a pair and the other children would check it against the record. The sequence of choices followed no apparent order through the six possible pairs and, until the last two pairs, the children had no difficulty thinking up a new pair that had not been done. The last two pairs were also arrived at without apparent system but with growing concern about finding more to do. After Candy's second turn, the six pairs had been done but Elvia took an empty test tube from the rack, preparing to mix another pair. With a sigh, Elvia says "I don't know what color to <u>use</u> now ..." Thomas suggests 2&4 but Elvia finds it on the worksheet. Thomas jokingly suggests 2&2 and Candy suggests 2&4 again. Thomas thinks of 2&1 but finds it has been done. Candy suggests 4&2. There is a mild rebuke from Thomas that it is the same as 2&4. Elvia comes up with 4&3 but Candy finds it has been done. Elvia suggests 4&1 and Candy recalls that she did it. At that point Thomas says "there's no more," Candy thinks of 3&1 and Elvia thinks of 3&2, but they find both of those on the written record too. Then Elvia suggests 3&4. At that point Thomas says "wait a minute, kay, we got, okay we got all the 1's." He moves his finger up the record sheet and hesitates when he only finds two of them but then finds the third. Candy says "all the ones with 2?: 2&3" and pauses then says, "they don't have 4&1," but Thomas points it out. At that point the teacher asked "You have them all?" And Thomas answers "yep."

The intersection sequence can be recovered from this interaction. For almost a minute, the three children name off pairs with 4 until Candy moves to 3&1 after which Elvia names the other pairs with 3. Then Thomas looks for all the 1's and Candy suggests looking for the 2's. The order is not "perfect" but as a group they manage to check through all the pairs with each of the chemicals.[6]

Finding our tracer, the intersection procedure, in the talk among the children as they set about to check their work should not have been a surprise. The tracer was first introduced during the movie star tutorial in the tutor-child checking interaction. What we found was that the children who used the intersection schema incorporated it as a checking procedure in their production of pairs. They used it in much the same way as they were taught to use it: as a checking procedure.

Determining who did it. We expected the second difficulty. Because the children were not working alone we could not always attribute the procedure to a single child. In the example of Thomas, Elvia and Candy the sequence was made up of contributions from all the children and no child carried out the

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6. Usually these checks would not strictly follow the 1 to 4 order but would skip around partially depending on the order the combinations were recorded on the worksheet. For example, a child would search for all the 4's by reading down the worksheet and naming off all the pairs with 4 as they were encountered. This strategy has the advantage of making the search of the record more efficient although it means the memory load is increased because the child must keep in mind which of the pairs with 4 have been found.

whole strategy independently. We want to say then that the intersection schema is regulating the interaction among the children rather than just regulating the individuals' actions.

It is also the case, however, that peer collaboration in the chemicals activity did not automatically obscure individual accomplishment. Some children divided the labor in such a way that it is possible to attribute the schema to an individual. In one case, two boys who were best friends collaborated closely such that Jorge would write down what Mike mixed and when they exchanged turns Mike recorded what Jorge mixed. They alternated turns through the six possible combinations which did not follow any apparent pattern. At that point, Mike took out a test tube to begin another combination but stopped to look over at the record. Mike started a checking sequence at 1&2 and from there continued through the whole sequence ending with 3&4. While he was naming the chemicals, he pointed to the numbered beakers which remained in a neat array. Jorge, in the meantime read the record, finding the combinations Mike was naming. Mike and Jorge divided up the checking roles just as they had divided up the roles in producing and recording the chemicals. One dealt with the chemicals while the other dealt with the written record. Because Mike was the one to name off the sequence of pairs we do not hesitate to attribute the schema to Mike. But it is also clear that the schema is regulating the interaction between the two boys. Thus we find again that the intersection schema is not just, or even primarily, an internal knowledge structure. It is also importantly locatable in the interaction among the children. It is, in Vygotsky's terminology, an interpsychological, cognitive process.

In an important sense the accomplishment of the intersection procedure was always a social accomplishment in our data. When we look back at the tutorial it is clear that the creation of the protected system in which the procedure could be carried out unimpeded was a piece of collaborative social organization. Such organizational support for problem solving is a systematic feature of settings organized for individual assessment. But when individual assessment is the motive for the activity, the organizational efforts tend to go unnoticed because they are background to the "data". In the less constrained setting, Mike's and Jorge's marvelous bit of organization can be better appreciated.

Locating the "Same Task"

One thing that our coding neglected to identify was the task that we wanted to find in the two settings. We found our tracer in many of the sessions (most of the movie star sessions and some of the chemical sessions) but what does that say about the existence of the same task in the two settings?

When we set about coding the movie star session we felt confident that we knew where the task was and that what we were coding was the child's performance on the task. We identified the task with the goal "make all the pairs" which was stated by the researcher just before the child began forming pairs of movie stars. The researcher was careful not to give any information until it was clear that the child was not going to make any more on his/her own. The slot between the researcher's instructions and the child's negative answer to the question "Can you make any more?" provided easy access to the individual child's use of the intersection procedure. We felt confident that we could say that in response to the task of making all the pairs some children used the procedure or used it partially and some children didn't use it at all. Our struggle with the chemicals setting, however, led us eventually to question those assumptions about the task always being present in the movie star sessions in the way we thought it was.

In the chemicals activity it became clear to us that the children, when they started out, were not doing the task. The teacher told them to make all the pairs before they started but there was no evidence that they were trying to make all the pairs. We have two kinds of reasons for saying this. The first is that there were other goals the children were clearly pursuing. The second is that they were not using the intersection procedure (or, apparently, any other systematic procedure) for making all the pairs.

Doing other tasks. If the children were not doing the task of producing all possible pairs, what were they doing? The teacher's instructions at the beginning of the episode stated but did not emphasize the goal of getting all the pairs. She emphasized the problem of finding out about the chemicals by seeing how they react with other chemicals. The reactions which were produced by different combinations were fascinating to the children, and they were generally interested in the problem of describing the results and getting it written down. Tracy's approach illustrates the common interest in the chemicals themselves. Instead of using the numbers on the beakers, he used the the actual chemical names printed on the beakers. After mixing Chlorox (2) with copper sulfate (3) he is excited and describes in detail the blue-green and brown dotted reaction. He appears to want to pursue reactions with "copper". After his partners, who were working together trade their beaker 4 for his beaker 3, he looks up from the worksheet and objects "I got copper!" While his partners had been making an attempt to choose their next pair with reference to the worksheet so as to avoid duplication of pairs, Tracy's criterion for choice appeared to be interest in a particular chemical.

Not doing intersection. A child who is not doing the intersection (or some other systematic) procedure while producing pairs of chemicals is finding the pairs "empirically" according to Piaget's original analysis. By this, Piaget meant the child thinks up a pair by some means other than the intersection procedure and looks to see whether it has been done. In this case, the child has no way of knowing when he is finished except that he can not think of any more.

Piaget's analysis suggests that a child who is making pairs empirically is doing the same actions (mixing pairs, writing the results on the worksheet) but is not doing the same task as a child who knows the endpoint the researcher has in mind. For the child without intersection, the task is like a request to jump as high as you can. The outcome is an empirical issue and could be different for different children. For the child who has the idea of intersection, it provides a definite and general goal to be achieved. In the chemicals activity the teacher's statement of the task goal "make all the pairs" was not acted upon. The task (as the teacher and researchers understood it) only happened when the children themselves formulated the goal of finding all the pairs because they wanted to make more pairs.

Evidence for the task in the tutorial. Tracy's comments about the chemical reactions with copper give us a kind of information which was almost never available in the movie star tutorials. The chemicals activity was loosely enough constrained that alternative tasks were possible. We can notice that children were not doing the task because we could find them talking about doing other tasks. In the tutorials, on the other hand, little was allowed other than pair making. Tracy, for example, starts his second trial (with five stars) by making a row of cards. We have no idea what he might have been trying to do (what his task was) because he was immediately "corrected" by the researcher and told to make a column of pairs...

The strict enforcement of pair making in the tutorial makes it difficult to notice that some children were not doing the task of making all the pairs. Differences in the pattern of pair placements did not stand out as indicating a different goal because it was not accompanied by any other behavioral evidence that the children were doing some other task. We assumed the children in the movie star activity were all doing the same task but only some were using intersection to do "it".

Piaget's analyses of task performance already implies that some children are not doing his task. (His analysis is, therefore, somewhat more powerful as a task analysis than many laboratory analyses which can not distinguish between doing poorly and not doing the task at all). The analytic weakness of the tutorial setting can be seen when we turn to Piaget's claim about what he considers to be a transitional level of performance between "empirical" and "intersection". These are what he called "juxtaposition" sequences and involved patterns such as doing the ends then the middle, e.g., 1&2 3&4 1&4 2&3 and so on. He describes these as a "search for a system" implying that the child understands the task and is searching for a solution. When such sequences occur in the tutorial we can not tell whether or not Piaget is right that the child is doing the task.[7] In the chemicals activity, however, we have clear evidence that some of these sequences were produced while the children were not doing the task.

For example, when Tracy, Leslie and Rebecca started out, Tracy took 1&2 while Leslie and Rebecca worked together on 3&4. When they finished their respective mixtures, Tracy offers his 1 for their 3 and mixes 2&3 while the girls mix 1&4. When the girls finish theirs, Rebecca checks the record and decides to do 1&3 so they trade their 4 for his 3. These trades resulted in a sequence 1&2 3&4 2&3 1&4 2&4 1&3. In this case the pattern resulted from trading for chemicals each had not used yet not from an attempt to create that particular pattern. In this respect, the unconstrained setting provides us with better information about task performance than the laboratory setting. The constraints of the laboratory obscure whether or not some subjects are doing the task.

Our original coding scheme must be drastically reinterpreted. We can now see that most of the children in the first and second trials of the movie star "task" may not have been doing the task at all. Scoring a "1" (for no intersection) may not be a low score, it may simply be an indication of not doing the task.[8] In the chemicals activity what we are coding must also be

7. Our tutorial design does provide one kind of relevant evidence. We found that children who made juxtaposition patterns were not significantly faster than "empirical" children to learn the intersection strategy in the tutorial. This suggests that those patterns are not a stage on the way to discovering a solution to the task.

8. The tracer method for identifying the same task can indicate (when the child does use the tracer) that the child did engage in the task but is not good for indicating that the child did not engage in the task (when the tracer is not used). The child may, of course, engage in the task and decide not to do anything about it. But as far as interpreting the test results is con-

reconsidered. None of the children started out doing the task. For those who finally did, their achievement goes beyond the achievement of any child in the tutorial because they discovered the task on their own.

Getting the Task to Happen in Psychology and Education

In both psychology and education there is the need to get people to do tasks that they would be unlikely to confront if left on their own. In both cases an expert must interact with a novice to present the problem, and to oversee the methods that are devised for solving it. But in an important sense the psychologist's job is a lot easier than the teacher's. The psychologist must move the child from not doing the task to doing it when told to do it in the laboratory. The educator must move the child from not doing the task to doing it on his/her own in everyday life. In everyday situations there is not always an expert getting the task to happen and explaining the procedures. But educators want children not only to be able to solve problems when they are told to do so in a lesson or on a test but also to "find" the problems in everyday situations.

Learning About the Goal

We designed the movie stars activity in part as a testing situation and in part as a tutorial on the procedure we wanted to use later as our tracer. The part of the tutorial during which we taught the checking procedure was designed to make use of the principles which are part of Vygotsky's (1978) theory of the "zone of proximal development". These principles and their application are discussed more fully in Chapters 2 and 4. Suffice it to say,

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cerned, ignoring a task is just another way of not doing it.

in the procedure we used, the tutor started out the checking tutorial giving as much help as the child needed to carry out the systematic check. Where it was necessary, the tutor would start out asking about every single pair. But as the tutorial progressed, the tutor began giving less and less help until the child was, as the expression goes, doing the procedure on his own. Thus the procedure moved gradually from a location "in" the tutor-child interaction to a location "in" the child.

Following Vygotsky's theoretical formulation, we would expect tasks to be found first in the interaction between expert and novice and later in the novice's independent activity. We take this to mean that the novice not only lacks the skills that are necessary for carrying out the task on his/her own but more importantly s/he does not initially understand the goal. The expert must insure that the task, itself, occurs in the interaction between the expert and novice. We want to suggest that our teaching not only provided (most of) the children with the intersection procedure, it also gave them the goal of finding all the pairs. That is, it introduced them to the task such that the goal and the procedure are simultaneously internalized in the course of the interaction.[9] Examples from the tutorial and the chemicals activity suggest how this might happen.

In the movie-stars tutorial, the children first produced a column of as many pairs as they could and then the tutor began teaching the checking strategy. The conversation at this point is important. The tutor asked "How do you know you have all the pairs?" The child usually answered vaguely or, like

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9. This is not always the case. More than one procedure can achieve the same goal and if the child knows one procedure and is just learning another, s/he does not have to relearn the goal.

Tracy, with a hint of frustration "I can't think of any more". The tutor then asked, "could you check to see if you have all the pairs?" The child usually said little and the tutor said "Well I have a way to check. Do you have all the pairs with Mork (or the first star on the left)?" From there she proceeded through the checking procedure allowing the child to take over more and more as they went along.

The tutor's question "How do you know you have all the pairs" presupposes that the child was trying to get all the pairs. This may be a false presupposition but it is strategically useful (cf. Gearhart & Newman, 1980; Stone & Wertsch,). The question treats the child's column of pairs as if it had been produced in an attempt to get all the pairs. The teacher then invokes the intersection procedure as a means to fix up the child's "failed attempt to produce all the pairs." In other words, she appropriates the child's pair-making, making it into an example of how to achieve the stated goal. It appears that when their own "empirical" production of pairs is retrospectively interpreted in terms of the intersection schema children begin to learn the (researcher's) meaning of "all the pairs".

This retrospective appropriation process can also be seen at the end of the chemicals activity. The teacher always checked when the children thought they had finished and attempted to elicit a rationale for their thinking. Like the tutorial, the teacher is working with a concrete set of already produced pairs which were not necessarily produced by the children using the intersection procedure. In the chemicals task, far more than in the movie star activity, the (researcher's) task completely disappeared from the scene in many cases. The teacher's questions at the end bring the task back to the interaction. Her discussion demonstrates to the children how the work they did can be understood as doing her task.

In an important sense the tutor and teacher were treating the child's production as if it were a poorly executed attempt to achieve an agreed upon goal. In education such assumptions may be a useful way of importing the goal into the teacher-child interaction and from their into the child's independent activity. Our original coding scheme also treated many of the children's productions as poor strategies for getting all the pairs. In psychology, such overinterpretations can be dangerously misleading. Children are scored as doing poorly when in fact they are not doing the task in the first place.

The traditional business of cognitive psychological research has been to identify knowledge and processes in the head of the subject. It is only natural, then, that the subject should be isolated and the part of the experiment during which the experimenter and subject interact, i.e., the initial instructions or training, should be ignored. But just as the laboratory setting does not have privileged status as a place to study what people can do, "in the head" does not have privileged status as a place to locate schemata. They can also be located in the interaction between the experimenter and subject or in the interaction among a group of subjects collaborating on a task, or in the interaction between a teacher and a child who is learning to do something new.

Getting the "Whole Task" to Happen

It is one thing to get tasks to happen when the teacher (or researcher) and the child are in direct interaction. It is another thing to get tasks to happen in the everyday world over which the teacher or researcher have little or no control.

A difference between everyday and laboratory-style tasks which is important for our argument is illustrated in the following example from the chemicals activity. Rebecca was working with Leslie and Tracy. When it seemed like there were no more combinations of chemicals to be made Rebecca looked to the record sheet and began naming off the combinations following the intersection schema. She did not use the canonical order, however. The first pair on the sheet is 4&2. She started with 4&2 and scanned the record for the other combinations with 4 and then for the combinations with 3. Within each group (i.e., the 4's and 3's) she named the combinations in the order they appear on the sheet. When she got to the end she said "We're done" and the teacher came over and asked "How do you know". Rebecca repeated her intersection strategy but this time she spoke more clearly and did the sequence in a stricter numerical order: 4&1 4&2 4&3, 3&1 3&2 and so on.

The difference between Rebecca's first and second intersection procedure corresponds to a crucial difference in the source of the task. As Lave (1980) has pointed out, everyday tasks usually arise from, and are constrained by, the actor's own higher level goals. When Rebecca checked the worksheet the first time it was to establish for herself that all the combinations were done. The order in which she named the pairs followed fairly closely the order on the worksheet she was checking. When she did it the second time, it was to display for the teacher how she had arrived at her conclusion and she kept closer to the canonical order. She was answering the question "how do you know," not trying to find out if there were more chemicals to be done.

At the beginning of this chapter we introduced the notion of the "whole task". We can now give it more specification. A "whole task" is a task considered in the context of the activity or higher level goals which motivate it. Whenever there is a task, there is always a whole task. But in some settings like the laboratory or the classroom (or whenever there is a hierarchical division of labor,) the higher level goals may not be under an actor's individual control. In other cases, the actor(s) must formulate the instrumental relation between the goal of the task and the higher level goal they are primarily trying to achieve. This is what we saw happen in the chemicals activity. The children wanted to mix more pairs of chemicals so they tried to figure out if they had done them all. Finding all the pairs was not a task which was presented to them by somebody else; it followed from the concrete situation they were engaged in. In standard laboratory practice, in which it is necessary to have as complete control as possible over the goals the subject is trying to accomplish, subjects are never called upon to formulate their own goals and so are confronted with only part of the problem--the solution part.

This is not to say that whole tasks are not part of the social interaction in the laboratory. The subject may be very much aware that the researcher has goals which are the reason for getting the subject to do the task, even though the subject has no part in formulating the task. When Rebecca changed the order of the procedure, she appeared to be displaying the procedure for the purpose of the lesson the teacher was conducting. In short, there is always a "whole task," but standard laboratory cognitive tasks are organized so that there is a particular division of labor such that the subject is confronted only with the solution part.

In education there is an attempt to get children able to do the whole task when an appropriate occasion arises. We suspect that providing opportunities such as found in the chemicals activity where children were allowed to discover a task in the course of doing some higher level problem, is an important kind of experience for children to have if they are going to learn how to apply what they know to new situations. They will not learn to do that if they are always presented with a ready-made task. A teacher's retrospective discussions are also a crucial part of that experience. For the children who did not formulate the task themselves, such discussions are an opportunity to see that a task had been potentially in the activity.

A framework such as the one we have been working with, that conceives of schemata as moving from the interaction to the individual, makes the interaction and how it changes over time the central topic of analysis rather than an aspect to be set aside. Our discussion of the combinations task has provided a concrete illustration of a whole task first appearing in the research-child interaction and later emerging in the peer interaction. The concepts of whole task and appropriation find a central place in the theoretical framework we propose in Chapter 2.

CHAPTER 2:

BASES FOR A THEORY OF LEARNING IN INTERACTION

In chapter 1 we saw an identifiable procedure being carried out sometimes by groups of children, sometimes cooperatively by a tutor and child and sometimes by individual children. The procedure we called "intersection", to borrow Piaget's term, allowed us to locate the "same task" in two quite different kinds of settings. But this exercise leaves us with profound questions about what will be required of a theory of cognitive change. As soon as we allow our abstract schemata to mediate social as well as mental interactions, difficult questions arise about the existential status of such abstractions. How can a psychological theory handle entities that are not reducible to mental processes? Perhaps even more important: how can a psychological theory handle situations in which the same material objects (e.g., the array of cards in our combinations tutorial) can simultaneously have two very analyses (e.g., from the child's and the tutor's perspectives) as is required by the process of appropriation that we illustrated in chapter 1?

In this chapter, we take some steps toward answering these questions and formulating a theory of learning in interaction. Our point of departure now is the "whole task". We assume that cognitive change includes more than learning solutions, it includes coming to understand and formulate the goals of the task as well. Tasks, that is whole tasks, are usually divided up among people, very often experts and novices, so cognitive change is usually a socially interactive process. The change we want to trace is not just in the mind of the learner but is simultaneously a change in the interaction between the teacher and learner as the capability and responsibility for the whole task comes under the learner's control.

We draw heavily in this chapter on work done within the sociohistorical school of psychology particularly by Vygotsky (1978) and Leont'ev (1978, 1981). Their approach is useful because it treats the social environment for learning in a principled way as part of the process of change rather than as an unanalyzed force impinging on the individual organism. We will explicate several theoretical constructs, particularly Leont'ev's analysis of <u>activity</u> and Vygotsky's concept of the <u>zone of proximal development</u> continuing to draw on the combinations tasks as a source of examples. We will attempt to draw out further implications and advantages of the sociohistorical framework as well as some of the questions that still remain unanswered but which become of interest from this point of view.

Theory of Activity.

We find in the Soviet approach to psychology ideas that are of great practical value to education and research on learning because they take into account the influences of the social environment without reducing the roles of the teacher and learner to mechanistic ones. In doing so, theories such as that of Leont'ev add an important element to developmental theories. While accepting the fundamental notion put forth by Piaget that the child actively constructs knowledge through interaction with the environment, Leont'ev replaces Piaget's concept of "assimilation" with the concept of "appropriation". With this distinction he moves from a biologically oriented approach to a socio-historical one. For Leont'ev, the objects in the child's world have a social history and a definite function that cannot be discovered through the child's unaided explorations. The function of a hammer, for example, cannot be understood by exploring the hammer itself (although the child may discover some facts about weight and balance). The child's appropriation of culturally devised "tools" comes about through involvement in culturally organized activities in which the tool plays a role. Leont'ev thus preserves Piaget's fundamental insight that the child has his/her own structured system of activity but points out that the child cannot and need not[10] reinvent the artifacts that have taken millenia to evolve.

The child is not the only active organism in the social world, of course. Our particular interest in education leads us to notice that the teacher also applies the process of appropriation in the domain of educational activity. The reciprocal appropriation that we notice in teacher-child interaction calls for a theory in which artifacts like "intersection" can be mobile with respect to the multiple systems simultaneously at work in the teaching/learning interaction. Several features of Leont'ev's theory are well worth attempting to explicate and illustrate in this context.

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10. For a child to appropriate such objects into his own system of activity, the child does not need to recapitulate the social history that led to the invention of the socially defined object. The child has only to come to an understanding that is adequate for using the object.

Units in the Theory

Three levels of analysis can play a part: activity, action and operation. These can be viewed as a hierachical group, with an activity being composed of actions which are composed of operations. An entity like "adding 5 and 32" could be one of the operations involved in an action of "totaling the check" that is a part of an activity "waiting on tables for a living."

Operations originate as actions: once an action is embedded in another action, it can become technicalized; its goal is no longer distinct. At this point it is analyzable and performable as an operation. In an analogous way, actions originate as activities when an activity is removed from its object (as in a division of labor). Intermediate goal-directed actions provide the link between activity and object. Activities originate in the system of social relationships within which people connect themselves adaptively to objects in the world. Any "independent" activity has its origin as a collabor[illegible], social, interpsychological activity.

In spite of this genetic sequence for the origin of the system (which serves to explicate the hierarchical relations among its units), Leont'ev takes pains to note that in everyday life, the genetic transitions are not unidirectional, nor does every system of activity have to display all levels of the hierarchy. Mutual transitions are possible between inter- and intra-psychological activities since practical concrete activity and "thought" have a common structure. An activity can be transformed into an action implementing a different activity once it loses its motive; an action can acquire an independent motive and become an activity.

Usually, when a theory requires that one think of units like these three, one looks to see how paradigms for each can be constructed. One expects a description of morphological features that group together instances of one unit in a paradigm. This description should also exclude instances that belong to other paradigms and describe permissible variation. Paradigmatic identification allows the investigator to do two important things: first, instances of the unit can be identified in an ongoing stream of behavior; and, second, different instances of the unit can be identified as the same in some respects and as different alternatives in other respects.

A theory also needs to provide us with an account of the interrelationship among the units, e.g., among the paradigms. As we have already said, in the theory of activity as developed by Leont'ev, this syntagmatic relation is hierarchical.

The syntagmatic and paradigmatic aspects of a unit in these kinds of theories are intrinsically related, raising problems and producing misunderstandings if one is accustomed to standard cognitive psychological theories. Unless one entertains a different notion of how units can be identified and related, these kinds of theories appear vague and seem resistant to empirical inquiry. On one occasion "the same behavior" can be analyzed as an operation, and on another as an action (cf. Zinchenko, 1981). Two different analytical and participant perspectives can be applied to a single behavior instance, one treating the instance as an action, the other treating it as an operation. Behaviors with radically different morphological features, can be analyzed as the same kind of unit, say an action. This mobility of the basic units of analysis is a problem given normative expectations about paradigm construction and empirical identification.

The mobility of units is also a problem for normative expectations given the syntagmatic hierarchy defined in the theory. We need to consider two kinds of syntagmatic relations. First there is the hierarchical syntagmeme posited by the theory. Second there are the real time relations among behavior instances during which the hierarchical relations are transformed to such a degree that only abstract analysis retrieves them. There are also non-overt actions, discontinuous activities, fragments and collaborated constructions. This real time syntagmatic variation and the paradigmatic identity of units are mutually defining and together define the theoretical units.[11]

From our perspective, this mobility of units is fundamental to explaining the nature of cognitive change. Implicit in the theory is the claim that instances of behavior have a property which makes them available for social

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11. This is just such a case as the one in grammatical theory where the word class 'Noun' describes instances that occur with certain morphological features (fit in a paradigm) and in certain positions in constructions (theoretical syntagmatic relations) and is permitted to undergo certain transformations (real time syntagmatic relations). Only abstract analysis would retrieve each of the underlined instances as a member of the class noun (phrase):

(a) It is going to rain.
(b) That Harriet wants Alice to become a physicist is not relevant.
(c) The man sang.

Another definition of 'noun', a word describing a person, place or thing, would be offered by a grammatical theory modelled on usual kinds of psychological theories. Identification is essentially paradigmatic. While such a definition appears more certain and substantive [and may be seen as satisfying given that the semantic identification can be used as an independent factor allowing more flexibility to the sentence syntactic theory], in fact it runs into difficulty in accounting for data. Further, the degree to which it is true can be derived from or accounted for in an interesting way given a theory of the less usual type which provides the first definition.

negotiation and transformation. In particular, it permits analysis of multiple concrete locations for phenomena like "intersection" whose existential status we are examining. We shall call this property of the units "non-unique analyzability." By "non-unique analyzability we mean (1) that a behavior instance can be analyzed synchronically in more than one way--by a participant in the behavior or by an investigator of the system producing the behavior and (2) that it can participate in diachronic systems (development, learning) in more than one way.

Theories which include this kind of dual nature (paradigmatic and syntagmatic) of units and this kind of mobility, cannot rely on the precise and context-free identification of behavior units that is typical of standard cognitive psychological theories. Instead we arrive at a procedure that begins first with an identification of the largest relevant units (activities) and proceeds in a context-dependent manner to the lower units:[12]

> Thus, in the general flow of activity that makes up the higher psychologically mediated aspects of human life, our analysis distinguishes first separate (particular) activities, using their energizing motives as the criterion.[13] Second we distinguish actions--the processes subordinated to conscious goals. Finally, we distinguish the operation--which is directly dependent on the conditions under which a concrete goal is attained. (Leont'ev, 1978)

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12. Elaborated discussions of such kinds of analyses, often called system analyses, can be found in Bateson (1980) and Scheflen (1974) where attention is called to their history and development in a variety of the natural sciences.

13. Warning must be given that the use of the words "motives" and "goals" are somewhat different in this framework. Leont'ev (op.cit.) discusses in some detail these topics; the differences should not interfere with the use made of the constructs "activity" and "action" in this paper.

Subjective Objects

These transitions, which are necessary for systems that undergo cognitive change in interaction with others, raise difficult issues for determining the existential status of abstractions like "intersection". To solve these difficulties we must introduce the concept of a "subjective object". Consider our use of materials. The material objects we provided (stacks of colored cards with pictures on them, beakers of liquids, worksheets) were carefully picked to enable the use of intersection; where they were placed and when and how they were given to the children was carefully planned and executed. We could say that "intersection" has an existential status in these material objects: in fact, the changing states of these objects is routinely used by experimenters to claim that intersection is "there" or not, and the child "has" the formal operational strategy or does not.

Leont'ev theoretically motivates a different understanding of the importance of these materials and underscores the problematic nature of treating them as the location of intersection:

> ...the object of activity emerges in two ways: first, and foremost, – in its dependent existence as subordinating and transforming the subject's activity, and secondly – as the mental image of the object, as the product of the subject's detecting its properties. This detection can take place only through the subject's activity. ...the mental reflection of the object world is [produced] by processes through which the subject enters into practical contact with the object world.

The product of such activity is what we refer to as a "subjective object". We, the investigators and teachers, participate in a system where the little colored cards and the beakers of chemicals are subjective objects for us. We, as subjects of an activity (courtesy of Piaget's experiments and his cultural transmission of them through writing) participate in the transition of the objects to intersection. Once objects have been made a part of an activity that embodies a concept like intersection, their properties as objects change. They now embody a part of those prior actions. In this particular case, they embody "intersection." It is this consideration which lies behind Leont'ev's comment that: "...the transition of the process into a product takes place not only from the subject's point of view. It occurs more clearly from the point of view of the object [as it] is transformed by human activity." (Leont'ev, 1978)

In this case, the materials and their existence as an example[14] of intersection for the teacher make possible educational activity in which intersection as a subjective object can emerge for the child. During instruction, intersection has an existential status for the children on the interpsychological plane. In the teacher-child interaction it can become a subjective object. Any activity, according to Leont'ev, constitutes a "special inherent function", specifically, "the function of placing the subject into objective reality and transforming this into a subjective form" (p. 10). However, it must be remembered that in teaching interactions, there are (at least) two subjects of activity. One subject, the teacher, has a special status. For one thing, intersection as an objective reality and subjective form has a prior existence for the teacher; for another, the subjective object as an example of intersection is a tool of the teacher for placing the collaborating child subject in the objective reality of intersection.

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14. Such examples in Soviet work are called "genetically primary examples" because they provide a general but concrete instantiation of the abstractions relevant to a domain of activity from which all the relevant abstractions can be derived.

Our interest is primarily in the status and emergence of intersection for the child-subject. In the socio-historical framework, the issue of when and in what sense the child "has" intersection is not as straightforward as it might be in some others. The actual (activity) form of intersection is not the teacher's alone; it is the form in the collaborative activity, limited, hence, by the child subject. Furthermore, as the activity unfolds over time in social interaction, the subjects change, especially the child. In fact, an object of educational activity is to change the child subject. An analysis of the mobility of the units of activities, actions and operations reveals some of these changes.

The emergence of intersection for the child subject should be seen originating from the interpsychological system participated in by the teacher and the child. Its emergence as an action of the child should be seen originating in the interchange of activities between the teacher and student subjects. Internalization of intersection, following Leont'ev, can be claimed to emerge for/in a (child) subject when it appears as an action, as a goal directed process mediating between an activity and operations. In short, it is the genesis of one kind of unit from another and between the inter- and intra-psychological planes that constitutes cognitive change.[15]

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15. Components of a task analysis may be involved as activities, actions or operations that undergo genesis; differences associated with successive developmental stages are not inconsistent with genesis. The theory of activity does not rule out stages or component task elements; it simply considers them insufficient to describe the process of cognitive change.

Illustrations from the Combinations Tasks

Teacher-child dyads. As the theory suggests, "same" behaviors can be analyzed differently. Pair making is a good example. For subjects for whom intersection is a subjective object, the issue of how many pairs can be made has an epistemic status: there is an answer that can be arrived at via intersection, six pairs if there are four objects to be paired, ten if there are five objects, fifteen if there are six, etcetera. For subjects for whom intersection is irrelevant, its status is different: the command "make as many pairs as you can" is not very different from the command to "say your name as often as you can," or to "count as high as you can count up to." Subjects with only this second analysis of pair-making do not deal with the notion that there might be a general answer (one not influenced by who is pairing what on a specific occasion) or that there might be an abstract approach that was somehow the same each time it was used, even though it could result in different concrete answers depending on what number of objects were being paired.

Our claim is that the tutor works with both analyses of pair-making: that "intersection" has an existential status as activity and action and that specific concrete pair-making, where intersection is irrelevant, is simultaneously present. In fact, the tutor appropriates the child's specific concrete pair-making actions and products and in this act of appropriation, the inter-psychological emergence of "intersection" becomes apparent. Regularly in our tutorials, the child-subject claims to have made all the pairs that s/he could; the teacher then offers to help check the work, going through the moves

Table 1

The Intersection Procedure

given:	A	B	C	D	E
first move:	A	B			
second move:	A	C			
third move:	A	D			
fourth move:	A	E			
fifth move:	B	C			
sixth move:	B	D			
seventh move:	B	E			
eighth move:	C	D			
ninth move:	C	E			
tenth move:	D	E			

Insert Table 1 about here

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schematized in Table 1 with the child. Some pairs from the child's independently produced column are discarded (duplicates); other pairs are made up and added. The general concrete solution is achieved between the subjects. If there were four objects, the solution is six pairs; if five objects, ten pairs. In the column of pairs and in the sequence of behaviors of the teacher and the child, there is evidence for the claim that "intersection" as an interpsychological function appears. The column of pairs that the child-subject made and his/her actions and operations in making them are appropriated and re-organized by the "intersection" organization of the child-teacher system of actions and operations.

In our tutorials, the tutor repeated the "make all the pairs and no duplicates" request several times, each time adding another object to the row. Thus, we have opportunities to see what happens after intersection has gained an interpsychological existential status. Sometimes, for some of the children, just the same thing happens over again: the pair making they do alone is organized as a series of actions--which pair is made next and when pair-making should stop does not exhibit any orientation to an epistemic notion of how many pairs can be made of the objects in an epistemic sense, i.e., intersection is not visible as a subjective object for the child. Instead, the child's choice of cards appears to be based on pleasing colors or any of a variety of different systems for dealing with the situation; the child stops making pairs at a point for which we have no particular explanation (e.g. running out of "room" on the mat s/he was working on). Once again, as the tutorial proceeds, the adult appropriates the child's actions and products such that intersection appears interpsychologically.

However, for most of the children, intersection appears in a different status after its interpsychological emergence. For these children, on the second or the third trial, the independently produced column of pairs looks just like the array in Table 1. The operations that occur are not exact copies of those undertaken earlier, interpsychologically. There are, in this theory's terminology, transformations. For example: During the interpsychological emergence of intersection, the pairs are talked about in the order charted in Table 1, but as a pair is found to be "missing", the pair may be added "out of order" at the bottom of the column; however, during the subsequent independent action by the child, the pairs are produced materially in the order charted in Table 1. The interpsychological appearance was: make some pairs, talk and act with the tutor to change/add to pairs by "pairing each card in the row with every other card in the row." The intrapsychological appearance is: make the right pairs by "pairing each card..."[16] For these children, intersection organizes their operations; it emerges as an action. There is a concrete general solution, intersection, which, when brought to bear on the specific problem with five objects produces ten pairs; with six objects, fifteen pairs, and so on.

Among the group for whom intersection emerged with an intra-psychological status, three are particularly interesting to consider.

16. With the notion of transformation, the theory makes interesting a variety of questions, particularly what is the permissible class of transformations, and what are the constraints on them.

(1) One child, Rebecca, made a lengthy column of pairs doing the moves almost in the order charted in Table 1. She did not include one required pair. Observers of the behavior as well as the tutor and Rebecca (who talk about this) all agree that Rebecca "forgot" one pair. But, she did it right. Everyone agrees. That Rebecca "forgot" one pair has little bearing on the inference that she can produce all the pairs. In terms of the theory of activity, Rebecca's lapse and this interpretation of it by observers, brings out an interesting point: Missing an operation or two may have a minimal impact on the action, and/or on judgements about whether the action was present. "Just forgetting" or "being wrong on the details but right in general" may have a specific characterization in this theory.

(2) Another child, Nina, manages to produce a column of pairs without producing any single pair at one time. Nina counted out a group of cards from the first stack on the left of the given row (represented by A in Table 1); the tutor intervened as Nina started taking more than one from that first stack, but Nina told her to wait and see; then Nina piled the stack of A's near her on the mat; then she took one card from each of the other stacks (B, C, D, and E in Table 1) and put that varied stack near her. Nina then dealt out a column of cards B, C, D and E and next to that column a column of A's. Nina transformed a column of pairs into a pair of columns as she demonstrated the intra-psychological status of the intersection action. The transformation from the inter- to the intra- psychological plane wipes out the operations that occurred on the inter-psychological plane, and institutes novel operations. The theory of activity provides this characterization for this rather interesting situation: the child demonstrates that s/he has learned what has been taught, but not by doing, on the level of operations, what has been

taught. Of course, this remains underspecified as an empirical claim. As the theory develops and constraints on transformations from the inter- to the intra-psychological plane are proposed, Nina's case will be seen to be either one which is predicted (i.e. there is a class of transformation that will map a function from the behaviors of Nina and the tutor onto Nina's independent behavior) or it will be counter-evidence to this (or perhaps any) social origin of Nina's kind of learning.

(3) Tracy, another child, at first displayed intersection only as part of a collaborative action with the tutor. Then, on the next trial, he displays intersection in a perfectly arranged column of pairs without the tutor's intercession. When the tutor added another object she mentioned that the next specific problem would therefore be harder. Tracy objected, claiming that no matter how many objects there were, it wouldn't be harder. An observer is drawn to Tracy's statement; it seems to suggest an abstract characterization of intersection, not merely a general concrete one. Almost any theory would attend to the fact that Tracy commented on intersection. In the theory of activity, this behavior is not unique evidence that intersection can organize Tracy's behavior, because we have already seen interaction emerge as an <u>action</u> in Tracy's adept arrangement of the cards. In the theory of activity, internal representation is seen as emerging when a function emerges as an action; the internal representation is (some transformation of) the prior external form of the function. However, the theory makes no claims on the basis of this evidence (verbal and nonverbal) for the generality or abstraction of intersection as a part of Tracy's system of intra-psychological functions.

A well designed series of problems involving intersection would have to be constructed and analyzed to permit us to map the extent of generality and abstraction in Tracy's subjective form of intersection.

It is interesting to note that the socio-historical framework, which puts such emphasis on what goes on "in the interaction" rather than just "in the mind", makes theoretically interesting a range of questions about what shape the construct has "in the mind". Theories that posit an a priori structure for, say, intersection, assume away any question about what intersection "in Tracy's head at a particular time" looks like. A Piagetian "operation", for example, is usually formulated as completely general. According to Flavell & Wohlwill (1969) as soon as a child "has" the operation with respect to one task then s/he has the operation in general. Task difficulty is considered an independent functional barrier to the operation's expression on other tasks. In this framework, claiming that intersection is "in the head" is just a step along the way; questions can be raised about what generality intersection has for Tracy and what kinds of abstractions are involved in it for him.

Children-only groups. The combinations task was also presented as a group task involving chemicals. In the group task, question of attributing internal representations to the individual participants is systematically problematic. The group activity also provides evidence for another aspect of intersection-as-an-action which is systematically unavailable in the tutorials. This aspect is goal formation. As Leont'ev notes:

> Under laboratory conditions or in a pedagogical experiment we always give the subject a "prepared goal". Therefore, the process of goal formation usually escapes the investigator's attention (p. 27).

Actions are goal directed processes; without a study of the genesis of the goal the study is incomplete. Therefore, in the tutorials where the children work with a prepared goal [illegible] analysis must be incomplete. As we saw in Chapter 1, in the children[illegible] groups, we have a situation where the process of goal formation can be studied.

We have many children-only groups where the goal was never formed, where an intersection action does not appear until the teacher comes into the scene and engages in a pedagogical exercise (cf. Gearhart & Newman, 1980). For some children-only groups, however, intersection emerged among the children. Typically, some pairs of chemicals had already been mixed and recorded when a question arose about "what to do next". Sometimes the question was focussed on whether a particular child "needed" a particular chemical (that another child wanted to keep) in order to do a pairing that should be done; sometimes it was focussed on whether there were any more pairs left that someone could work on in order to get another turn at mixing. Whether a pair should be done, and whether any more pairs could be done can be solved in specific concrete ways: are there any more test-tubes left for mixing, is anyone interested in doing any more mixing, is the child with the chemicals a "sharer"? On the other hand, intersection provides a general solution to the problem of whether or not a pair should or could be made. Some of the groups of children worked with the list of pairs on the worksheet and the row of beakers of chemicals in just the way the tutor in the adult-child situation had worked with the column of pairs of cards. Intersection emerges to reorganize the earlier actions and operations of mixing pairs of chemicals into a new intersection action directed toward the goal of finding out if a new pair could or should be done.

As Leont'ev notes "the subject(s) did not devise or establish goals voluntarily. They are given in the objective circumstances" (p 28). The circumstance here appears to be the question of what, if anything, could be mixed next. The question arises because (1) the children want to mix all they can and (2) no other possible "next pair" action comes up (i.e., the specific concrete solution is reached) or (3) the "next pair" that one or more child wants to do is blocked by scarce resources (e.g., only one beaker of a chemical) or distributed among too many people with conflicting actions (i.e., the various specific concrete solutions among the subjects are in conflict). It seems then that the intersection action comes from two sources: 1) the activity's energizing force, and 2) the limited value of the alternate actions (simply making pairs). The children seem to be acting out Leont'ev's "relatively long process of testing goals through action" (his emphasis). Making a chain of pair-making actions failed to satisfy the demands of the group activity and intersection emerged, reorganizing the system.

The children-only group data provide us then with evidence that intersection emerges with the existential status of an action. Recall that for Leont'ev, emergence of a function as an action is associated with internal representation; what we have here in the case of these children-only activities is an interpsychological activity. We seldom have clear evidence from the interaction that one child subject is organizing and appropriating the actions and operations of the others. In short, we do not know how to attribute the internal representation that the theory implicates in the emergence of action when this occurs in interpsychological activities.[17] We are not

17. The problem also arises in the analysis of the interpsychological action of the teacher and child in the tutorial at the point before the emergence of

sure at this point if the theory needs to be changed to block the implication in this case or if attribution machinery needs to be added to it.

Zone of Proximal Development

Vygotsky's notion of a "zone of proximal development" (ZOPD) has been most often discussed in the context of a psychological test of mental ability. Here Vygotsky defined the ZOPD as the difference between the level of problem difficulty that the child could engage in independently and the level that could be accomplished with adult help (Vygotsky, 1978). More generally, the concept refers to a collaborative effort in which a more capable partner works on a problem with someone else who could not work on the problem effectively alone. In our work the term, ZOPD, includes this broad notion of collaborative problem solving in which the more knowledgeable partner is interested in having the less knowledgeable partner take over as much of the work as s/he can.

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the child's independent action. But, in the tutorial situation there are some pointers toward a solution. First, the clarity of the teacher's role as the expert in the discourse is striking (c.f. Mehan, 1979; Griffin and Humphrey, 1978). Given her conversational role, it is easy for the analyst to pick out the teacher as the subject who has an internalized form for intersection. Second, the prior existential status of intersection as a subjective form for the teacher is witnessed not only by the history of activities which we have records of her engaging in but also by her involvement in the presentation of the subjective objects as a genetically primary example in the tutorial. Again, this makes it easy to claim that at least the teacher has an internal representation of intersection as it emerges as an interpsychological action. However, we have as yet no understanding of whether or not intersection should be or could be claimed to have an internal representation for the child who is being tutored before it emerges as that child's independent action.

One of the most important [illegible]s of the concept of a ZOPD is that it was developed within a theory that assumes that higher psychological functions have a social origin. The interactions that constitute a ZOPD <u>are</u> the social origins referred to; not only <u>what</u> is carried out between participants, but <u>how</u> they carry it out appears subsequently as the independent function of the novice. That is, the interaction between the expert and the novice is internalized by the novice becoming a new function of the individual.

The theory assumes that prior to any particular episode involving a novice and a more knowledgeable person (an expert) the novice's psychological functions constitute an organized system that permits the novice to form some notion of what the episode is going to be about. But this "entering" organization of functions may be widely variable with respect to how closely it maps the interactions that will organize behavior in the full realization of the activity at hand. The major requirement is that the adult find some way to include the child in the activity that s/he wants the child to master. This may be accomplished in a great variety of ways, some of which have been explored (Wertsch, in press; see L.C.H.C., 1982, for a more extended discussion).

The important point is that a great variety of systems of cognitive functioning may be appropriate entry points into a given ZOPD, such that there is no simple mapping from adult system onto child system. Furthermore, children who may be similar with respect to their entering cognitive systems may have experiences in very different ZOPD's with very different interpsychological cognitive systems, so that there is also no simple mapping between entering child system and resultant child systems.

Participation in the ZOPD does more than simply supplement the child's existing organization of functions. Rather, the ZOPD is a novel system of functions that exists on the inter-psychological plane, as a system of functions between people. As a consequence of interactions in the ZOPD, there is some probability that the child's entering organization of psychological functions will be modified. In this case, we have some relatively specific hypotheses about the form that the modification will take. We expect that the child system will come to approximate the system of interactions constructed in the ZOPD. These will be dominated by the adult (expert) system of understandings with respect to the activity at hand. If the child subsequently performs the task independently, the new system of functions displayed by the child is seen as the "next step" of the intra-psychological system attributable now to the child. Here the socio-historical school departs significantly from other developmental approaches. The child's new system of organization is seen to be continuous with the prior interpsychological system represented by interactions in the ZOPD. It is discontinuous with the system that the child displayed prior to entering the ZOPD. The relation between steps in an individual's independent development is not immediate, but rather is mediated by the social situations in which the individual participates.

Alternative frameworks, such as Piaget's, seek continuities between steps of independent development, an enterprise which has come under concerted attack in recent years. Fodor (1980) points out a problem with the Piagetian constructivist position that arises when one attempts to derive a formal mathematical model of stage development: a higher order calculus or logic can derive lower order ones but cannot be derived from them; hence, it is very difficult to see how children can progress from "lower" logical stages to "higher" logical stages unless one posits (as Fodor would) that the "higher" stage is in some way innately in place and that what looks like constructivist stage development is in fact just the gradual maturation and environmental triggering of innate mechanisms. From this vantage point, the claim is that the innate biogenetically constrained cognitive constructs account for the "highest" order logic (formal operational) and that earlier logics (sensorimotor, concrete operational) which can be derived from them appear under certain maturational and (minimal) environmental conditions. The argument appears to sound.

In the same article, Fodor develops a critique which he apparently believes similarly reduces a Vygotskian position to an innatist theory.[18] In an interesting way, Fodor's argument provides its own contradiction. He considers the typical "concept learning experiments" and claims that such work can develop information on rate of learning and influences on learning ("fixation of belief") but cannot inform the investigator about where concepts come from, leaving inquiries about "concept acquisition" to the nativist. He describes in detail the steps of such learning experiments, showing that the experimenter provides some materials and some interactions and that differences in these conditions can be studied to see what conditions promote, say, faster learning; but, Fodor says, you cannot tell where the concept comes from

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18. It is important to note that the socio-historical school, and particularly Vygotsky, are not in principle opposed to positing innate elements; work in the framework includes work on biological materialism and phylogentic inquiry. It is consistent with this framework to posit that some aspects of mind originate and are constrained biogenetically and that others originate and are constrained culturally. This is similar to a position Chomsky presented at the conference where Fodor developed his critiques [Piattelli-Palmarini, 1980].

that the subject is learning so fast or so slow. We think, reading his article, that he has just told us where the concept comes from: it comes from the experimenter. There is a social origin for the concept, just as Vygotsky assumes. Of course in the case that Fodor uses ("miv" is red and square), the society which originates it is rather odd, small and restricted (the laboratory society) and the social interactions are rather dull and limited (the experimental procedure script), but nonetheless, the social origin is clear. It is even important in some such experiments that the concept being investigated come only from this restricted little society, lest unknown variance from prior history vitiate the conclusion. (Where else could "miv" for instance, come from except from some society of experimental psychologists?)

Fodor is wrong with respect to Vygotsky's theory when he says, "What it doesn't tell you is where the hypotheses (and the concepts they deploy) come from!" (p.146) Vygotsky claims and Fodor himself describes the experimenter as origin of the experimental subject's concept. Fodor is correct, with respect to Vygotsky's theory, when he says "...it presupposes the availability of that concept" but is evidently unaware that the theory presupposes that the concept is available in the social system and that this is a reasonable alternative to Fodor's supposition that the concept must be presupposed available via innateness.

Summary and Conclusions

The socio-historical framework provides concepts from the theory of activity and from the zone of proximal development that allow investigators in the human sciences to note abstractions like "intersection" in multiple locations. As a subjective-object, intersection can be located in: 1) the activity of the teacher and the collaborating researchers; 2) in the subjective objects of the zone of proximal development; 3) in the interpsychological activity of the teacher and child subjects during the tutorial; 4) in the interpsychological actions of the teacher and child subjects during both the tutorial and the chemical activities; and 5) in the intra-psychological actions of some of the child subjects during the tutorial.

The framework further specifies that the external locations (the interpsychological, observable instances) are related to the internal locations that are difficult to observe: the relation is one of origin. Transformations during the genesis from the inter- to the intra-psychological plane can be noted as consequences in the reorganization of operations described for children like Rebecca, Nina and Tracy in the tutorials. Transformations also occur when intersection changes from activity to action or when it emerges in an activity as an action. The teacher's subjective-object, "intersection", is (in the activity as well as in his/her intrapsychological state) fairly well represented by the moves charted in Table 1; however, as s/he enters into the action of intersection with the child, "intersection" can take on a great many specific forms. It might, for example, begin as an incomplete column of pairs and, mediated by a verbally ordered sequence of pairs, end with pairs out of the preferred order in the material column. As the intersection action emerges for the children in the chemical activity, there is a similar transformation of the material display and mediation by the verbal display. [19]

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19. We have nowhere in our records any observation of intersection emerging as an operation; it is possible to imagine "counting by intersection" as one counts by 2's or 5's or 10's and as the addition gets technicalized in the rote recitation 2, 4, 6, 8, so would intersection get technicalized (be an operation) in a rote recitation 6, 10, 15, 21. Seldom, evidently, in the human activities and actions of our culture is there an embedding of intersec-

In all, the framework seems to be fruitful for those interested in empirical investigations of abstractions like intersection; it even provides us with some interesting and some unanswered theoretical questions.

Also important to us is the relation of the framework to the practical activity of education. First of all, in a framework where psychological functions are expected to have an external interpsychological origin, educational encounters are clearly important. The discontinuities that this framework claims exist in a child's development imply that variation in the educational activities among children will result in variations, and perhaps in inequities, among the children's eventual states of psychological functioning. Secondly, the framework suggests that a value-laden view of educational activity can be developed without depending on the problematic vehicle of post-test outcome measures. Rather than having to rely on whether the child can transfer the object of an educational activity to a testing situation, the framework suggests that we can examine the activity system directly. An evaluator can locate the object on the interpsychological plane and see if an (inter) subjective form of the object of education appears. If it does not, there has been no education. The child either already knew it, and performs intra-psychologically, or he still hasn't encountered it as an (inter) subjective object. Furthermore, an evaluator can locate the teacher's use of the children's "first attempts" and assess the success of his/her ability to (a) elicit first attempts in an activity and (b) appropriate these actions, operations, [illegible] products of the children for the activity which the culture has dete[illegible] [illegible]hildren should participate in i.e., the curriculum topic that [illegible]

tion [illegible] [illegible]er action such that it would undergo this kind of transformation [illegible] operation.

is the object of the educational activity. Preferable educational actions for teachers could hence be located and used in teacher training and curriculum development.

Thirdly, the framework has a specific recommendation for curriculum: the problem of what cannot be seen when subjects are always in situations where they deal with "prepared goals" is not only a problem for experimenters. The question of whether skills learned in schools will be used in the outside world is the question that educators regularly deal with. A criterion for a topic being in a curriculum should be that it somehow is embedded in life after school; yet if the curriculum sequence does not specifically provide for activities where these embeddings can be discovered by the children, and practiced, and perhaps assessed, then how can it claim to be a preparation for life outside of school? Designing these kinds of activities, where children come upon the object of education is a difficult task. As we mentioned above, our chemical mixing task failed to "work" with several of the groups of children and intersection did not emerge.

While we want to leave the impression that we think it is important to be able to identify and undertake true educational activity, we do not want to leave the impression that we think we always accomplished it, or that we can do so with our current knowledge. In fact, in spite of elaborate preparation and background work and unusually rich resources for the tutor and curriculum planner, we can point to failures with particular children. When it came to appropriating some children's actions and products into an interpsychological intersection action, she failed to produce, on line, an abstraction that could apply to the specific configuration that the child's behaviors and products created. After the fact, we can notice that the child was using (say) an unusual order in moving across the array; he appeared to be moving from right to left for both the anchor and the variable choices. After the fact we can also notice that the particular form of the materials contributed to the problem. We had pictures of movie stars on our little cards, one movie star for each of the different stacks, i.e. for each color. The children and the tutor were encouraged to use the star's name to refer to the cards. Unfortunately, for Ricardo two of the stars he was working with had names which he pronounced in a way that made it difficult for the tutor to discriminate between them when they were used out of context. His pronunciation was not abnormal for a native Spanish speaker producing a proper noun. When Ricardo said Sean, the tutor interpreted it as John on some occasions and on others as Sean. The same with John. We have pointed out the importance of the verbal ordering of the pairs in the inter-psychological action--the ordering does not appear neatly in the material column of pairs. Neither Ricardo nor the tutor could comfortably produce intersection as an (inter) subjective object under these conditions. Sadly, what appears to be the beginning of the emergence of "intersection" as an independent action for some of the children gets submerged in the difficulty of the interpyschological operations and never appears again in the tutorial.

Educational activity is not a unidirectional process for the child, for the teacher or for the teacher-child interaction. In the Chapters that follow, we take up some of the difficulties and opportunities afforded by learning in interaction.

CHAPTER 3:

MISAPPROPRIATING COGNITIVE PROCESSES

The work we will describe in this chapter is part of a general effort by members of the Laboratory of Comparative Human Cognition to develop an overall theory of the way in which the cultural organization of experience influences cognitive behavior. In this particular study, we are interested in how different ways of structuring classroom events influence the cognitive activities and learning achievement of different children.

From the point of view of the practicing teacher, the phenomenon we see as basic to our inquiry is the frequent intuition that a child knows more, is more capable, than she/he shows in a given evaluative context. In an example in our videotapes of the activities of third and fourth graders, there is a child who seems to know a great deal about the social organization of Native Americans. He volunteers relevant information, answers questions effortlessly. He "knows it all." But when a seemingly trivial task requiring that the child fill in an incomplete chart containing the information he has just discussed is presented, the child fails effortlessly to demonstrate what "we know he knows." There is no scientific apparatus to account for such observations. It is to provide such an apparatus in a sufficiently explicit and detailed form that it can be applied to a variety of issues that grow from this familiar observation that we have undertaken our current research.

The practicing teacher's dilemma is a version of a problem that faces research in a variety of areas. The most general statement of the issue is: How does performance on one occasion relate to performance on another occasion?

<u>Another location of the problem</u>

[illegible] general issues can be seen in studies considering the cognitive consequences of education, including investigations we have undertaken with colleagues in the Yucatan (Cole, Gay, Glick and Sharp, 1971) and in Liberia (Cole, Sharp and Lave, 1976). By and large, and as long as we stay with evidence from commonly used tests of cognitive behavior, the findings are that schooling has produced a very significant transformation in the way people think.

There are good reasons, however, to be suspect of the face value of this evidence. On logical grounds alone, we might be concerned that all we have done is to show that special practice produces specialized learning. That is, the commonly used tests of cognitive behavior have a special relationship to what people do during their schooling; thus, conclusions drawn on the basis of such tests are problematic. The issue can be posed best by stepping outside of the school to consider a test for the consequences of career training. Cole, Sharp and Lave (1976) provide the following example and discussion:

> Suppose, for example, that we wanted to assess the consequences of learning to be a carpenter. Sawing and hammering are instances of sensorimotor coordinations. Learning to measure, to mitre corners, and to build vertical walls requires mastery of a host of intellectual skills which must be coordinated with each other and with sensorimotor skills to produce a useful product (we are sensitive to this example owing to our own lack of success as carpenters!) To be sure, we would be willing to certify a master carpenter as someone

who had mastered carpentering skills, but how strong would be our claim for the generality of this outcome? Would we want to predict that the measurement and motor skills learned by the carpenter make him a skilled electrician or a ballet dancer, let alone a person with 'more highly developed' sensorimotor and measurement skills?

Lest it be thought that the example is too absurd to merit juxtaposition with the outcome of schooling, consider psychological experiments in light of the contexts from which their procedures have been derived and the domains in which they are routinely applied.

Some version of virtually every experimental task reported in this monograph can be found in Alfred Binet's early work on the development of behavior samples which would predict children's success in school. The inspiration for their content came from an examination of the school curriculum, combined with Binet's sage guesses about the fundamental principles that underlie success in mastering that curriculum. The correlation between successful performance on Binet's tasks and success in school was a tautology; the items were picked because they discriminated between children at various levels of academic achievement. Might we not be witnessing the converse of that process when we observe people with educational experience excelling in experimental tasks whose form and content are like those they have learned to master in school? Is there any difference in principle between their excellence in recalling word lists, and the master carpenter's ability to drive in nails quickly? After all, practice makes perfect; if we test people on problems for which they have lots of practice, why should we be surprised when they demonstrate their competence? Conversely, what leads us to conclude that they will be equivalently good at solving problems for which they have no specific practice?

This work reveals as a problem the close tie between the strategies available for psychological studies and the tasks embedded in educational curricula. It also makes clear the need for developing new strategies in order to investigate psychologically interesting phenomena related to education. Specifically, we need to be able to locate and study behavior in tasks other than those found in standard experimental studies in order to understand whether the performance difference noted in studies of the cognitive consequences of education is anything other than a function of the school populations' prior exposure to test tasks in school.

In order to understand on a more basic level how performance in culturally organized educational settings is related to an individual's cognitive behavior in other settings, or in general, we also need strategies to determine 1) how schools do the reorganization of thinking that they seem to do, 2) how the competencies promoted by schools are related to the competencies demanded by other parts of life, and 3) whether students transfer learning from the school to the non-school setting.

All of these questions presuppose for their answer knowledge of how school- and non-school-like tasks come about, inside and outside of schools. However, none of the methodological pre-requisites exist currently in the social sciences, from which it follows that we are not in a position to make professional statements about the effects of education on human thinking, let alone the impact of different kinds of schooling on different children.

In an effort to discover how to answer questions raised by our cross-cultural work, we began a series of investigations of U.S. children. In an initial study, we looked at a group of children in a range of activities: formal tests, various kinds of school activities, and after school clubs (Cole, Hood, and McDermott, 1978). How and why our current study differs from this first attempt is basically the story of this paper.

That first time we looked for several cognitive activities that we believed would occur in the everyday world as well as in school: remembering, noticing similarities, reasoning and so on. In the tests, we found these cognitive activities to be dense and visible; in the classroom, we found them to be scattered but more or less visible; but the club was different: Except on rare occasions it was very difficult to identify any of the cognitive tasks that we had posed for the children in their testing situations and seen during our observations of the classroom. Somehow, cakes were getting baked, plants grown, rat mazes constructed, and electric circuits lit without anyone doing anything that a cognitive psychologist could recognize as thinking. On the rare occasions when we thought that a cognitive task-like problem had occurred, we found it virtually impossible to specify how a particular child had responded.

Perhaps our difficulties should not have come as a surprise to us, but in terms of our goal of building a technology whereby cognitive tasks could be discovered and their sequalia studied in non-classroom and non-test situations, we were (and remain) in deep difficulty.

Crudely speaking, our data indicated to us that the source of the difficulty resides in the social constraints operating on people during the conduct of a problem. The psychologist's task (classifying, paired associate learning, logical reasoning) is not a physical object in the world. It is, rather, a set of activities (perhaps involving physical objects) the goal of which is specified by the psychologist along with a set of constraints that must be honored in meeting that goal. One of our difficulties when moving from club to school to test was that the larger social context within which "the same task" was embedded placed very different constraints on the individuals participating in the scene. As a consequence, the individuals were more or less free to change the conditions of the task, even to the point of making it go away, depending upon what social context it occurred in.

A second problem concerned the specification of goals. Even casual analysis of a single testing situation quickly reveals that an enormous amount of "social work" goes into maintaining the psychologist's task as a focus of attention. Subjects often are as anxious to demonstrate their friendliness or intelligence, or simply to get-it-all-over-as-quickly-as-possible, as they are to "think hard." Test situations are designed to minimize the impact of these alternative goals, of course, and large groups of subjects are usually run on quantifiable tasks so that "valid" inferences regarding thinking can be achieved.[20] What is crucial to point out is that in non-test settings including the school and the club, the multiple goals that occupy an individual at any single point in time are very difficult to ignore because the settings are rarely constrained to the extent that they keep people from working to achieve several goals at the same time. That means that we have some difficult problems of "task analysis" to deal with in order to specify real task similarity across contexts. And without task similarity we cannot get far with an investigation of how performances on different occasions are related.

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20. We don't wish to question the validity of this approach (See Cole, Hood and McDermott, 1978 for an extended discussion). Of course it is possible to claim, often with great justification, that the psychologist has been unsuccessful in creating a properly constrained model task environment and that the subjects are not simply trying to achieve the goal specified for them. Elsewhere we have developed the implications of this critique (Cole, Hood and McDermott, 1978) for experimental psychology. Here we want to point out that even with maximal constraints erected to permit flawless inference about "intent" the flaws remain.

Assistance from Psychological Research

A useful starting point for thinking about making different cognitive tasks occur in a range of different contexts is to consider the procedures that psychologists use to maximize the probability that the same task will re-occur in the same context. The key idea goes under the label of standardization. Materials are pretested so that the subjects can plausibly be said to be working at a uniform level of difficulty; instructions are given in a standardized manner restrictions specifying what the subject may not do are emphasized; the time taken to deal with any part of the materials is fixed; scoring procedures are rigidly adhered to so that only "relevant" parts of the subject protocol are included.

Even under these circumstances, all psychologists recognize that the same task is never repeated in all of its details. Instructions are sometimes garbled; subjects ask questions for which no standard answer exists; a subject with a cold keeps taking time out to blow his nose. To accommodate this recognized variability, the psychologist works with a model of "the same task" that permits him/her to proceed with the work. The model assumes that the variability in what happens from one experimental/test session to another is randomly distributed with respect to the essentials of the task. This assumption is built directly into the statistical tests that are used to evaluate psychological tests; these statistical tests include the assumption of random error by making each subject's score consist of two components-- the true score and an error term. Discussions of test reliability looked at in this way reduce to tests of the size of the random error component relative to the true effect. It is also important to note that this model of standardization relies on testing relatively large numbers of subjects so that the real effects can be distinguished from error.

This model is not without its critics. Although the argument is made in a variety of ways, the basic point boils down to the contention that the error term in the standard model is not random. For example, Cicourel and his students (Cicourel et al, 1974; Mehan, 1973) show that experimenter/testers systematically provide information for some subjects that they do not provide for others, thereby inadvertently changing the difficulty of the task. When this observation is combined with the work of Labov, who makes a convincing argument that some subjects view their task in some standardized tests as that of self defense against an antagonistic adult (Labov, 1970) or a variety of demonstrations that the contents of tests are subtly non-equivalent for different subject populations (see Houts, 1977 for a summary of such criticisms), one comes to appreciate that the sense in which many psychological experiments and tests represent instances of making the same task happen over and over again is a very technical sense indeed.

It is also essential to consider and to make explicit the basic procedures by which cognitive psychologists make plausible their claims that a particular task has occurred in the first place. Cognitive tasks don't just happen, they are made to happen. Speaking schematically, the psychologist creates an environment for action and observes the actions that follow as they relate to the hypothetical structure of the environment-as-constructed. Psychological tasks constructed in this way are virtually never one shot affairs. Rather, the psychologist does a good deal of "pilot" work. This is the part of the study where the experimenter's intuitions about the task that he has constructed are tried out. The psychologist looks to see if the environment-as-constructed seems to be the environment-as-responded to. It is crucial that the subjects be responding to the stimuli (including the instructions) in the manner prescribed and that the subject not engage in behaviors that are considered to fall outside the limits of the task. In effect, the psychologist creates a model system and studies behavior within it. The goal of theorizing is to account for as many details of the subject's behavior within the model environment as possible. In this approach, the psychologist's theory is simultaneously a theory of what the task is, what the relevant behaviors are, and the relation between elements of the tasks and elements of behavior. As a general rule, the psychologist's theory of the task- behavior interaction he has set up will prove faulty in one or more of its details. This leads to the construction of a new task environment that differs in some principled way from the first, but is similar to it in many respects. The new task presents the subject with somewhat modified conditions for action and again the psychologist sees how well his theory can account for the pattern of behavior-environment relations that results. Excellent accounts of this research process are to be found in Estes (1975-79).

Two major characteristics of cognitive psychological research can be abstracted from the foregoing discussion. First, cognitive tasks are constructed, not discovered. Their construction involves the design of a functional system (Luria, 1979) which provides for the structure of micro-environments. Within this system, subjects are constrained in a variety of explicit and implicit ways. These constraints are essential to the analysis because only when they are met to a reasonable degree can we think it plausible to conclude that we have identified the task that the subject is engaged in. Second, the procedures for constructing a task also yield a set of rules about what counts as relevant behavior for analysis. In effect, the psychologist has constructed a coding scheme for behavior. It includes many subcategories of relevant behaviors and a catchall category called error.

In order to tie classroom observations to laboratory-generated cognitive psychology in anything other than a casual way, we must find ways of specifying tasks and establish the relevant behaviors in a manner that can yield the same kinds of statements about task-behavior interactions. In so far as we fail in this enterprise, we are subject to virtually unlimited uncertainty about the validity of our claims concerning such matters as cognition, transfer, and learning.

Our current work with third and fourth grade children grew out of the earlier observations of children in tests, classrooms and clubs. But now our collection of data is designed so that we can construct something like the psychologists' model systems within which we can study the children's behaviors in interaction with various environments. What we have done is introduce a "tracer" element, in the form of a topic or a problem, that confronts the children in lessons, and in peer work situations, and in tutorials, and in clubs. The topic or problem can serve as a trace of the task being searched for, as it appears in different guises, under different constraints, in different settings, and as it evokes different behaviors from varying participants. We can locate recurring situations where a goal can be isolated (that is, we can identify it via its relation to the tracer) and the interactions of that goal with other co-occurring goals can be studied. By having a tracer element, we have a clearer chance to see what is varying; we can see how the researcher/teacher/club leader's plans concerning the task are transformed to create the task or tasks that the participants perform. Some of the problems revealed by our earlier attempt to look at children seem to be resolvable using this technique.

Assistance from Educational Research

If our tracers work, then we will have engineered the appearance of the "same" behavior (or at least "same in some respects") in a variety of differently organized events. But what we will need, in order to see if we have been successful, is something corresponding to the other aspect of the cognitive psychologist's work: that is, we need a way to identify what is to be counted as relevant for analyses of how performance on one occasion (in one setting / by one person) is related to performance on another occasion. The construction of the highly constrained task settings produce, in effect, a coding system for the psychologist; we need the same effect in order to analyze the behaviors in our less constrained and more varied task settings. In educational research, there is a history of concern with this issue. The process-product paradigm in educational research has developed as a way to investigate how the conduct of teaching sessions (i.e. the processes involved in education) are related to what the students end up knowing (i.e. the products of education).

Some problems in the process-product paradigm have been discussed in detail elsewhere (Koehler, 1979; Soar and Soar, 1976; Fenstermacher, 1978; Borich et al., 1978). Several inter-related problems arise in connection with the product measure, the test. First are the difficulties of the sort we have already referred to: The non-random errors that can be argued to occur in psychological experiments can also be found in tests; the close relationship of tests and school tasks leave us with the problems we encounter in our work on the cognitive consequences of education.

Another problem, central to our general line of work, is that the reliance on product measures often includes an implication that what is measured (cognitive level, academic skill) is an entity apart from its use. An analogy is in order: a tape measure can be used to determine whether two pieces of wire are of equal length. Say that one piece of wire is hair thin tungsten, the other is coiled nichrome. While there is a standard somewhere, a theory of tape measures and of the materials tape measures are made of, that will tell us that the measure is adequate or to what degree it might vary over occasions of use, this theory may not be sufficient for all purposes. In fact one must decide what length means for tungsten and for nichrome (how much stretching or uncoiling is valid) in order to use the measure at all and one must decide this in relation to the use to which the lengths of wire will be put. Length, like cognitive development or academic skills, is as much the product of an occasion of use of a measure as it is of the measurement's measuring theory; and length, like cognitive development or academic skill is related to the use to which it is put outside of the measuring environment. A product measure used in educational research may in fact vary with respect to how generalizable it is to other contexts where the skills measured might be used and may also vary related to differences among the children. For some children it may elicit the highest performance they have ever had available to them, for others it may elicit the lowest.

A final problem with the process-product research, from our point of view, is that the paradigm assumes that the children's cognitive or academic skills cannot be measured _in situ_; but this assumption flies in the face of what the classroom teacher does everyday. (Cf. Mehan, 1979; Cazden, 1977; Griffin and Humphrey, 1978). In effect, process-product studies write off the chance to answer teachers' need to know how to work with the evaluation aspects of daily instructional encounters: to what degree and how can you find out where a child is (and gets to be) during the day or a unit; what kinds of inferences about children's capabilities in what situations are warranted and what kinds of situational variation in displays of competence is one likely to encounter?

In spite of these uncertainties, our research has much to gain from an examination of work carried out in the process-product paradigm. The strengths of the paradigm include: (1) reliance on observable behavior in naturalistic settings as data, i.e., non-test tasks are considered (2) treatment of at least some of the environmental variations (e.g., teacher behaviors, time on task) related to children's behaviors; and (3) an interest in differentially evaluating performances by various children and/or from various settings. A great many different kinds of process measures have been developed that reflect these strengths. Process measures characterize what goes on in educational settings, often by categorizing the kinds of questions teachers ask and the kinds of responses children provide.[21]

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21. Elsewhere (D'Andrade, 1974; Borich et al.,1978; Griffin and Mehan, 1979) there are extensive discussions of the problems that arise in many coding systems, of these types.

Views of a Scene

We are interested in seeing how much further we can stretch the coding systems that serve as process measures, to see if they can meet our needs. With our "tracers" we have a chance to locate tasks (and "same" tasks in differently organized settings) Our question is whether existing coding systems can help us locate differences in the achievement of children, and among children, and perhaps differences in the tasks the children encounter as the tasks that we present to the children are operated on by the varying contextual constraints. In short, we want to know if existing measures can (or can be adapted to) show when children appear to be more and less smart as well as when their work appears to be easier, when harder.

We have chosen two coding systems to illustrate the kinds of variations that can be noted and the kinds of problems encountered when the systems are used. Stallings' system developed for the Follow Through evaluation project is the first example (Stallings, 1973); the second is Blank's system which has been both for studies of children and studies of lesson appropriateness (Blank et al., 1978). Both systems have been applied to one of our lessons from a unit, the topic of which was cultural variations among six groups of Native Americans. The lesson we chose is a good candidate for this purpose because of the variations noticeable. It was conducted as a small group lesson with a teacher and five children. Within the lesson, the participants make overt mention of how much some of the children know, and they also notice negatively the performance of another child. Furthermore, the lesson has clear cut phases or episodes that serve as mini-contexts in which the "same" task can reoccur. We coded ten phases: Phase 1 --getting organized; Phase 2 --

reviewing the unit without visual aids; Phase 3 --reviewing by reading from a filled in chart; Phase 4 --reviewing characteristics of bands and tribes covered in detail the day before; Phase 5 --reviewing the concept of states, covered a week ago; Phase 6 --getting organized for role play regarding the characteristics of states; (Phase 6A --the role playing which we omit from consideration here); Phase 7 --drawing conclusions about the characteristics of states; Phase 8 --review by filling in a partially empty chart; Phase 9 --discussion of various forms of social organization that occur in the children's daily lives; Phase 10 --minimally supervised short matching item test. We will concentrate on what the two coding systems can reveal about two of the child participants in this lesson, Chuck and Angelica.

Stallings' Five Minute Observation system (Stallings, 1977) while clearly descended from Flanders' scale (Flanders, 1970) differs from it by taking individual children as the unit of analysis rather than the whole class. Each turn in the lesson discourse is coded separately. Speakers and addressees are coded for every utterance in Who and To Whom categories; a How category, capturing basically emotive aspects, is optionally coded and proved difficult for us to apply consistently to our video-taped data. Most important for our purposes are the What categories that classify each turn according to the kind of task that is involved. There are thirteen classifications altogether; three levels of questions are included.

> Code 1 asks for a response free of argument or speculation. There is one expected, acceptable response that is to be carried out, verbally or non-verbally...[e.g.] "Draw a line"
>
> Code 10 questions elicit the following responses: statements of preference, statements of fact, itemizing, classifying and definitions...[e.g.] "If you had two pears and three apples, what would you have five of?"

> Code 2 questions encourage responses that require: interpreting ideas, cause and effect establishing relationships, making comparisons, reasoning, applying previously learned materials to a new situation and describing a process...[e.g.] "Tell me how an electric train works" (Stallings,1977:269)

The other What codes include differentiations among responses, non-responses, informative statements and evaluative statements. We adapted Stallings system by creating an additional code to distinguish among correct, incorrect and irrelevant turns. We also added a dimension to the cumulative scoring system so that we could notice variations occurring among the lesson's ten phases.

The coding provides pictures of Chuck and Angelica, the two children that we are focusing on, that are best described in terms of their similarities and differences. Stallings' code without our adaptation shows striking similarities between the children: neither asks open-ended questions or fails to respond; they respond about the same number of times; the teacher asks each of the children about the same number of questions, and only one of her questions addressed to each child is a higher level question (category 2). Most of the responses given by both children are to questions that are not specifically addressed to them. Angelica makes more requests and issues more evaluations than Chuck. The teacher accepts and praises Chuck 10 times, while only accepting and praising Angelica 5 times. By using our adaptations, we can display an interesting difference: Chuck is correct for 70% of his 34 responses, Angelica is correct for only 46% of her 37 responses.

By looking at the ten different phases in the lesson, we can see that Chuck gives more of his correct answers during the discussion, Phase 9, than anywhere else; Angelica gives as many to her peers in the mini-test as she gives to the teacher in the discussion. During Phase 7, drawing conclusions, both children give five correct responses, but Angelica also gives five other responses to Chuck's one. In general, the modifications seem to work and Stallings' coding system seems to capture some of the situational variation as well as making a differentiation between a more competent Chuck and a less competent Angelica.

There is one clear problem, in principle, related to the use of a system like this that is peculiar to the nature of turn taking in a small group situation. As it happened, only one higher level "open question" was specifically addressed to each child. This should not be understood to mean that there was only one response by each child to a "higher" level question. In fact the preponderance of the teacher's questions in the lesson were Code 2. Notice further that one of the ways that small groups differ from large group lessons is in the potential for questions being on the floor without the answer-turn having been allocated by the teacher to a particular child. (Cf. Griffin and Humphrey, 1978; Mehan, 1979 for discussions of the strict turn allocation procedures that work in keeping large group lessons together.) In dyads, the addressee is specified automatically. But in small groups, the turn-allocation machinery is not called upon as regularly as it is in large groups and there is no automatic indication of who should answer questions as there is in tutorial dyads. On many occasions in small groups, children can self-select to answer. However, in a system like Stallings, the only way to derive that a child has answered a question of a particular type or at a particular level is to locate the child's name in the <u>To Whom</u> category for questions of that type. Hence, when questions are addressed to members of the group at large, and Chuck or Angelica answer, we have no way of noticing the level of the question they are responding to. The nature of small group communication processes and the nature of this kind of coding system make systematically unavailable for analysis a reliable assessment of how hard the questions were that the children were answering or failing to answer. Although the system is handy for on the spot coding, there is no adaptation that we can imagine that would overcome this difficulty in using the Stallings' system for our purposes.

Blank's system, specifically concerned with the issue of how "hard" or "easy" the demands on the child are, can be expected to avoid such a problem (Blank, 1977; Blank et al., 1978). The system, designed for use with pre-school children's language, codes the speaker on two levels: one is the social role, e.g., Teacher vs Child; the other is the conversational role, e.g., initiator of an exchange vs responder. Initiator's utterances are also coded on two levels: First, a determination is made about whether the utterance puts an explicit demand on the responder to respond; if so, it is an Oblige, if not it is a Comment. Second, each Oblige and Comment is coded for a level ranging from (in the order given) less to more abstract, viz: Matching Perception (Level 1); Selective Analysis of Perception (Level 2); Reordering Perception (Level 3), and Reasoning about Perception (Level 4). (See Blank et al., 1978:8-21). Blank describes an underlying model of cognition and language that assumes that acquiring language is a matter of mapping from one representational system (the child's conceptual notions) into the language system. Thus, an account is provided for the ordering of the levels which "reflect increasing distance between the perceptual style with which the children view the world and the language that they apply to these perceptions." (Blank et al., 1978:15) An additional hierarchy (from Fully Adequate to No Response) is provided for coding the utterances of the Responder.

Our adaptations for using the system with older children followed from suggestions made by Blank. She speculated that no interesting differentiations would be shown between tasks at Level 1 and those at Level 2 for older children, and that the interesting differences would be between Level 3 and Level 4 tasks. We therefore decided to adapt the Level 1 and Level 2 codes to capture particular aspects of our videotaped lessons that seemed to require special treatment. Our first adaptation was to code as Level 1 any utterances to which an adequate response could be made based on what was available in writing or pictures at the time of the expected response, regardless of what level the utterance could have been assigned on other grounds. We suspected that the presence of these kinds of environmental supports in a third/fourth grade classroom should lower the difficulty level of the task. This tactic is reasonable given the matching aspect of our special Level 1's, and the matching aspect of Blank's original Level 1 code. Our second adaptation was to distinguish as a special category those utterances that are related to the elements of the domain that had been drilled in the lesson just prior to the lesson being coded. Such utterances were coded at Level 2. Again, this adjustment seems defensible: these special 2's set up a demand for the selective analysis of the previously drilled materials analogous to the original level 2's. Our third adaptation was a direct recommendation by Blank, the establishment of an Adequate plus category for exceptionally good, relevantly elaborated responses.

This coding system shows few similarities between Chuck and Angelica; the differences between the children are most striking. The teacher asks Chuck more questions than he asks Angelica: 86% of Chuck's codable units are questions from the teacher (22) while only 34% of Angelica's are questions from the teacher (15). Only 9% of Chuck's units are repetitions, while 28% of Angelica's are. Chuck's repetition in answer to a question occurs at level 4; Angelica repeats in responses at levels 1, 2 and 3. The only indication of Angelica being higher than Chuck is that she issues two level 4 comments while he issues none. In general, the picture of Angelica is one of a child less advanced than Chuck and the fact that she performs adequately in response to only 47% of the obliges she engages in deepens the contrasts with Chuck who is adequate 87% of the time.

However, there is an even more interesting contrast. Chuck's adequacy decreases gradually as he is asked higher level questions (from 100% at level 1 to 89% to 80% to 50% at level 4). Chuck is a model child for Blank's notion of levels. Angelica, on the other hand is almost directly opposite: at level 1, she gets only 33% correct, she climbs to 50% at level 2, to 43% at level 3 and is correct the one time she is asked a level 4 question. Angelica seems to behave contrary to Blank's expectations.

An examination of how this coding system operates in the different mini-contexts related to the phases of the lesson as described above shows an interesting relationship between Blank's level of difficulty and the phases in this lesson. Twice the phases progress in level of difficulty in a way that fits Blank's notion of the progression that should take place in lessons: The teacher asks only level 1 obliges in Phase III, only level 2 obliges in Phase IV and only level 3 obliges in Phase V. A similar progression occurs after the getting organized phase: Phase VIII has only level 2 obliges and Phase IX starts with level 3 and goes on to level 4 obliges. It seems that Blank's notion of levels redundantly specifies the phases of this lesson.

Overall, Blank's system seems to be an interesting base for our work and amenable to adaptations related to the "mini-contexts" of a lesson and to the specifics of the lesson topic. However, the problem with Angelica points to a major concern. Children like Chuck "fit" the assumptions underlying the work. Children like Angelica do not "fit" the assumptions. One of the phases, Phase 7, is also odd -- it is not a part of the lesson's progressions in difficulty; in fact, it does not have a consistent level of difficulty like the other phases do. The system could allow us to draw a conclusion that the differences are quantitative (less developed child, inadequate teaching) rather than qualitative (Angelica and Phase 7 have a different, perhaps more complicated, relationship to level of difficulty and demonstration of strengths and weaknesses than the relationship that other people and/or situations have). The way that Angelica and Phase 7 diverge from the norm of Blank's system are related to the way they are inadequately accounted for in the theories (folk and formal) of education, cognition and discourse, that interact with the system in various ways. Angelica is from a Spanish speaking background and has been using English for only a few years. Phase 7 calls for some mixture of what might be called convergent and divergent thinking. The demands on theories to respond to these kinds of variations have not been met adequately by theories available to Blank, or to us -- which brings us full circle to the general work of our group.

Problems Remain

There are two general problems with coding systems for educational talk and tasks that bear an interesting relationship to the problems that we encountered in our earlier attempt to locate cognitive tasks in the clubs. The first we shall call the point of control problem.

Most coding systems assume that there is a point of control standardly locatable and that the category to which the control utterance is assigned affects the categorization or understanding of utterances which it controls. For example, most coding systems derive the cognitive level category of a child's response from the cognitive level category of the adult's question. We know enough about teachers' differential expectations of children and about the chance of these being evident in teachers' questioning behaviors (Cherry-Wilkinson, 1978) to suspect that using the teacher's question as a way to describe the cognitive level of the child respondent will systematically distort the data. Some children will be pictured with inflated levels and others will be underestimated. We may have a better picture of the teacher's expectations than of the children's capabilities. While we do not dispute that the teacher and teacher questions have a lot to do with constraining the tasks that children perform in classrooms, (and that the academic or cognitive tasks that are our primary concern are very heavily influenced by the teacher), we must not ignore the facts that <u>more</u> than teacher questions can be involved in specifying the tasks the children undertake and that teacher questions do other things beside specifying tasks.

We are here in the opposite corner from the one our earlier look at children in varied settings had painted us into. There we were concerned because the multiple goals in the settings made it too hard to see the kinds of cognitive tasks that could be seen in the engineered system of the experimental setting. We moved to a solution of that problem by specifying tracer elements that would let us highlight certain goals in our settings. Now, if we use coding systems that award control of our understanding of the child's performance to some preceding question, we will find ourselves assuming away the issue of multiple goals and how they interact. We have planted tasks so that the children's behaviors that we capture on video tape will be a little bit more comparable with the experimental subject's behaviors; the tasks are cultivated in the richly varied real world of the children; we cannot afford to have an analytic tool that works by looking for seeds.

The second general problem with many coding systems is related to the sequential nature of discourse. The best illustration of it is commonly available by noticing one of the best indicators of an easy task: children raising their hands, shouting for a turn. In many lessons, including many of ours, there is a point close to an end boundary where everyone wants a turn. The same question is a different question by virtue of its placement in the sequential development of the lesson. In one instance, like in the chart used in the lesson described above, there may be six slots to be filled and six fillers to use and so, of course, when five have been covered, the sixth is quite easy. One need only attend to what hasn't been said. In other circumstances, answering late may face the child with a more difficult task because all of the "easy" answers are used up. What has been said can make subsequent questions easier or harder or perhaps even different than earlier questions. Testers and teachers and peers all use the sequential nature of discourse events to be co-constructors of an answer with the person who appears to be the primary performer. This point of view is adequately argued and demonstrated in the work of classroom discourse analysts. But, in commonly used coding systems, an utterance is categorized uniformly whenever it occurs; changes in the constraints on it occasioned by the situation in which it is embedded are disregarded.

Once again, we return to the problems we found in our earlier attempt to locate cognitive tasks: the constraints on behavior differed so radically from situation to situation that we found it difficult to locate tasks. If the coding system we use in analysis assumes away the constraints imposed by the sequential nature of the discourse, then it may make it easier to locate tasks; but we have little faith that the tasks so located will be the tasks the participants were engaged in. We cannot afford to base our analysis on "same" tasks that are the same primarily by fiat of a coding system that ignores the influence of constraints operating on those tasks.

We have no easy solution to the problems we have been pointing out. We are pretty confident that there is no way to do on-line coding of this kind of interaction that can capture the complexities we have pointed to. We are currently trying to figure out how much specification is possible using our video taped records, and our in depth (via our planned tracers) understanding of some parts of the situations that we tape. The research in psychology and education upon which we are drawing is impressive. As with the child we mentioned in the beginning, we are struck by how much is known; but, as with the child, there are occasions when this knowledge fails to be displayed. Our tack is not unlike the practicing teacher's: we try to understand what underlies the success of this research, and what occasions the problems, and we do it over and over in the hope that we will finally get it right.

Another Level of Analysis

In the light of the critique developed above, it is apparent that analyses of classroom interactional data have severe limitations. On the substantive side, it appears difficult to make claims about children who differ from the mainstream. On the methodological side, it appears difficult to integrate information based on talk exchanges with information important to psychology and pedagogy. However, as we consider broader units of analysis, the picture changes in both respects. In this section, we will describe a change that occurred in the course of the unit and an aspect of teacher-child exchanges in lessons that appears to be implicated in the change.

After the first lesson of the unit we had an amazing outcome: the group of children who represented the lower achieving part of the class scored better on a test than the children who represented the higher achievers. By the end of the unit, everyone was doing better than they had done initially. However, by the end of the unit we had succeeded in recapitulating the achievement order: the higher achievers were once again scoring better than the lower group children. In the course of three weeks, almost daily lessons lasting about half and hour, we had a little microcosm of failure. In a sense, our unit was even worse than the real world: The children whom education failed to help had started out not merely equal, but ahead of, the children who were school successes. Even so, the group labeled high achievers regained their more successful position by the end of the unit. Like the real world, there was a disproportionate representation of children in the low group who could be identified as different from the mainstream in terms of language and culture.

Our analysis of this educational/instructional microcosm is simple:

(1) The low group children had to do an extra piece of intellectual work in the course of the lessons.
(2) The "extra" work involved exchanging one conceptual organization of the domain for another.
(3) On the nominal task (the "basic" work), the low group children were impeded by a very general and pervasive feature of classroom talk exchanges.

The nominal task of the unit was to master the following set of facts:

> The Diegueno people got their food by hunting and gathering; they governed themselves in bands and they moved their small families around.
>
> The Shoshoni people got their food by hunting and gathering; they governed themselves in bands and they moved their large multi-generational families around.
>
> The Tewa people got their food by farming; they governed themselves as tribes and they had permanent homes for their large families.
>
> The Navaho people got their food by trade; they governed themselves as a tribe and they moved their large families around.
>
> The Natchez people got their food by farming; they governed themselves as a state and they had permanent homes for their large families.
>
> The Aztec people got their food by trade and they governed themselves as a state and they had permanent homes for their small families.

Multiple formats represented the facts in the course of the unit: narratives with visual aids, same-different exercises, problem-solving, role play, question-answer sequences, workbooks. In each lesson, a chart representing all the facts was used for review. After each lesson, the children took a test: They matched the the ten blanks in a different chart with a list of possible answers.

The Beginning of Instruction. In the first lesson, the teacher told stories about the groups of people using line drawings (e.g. Figure 2) as the visual aids. After telling stories about food gathering among the Diegueno, the Shoshoni and the Tewa, the teacher asked the children to look at all three pictures and to find two that were the same and one that was different. The teacher focused the discussion on the two ways of getting food: hunting and gathering in two of the pictures in contrast to the farming done by the Tewa. Each group of people and each lexical term was presented in the same way. Following the eighteen narratives, pictures and discussions, the teacher filled in the answers on the review pocket chart (Figure 3). Then the children took the first test (Figure 4).

The average number of correct answers for the children identified as low achievers was higher than for the high group. Furthermore, no child in the low group scored lower than the highest scoring child in the high group. We had achieved a crossover effect.

However, an examination of the test papers revealed an interesting difference between the groups that was not represented in the quantity of correct answers. The incorrect answers are the key. High group children answered incorrectly but their answers were in the correct category. If the correct answer was "tribe", their wrong answers were "state" or "band." In startling contrast, the low group children showed no constraints from the category on their incorrect answers. If the correct answer was "tribe" their wrong answers were drawn from the whole pool -- they might answer "trade" or "moveable small" or "farming" or "permanent large".

Figure 2. Two line drawings used in the Native Americans cycle.

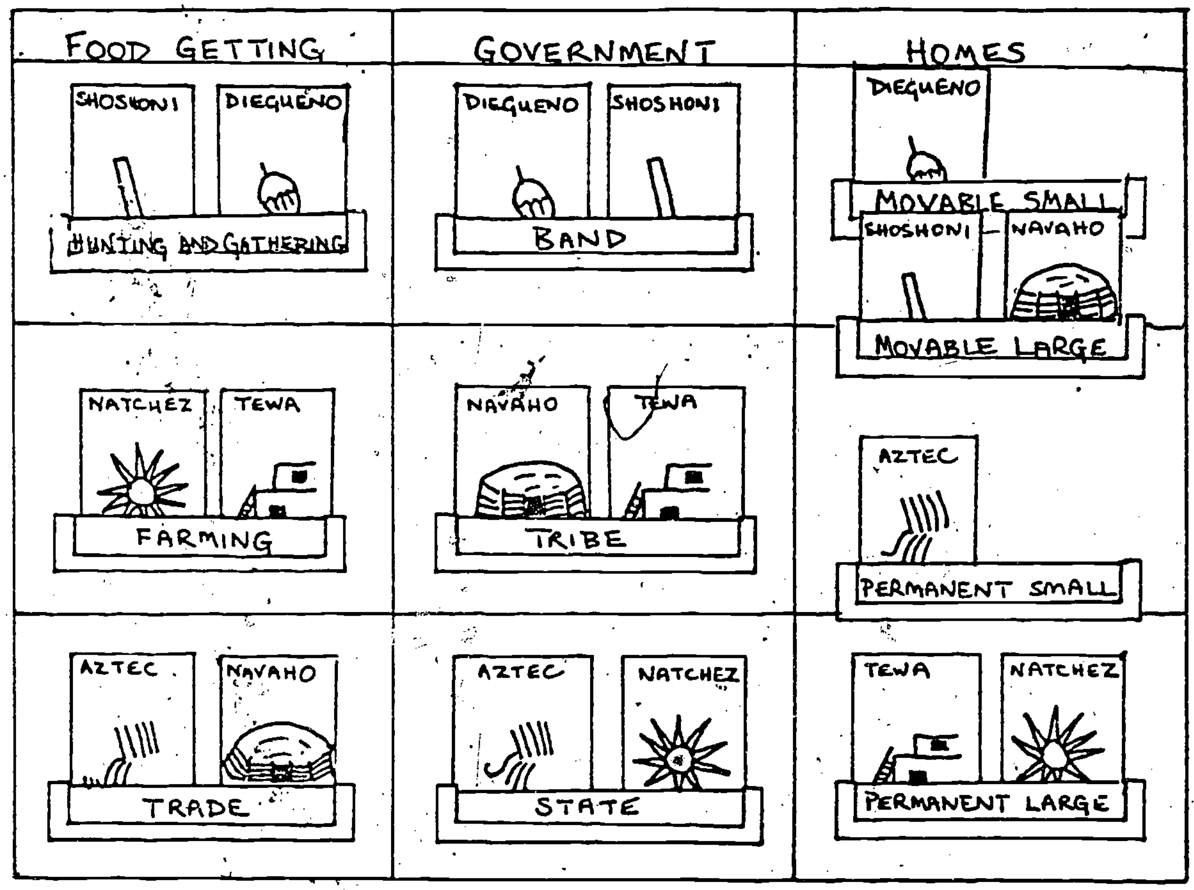

FOOD GETTING
GOVERNMENT
HOMES
SHOSHONI
DIEGUENO
HUNTING AND GATHERING
DIEGUENO
SHOSHONI
BAND
DIEGUENO
MOVABLE SMALL
SHOSHONI
NAVAHO
MOVABLE LARGE
NATCHEZ
TEWA
FARMING
NAVAHO
TEWA
TRIBE
AZTEC
PERMANENT SMALL
AZTEC
NAVAHO
TRADE
AZTEC
NATCHEZ
STATE
TEWA
NATCHEZ
PERMANENT LARGE

Figure 3. Pocket chart used in the Native Americans cycle.

SYMBOL	GROUP	HOMES	FOOD GETTING	GOVERNMENT
	NAVAHO	MOVEABLE LARGE	TRADE	TRIBE
	NATCHEZ	PERMANENT LARGE	FARM	STATE
	SHOSHONI	MOVEABLE LARGE	HUNT/ GATHER	BAND
	AZTEC	PERMANENT SMALL	TRADE	STATE
	DIE GUENO	MOVEABLE SMALL	HUNT/ GATHER	BAND
	TEWA	PERMANENT LARGE	FARM	TRIBE

Figure 4. Test format used in Native American cycle.

<u>The Mid-point of Instruction</u>. We continued with the unit. In smaller groups, the children met with their teachers; reviewed the unit chart and undertook a diversity of activities. There were role play situations with little figures that exposed the crucial features of social organization and gave more substance to the category as well as to the differences between bands, tribes and states. There was a problem solving situation where the children were given a tool used for obtaining or preparing food and the food item involved. They engaged in lively discussions and exhibitions of how hunters and gatherers obtained and prepared their food. The food-getting category also involved a lesson that tied in the children's experiences with gardening and climates with the farming done by the Natchez and the Tewa. Another role-play situation was undertaken to enrich the children's notion of trade to include money -- tokens of non-intrinsic value. The home category and the variables included in it were investigated by groups of children without a teacher present as they worked on booklets that included drawings and stories to complete.

<u>The End of Instruction</u>. A final large group lesson brought all of the categories and variables back together again as the children were involved in a discussion of how their lives were similar to and different from the lives of the Native American groups that they had been studying. Throughout this long series of lessons the children had taken tests that were in the same format, the sort of test that produced the "crossover" after the first lesson. After the final large group lesson, the children in the low achieving group turned in test papers that made it clear that they performed less well than the children in the high achieving group. However, even for the children who appeared to be "acting up" and not "taking the test seriously", an analysis of

the wrong answers no longer differentiated between the low and high achievers. All of the children were treating the categories like categories: If the answer was supposed to be "tribe", the wrong answers were either "band" or "state".

Interpreting This 'Aptitude X Instruction' Interaction. There are three ways to look at the differences in the way children changed between the first and the last test scores:

1) The unit was successful. All of the children got more answers correct after the full unit than they did after the first lesson alone.

   This analysis would draw only on the difference in the total number of correct answers.

2) The unit was only partially successful because the high achievers "got more" out of the instruction than the low achievers did. Although the high group children didn't "get as much" out of the first lesson as the low group children, they "got more" by the end of the full unit.

   This analysis would draw on a "change" score based on the number of correct answers.

3) The unit was only partly successful because the low achievers were "doing two things at once" in the course of the unit. They were learning the correct associations just as the high group children were. They were also learning a different way to organize the domain.

This analysis draws on the literature on mental representation and on the contrasting patterning of wrong answers.

We think that all of the above accounts can be considered true. Our initial job was to develop an explanation for the second sort of statement: How is it that high achievers "get more" out of an instructional unit than low achievers do, that is, how do the rich get richer? Part of the answer is related to the third sort of an analysis: <u>The lower group children start out doing a different task, they learn to do the same task the high children are doing, and, at the same time, learn the specific content in the task</u>. In the unofficial task, the extra one, the low group children achieved at a 100% level. In the official task, the specific content, they weren't quite so good, certainly not as good as the high group children.

The unofficial extra task brings up a contrast that is a mainstay in the psychological literature. Studies of memory and lexical organization have canonized a distinction among the ways that a set of items can be represented in the mind. On the one hand, elements can be related in a story fashion, with the items developing a cohesive theme. When a domain is represented in this way, the terms that are used to describe it are: functional, or thematic, or relational. For example, "Dieguenos hunted rabbits and gathered acorns. Aztecs farmed with irrigation canals," would be an expression of a functional-relational-thematic representation of a subset of the cycle domain: Dieguenos + hunt and gather; Aztecs + farm. On the other hand, elements can be related in a chart-like fashion, with the items expressing hyper- and hypo-nymic relations. When a domain is represented this way, the terms that are used to describe it are: taxonomic, or categorical. For example, Figure 3 and Figure 4 above would both be expressions of a taxonomic-categorical representation of the cycle domain. Often, in the literature, it appears that children and people from non-Western societies represent domains in a functional-relational-thematic way and older people and those from Western technological societies represent domains in a categorical-taxonomic way (Cole and Scribner, 1973). However, a variety of recent studies suggest that something other than a "developmental" interpretation should be put on such findings. The materials used, the content domains studied, the elicitation frame the experimenter chooses -- all appear to effect the conclusions one would draw about whether a group of subjects uses one type of representation or the other. In fact, the safest conclusion is probably that almost any subject could rely on either form of mental representation (LCHC, 1982; 1983).

As we examine the differences in the wrong answers that the children provided on the tests, we see the relevance of these distinctions between concept types. First, consider the first test: The high group children answered with wrong answers from the right category while the low group children's wrong answers had no such categorical interpretation. This suggests that the high group children were relying on the same categorical-taxonomic representation of the domain that we used for the visual aid charts and tests. We can make no such statement about the low group children: It is not clear what representation controlled their answers. It is clear that our categories did not control them. Since the first lesson relied on narratives and pictures, it is not implausible to say that thematic-functional-relational representations accounted for their correct answers; but there is no certain lesson to be learned from their incorrect answers.

Next consider the comparison of the performance of the low group children on the first and last test: Their wrong answers were just like the high group's on the last test; the wrong answers were from the correct category; the children had changed over the course of the unit. The children developed a categorical-taxonomic representation of the domain that constrained their answer choice, and it was like the one that we presented. At the minimum we have evidence that the low group children undertook two tasks: learning the content of the domain and learning our representation of it. Perhaps, too, the children changed from a functional-relational representation to a taxonomic-categorical one. One conclusion to draw from this sort of analysis is that the low group children did a really excellent job because they did two pieces of intellectual work while the high group children only did one. On the other hand, the low group children did end up performing less well on the test indicating that they didn't know as much about Native Americans as the high group children. It seems insufficient to leave the matter by stating a defense about the great work the lower group children did.

Classroom Discourse Support for Taxonomic Representations. Recent work on the structure of the talk exchanges in lessons can contribute to an explanation of how the language used in classrooms gives more assistance to learners with taxonomic representations than to those with functional-relational representations. One study (Griffin and Humphrey, 1978) provides a detailed description of the treatment of children's answers in lessons. Their work accounts for the interactional records of lessons in a variety of classroom contexts (their own corpus from a highly successful private school, Mehan's (1979) corpus from an inner-city school, Sinclair and Coulthard's (1975) corpus from a British school).

In lessons, much of the talk occurs in groups of three utterances:

1) Teacher initiates a topic in an incomplete way, often by using a question word that leaves out a part of the substance of the statement.

2) A child or several children propose a completion of the topic, an answer.

3) Teacher disposes of the child proposal, validating

its functional completion of the topic or

invalidating it.

Often, the three part sequence is called an "Initiation, Response, Evaluation" sequence or a "Question, Answer, Feedback" sequence. Griffin and Humphrey focused on the Teacher's Evaluation (or Feedback) turn in a different way, showing the role that the turn had in constructing the content domain that the lesson addressed. Rather than seeing it primarily as an evaluation of the Child speaker, they demonstrate that the third part of the sequence acts as a gatekeeper for the content of the lesson. Unless a teacher goes into a lecture format, this gatekeeping turn is about the only thing that a teacher can use to make sure that the proper information is available for learning and that improper content is removed. In essence, the three parts can be seen as one assertion that is collaboratively constructed by the teacher and the child. Griffin and Humphrey found clear patterns amidst the varying expressions of the third, gatekeeping, turn. As expected, a major line can be drawn between the group of ways that "correct" answer are treated and the group of ways that "incorrect answers" are treated. That is, the variants in the third turn can be clearly identified in terms of polarity: Each variant occurs only as a positive or only as a negative.

Of interest here are the ways that wrong answers are treated. In particular, suppose the sequence is as follows:

Teacher: How did the Dieguenos get their food?

Child: They farmed.

Teacher: ?????????

The child's answer is wrong. Because this is an educational conversation, somehow the discourse has to remove the wrong answer and get the right answer into the lesson. There is an overwhelming preference for a child speaker to supply the right answer; that is, seldom does the following occur as a third part:

Teacher: No. They hunted and gathered.

Instead, one of the following techniques is used:

1) Third turn occurs overtly. Then the teacher asks the question again, usually addressing another child.

   a) Simple negative (e.g. "Not quite.")

   b) Implicated negative (e.g. "That was a very good try.")

2) Third turn is covertly accomplished by a sequence of acts that the teacher initiates:

   a) Ask the same child the same question.

   (e.g. "The Diegeunos got their food by ....")

b) Ask another child the same question.

(e.g. "Renee, how did they get their food?")

c) Initiate a side sequence that will return to the same question.

(e.g. "What are the other ways to get food that we have been thinking about?"

(Child: Hunt and gather and uh...)

"Right, trading with money and hunting and gathering. Now they didn't have money and did they stay in one place so they could farm the land?"

(Child: No, they moved around.)

"So, if they couldn't trade and they couldn't farm, how did the Diegueno get their food?"

or

"Do you remember the picture of the women making those beautiful baskets?"

(Child: Yeah.)

"And do you remember those nets the Dieguenos had, too?"

(Child: Yeah, for catching rabbits.)

"Yeah, they hunted rabbits. How did the Dieguenos get their food?"

d) Ask a question whose answer implies that the previous answer could not be correct.

(e.g. "Did they get their acorns by farming?")

In effect, these procedures "erase" the incorrect answer and provide a place for the correct answer to go. Classroom lessons are quite nicely designed: Teachers present information content in lessons; Teachers of young children seldom deliver lectures to them; The three part units allow the teacher and the children to collaborate in constructing the information content; Part of the construction team, the children, are in the lesson presumably because they don't know the information that they are collaborating to construct, so they make mistakes; The three part unit has a built-in repair procedure in the teacher's last turn so that incorrect information can be replaced with the right answers.

Education is not merely constructing lessons; it is also children mastering content. One is not subordinated to the other. Within the lessons in our Native American Indian cycle, the chances that a child will come up with the correct answer after a wrong answer has been offered are related to the kind of domain representation the child is working with. In the case of the children from the high achievement group who shared our taxonomical-categorical representation of the domain, any treatment of the wrong answer ("farming") left them with a 50-50 chance of being right with their next proposal. There were only three alternatives in the category, and their responses were constrained by the category. In contrast, the children who are not working with a taxonomic representation, get help to constrain their next proposal from only one of the six ways used to treat an incorrect answer. If the teacher uses either of the kinds of overt negative gatekeeping, children like those in our low group have 9 possible answers left to choose among. The chance of being correct on a next proposal to replace the wrong answer are quite slim. If the teacher uses anything but the side-sequence treatment of a wrong answer, <u>the discourse gives children working with a categorical representation an advantage over the children working with some other representation of the domain</u>. The side sequence treatment does not reverse the situation, but it can even things up. It provides the opportunity for the teacher to provide more constraints on the answer choice than the domain representation does. As the teacher inserts a few more three part units and builds a little extra information with the child, it may appear that the group is "off topic". However, when the sequence ends back where it started, the extra talk can be seen as adding more constraints to the answer choice of the initial question. Considering a child's next proposed answer for the original question, the chances for it being a correct answer are increased. (In the examples above, in 2c, the first example appears to rely on the categorical representation, and the second on some more narrative representation.)

The box score is surprisingly lopsided. If the name of the game is having the classroom discourse support the student, then the high achievers who start out with a taxonomy win, with 6 supporting discourse moves, as compared to the low achievers who only score with 1 discourse move. The way that these small structures of discourse relate to the larger structure of the domain mirrors the content achievement discrepancy in our data. One answer to how the rich get richer in classrooms appears to be that the discourse of lessons gives them extra support. In order to work effectively in the classroom on this sort of a domain, it makes sense for the low achieving children to switch to a taxonomic-categorical organizational structure by the end of the unit.

<u>Academic Content Support for Taxonomic Representations</u> A set of questions are raised by the preceding observed preference of classroom discourse for taxonomical representations of a domain: If the information content of a unit of lessons is represented with a functional-relational organizational structure, would our low achieving children who appeared to start out with such an organizational structure maintain their advantage throughout the whole unit? And, would the high achieving children demonstrate the ability to switch the organizational structures that constrained their answers? And, would the language used in the classroom, show a marked preference for the side sequence treatment of wrong answers as the technique that supports a non-taxonomic representation?

We attempted to find a topic for a cycle that would provide us with the appropriate test case. We wanted to design a cycle where a taxonomic representation might be devised, but where it would be clearly inferior to a functional- relational organization of the domain that the unit teaching would support. Whichever topic we investigated, it turned out wrong. Menu planning, for instance, turned into the categories known as the seven basic food groups. Kinship systems in anthropology may have fit the bill, but couldn't be rationalized as educationally relevant in the classroom for the children.

As the search continues it becomes very clear that the topics in education are more suited to taxonomic representation. The topics, the discourse structure and our high achieving children all favor that mode of organization. While we could not find the test case to answer our questions, we found instead the same difficulty that the low achieving children found in our cycle of lessons: what our society considers appropriate for education does not favor a functional-relational organization of domains.

In this work we found a way in which psychological categories, language use structures and educational achievement discrepancies could be related. We have not arrived at a clear answer about how this integration can be used to ameliorate the situation. On the basis of our cross-cultural work and historical assessments of literacy and its world impact, we can relate the events in this small unit in this one classroom to a more general issue: the taxonomic mode is central to the technologies upon which the modern world prides itself (Goody, 1977).

CHAPTER 4:

LEARNING AND ASSESSMENT

One of the tasks of a teacher is to assess the pupils' progress so she can gear instruction to their level of mastery. This assessment often takes place during the course of interactive teaching (Shavelson & Stern, 1981). For example, through the use of a stimulated recall interview procedure, McNair (1978-1979) showed that the largest number of the decision points in a teacher's interactive teaching are motivated by concerns about whether the pupils are learning the lesson material. But as Wallen (n.d.) shows in his survey of elementary level methods texts, methods for interactive assessment are seldom treated explicitly in teacher training. Instead they are generally left to practical experience and apprenticeship. This paper suggests one source of information about children's learning which is systematically available to teachers in interaction with children. Through the analysis of a set of fourth grade science lessons, we illustrate a model of assessment and discuss the limitations on its effectiveness.

Neither psychological nor educational research has addressed the question of how interactive assessments can be accomplished. The model of assessment in experimental psychology is the laboratory task in which the subject is isolated from interactions with others. But in classroom activities, interactions with others is the norm rather than the exception thus presenting serious problems for this model (Newman, Griffin & Cole, in press). The process/product model of educational research explicitly distinguishes between the teaching process and the pupil's competence at the completion of the process. It has not typically looked for ways to assess the pupil's progress during the course of the teaching process.

What is needed in order to observe and study the <u>in situ</u> process of assessment? The first requirement is an analysis of the task as the teacher understands it on line. Here we need to treat the teacher as an informant so that, for example, we do not attempt to measure changes in behavior that are too subtle to be noticeable while teaching.

The second requirement is that we consider in what ways children change while interacting with the teacher. Here is where we must formulate a model of assessment that does not make the usual assumptions of psychological and educational research.

In the usual model of assessment, children's competence is measured by their individual performance on a criterial task. Change over time is seen as an increase in the performance measure. For our purpose, a useful alternative is provided by Vygotsky (1978). Vygotsky's theory contains an important idea which can be summarized as follows. In sharp contrast to this standard view, Vygotsky has given us a way of understanding children's competence as an expression of how they interact with others. Children are able to do many things while obtaining support from others that they could not do if left entirely on their own. As the child learns, he is able to do more and more of the task on his own. One way to tell how "competent" a child is, if we take this view of learning, is to gauge how much help the child needs in order to complete the task. Instead of just giving children the task and measuring how well they do or how badly they fail, we can give children the task and then observe how much and what kind of help they need in order to complete the task successfully. This model of learning as the progressive internalization of outside help has important implications for testing (Brown & Ferrara, in press). When applied to testing, the idea is often called "dynamic assessment" (Feuerstein, 1979). We believe that this process of progressively removing support is also an important method by which teachers assess their students' progress while they are teaching a lesson.

Analysis of a Fourth-Grade Lesson

We can illustrate the strengths and weaknessea of this in situ process of assessment with an analysis of a set of lessons we videotaped during a research project concerned with the assessment of cognition in nonlaboratory settings (Newman, Griffin & Cole, in press; Griffin, Cole & Newman, 1982).

Since our model of this process focuses on decrements in the amount of help needed over a set of trials on the same task we needed to look at lessons that contained a recurrent task. This is the kind of lesson to which our model would apply. If a decrement were clear, then we could point to the kind of evidence a teacher has available for assessing children. If there were no decrement in amount of help then further analyses and revision of the model would be indicated.

We found a set of such lessons among the data we collected in a fourth-grade classroom in a suburban area near San Diego. The set of lessons were part of a unit on household chemicals that we designed in collaboration with the classroom teacher and with the help of curriculum materials developed commercially. On the third day of the unit the teacher taught a set of small group lessons to each of the "Math groups." We set our cameras up focused on the kidney-shaped table as each group of four to six children, in turn, spent their 25 minute time slot in a lesson where, for the first time, they actually got to mix chemicals. The lesson had three main phases. First, the teacher discussed the classification of chemicals and the use of indicators to identify them. They were told how iodine turns starch purple and how red cabbage solution changes to different colors when mixed with an acid or a base. Second, the teacher divided the group into pairs and distributed two chemicals and the two indicators to each pair. Each pair of children was told to mix each of their chemicals with each of their indicators and record the four reactions on a worksheet. In the final phase of the lesson, the teacher discussed the results with the children, and reviewed what could be said about each chemical on the basis of the results.

The phase we will be concerned with primarily is the phase in which the children actually set about mixing chemicals and recording the results. In this phase she told pairs of children to work together but each individual was, in effect, given responsibility for only one chemical. So all that any one child had to do was mix her chemical with each of the two indicators and record the results of each mixture.

<u>Changes in Amount of Help</u>

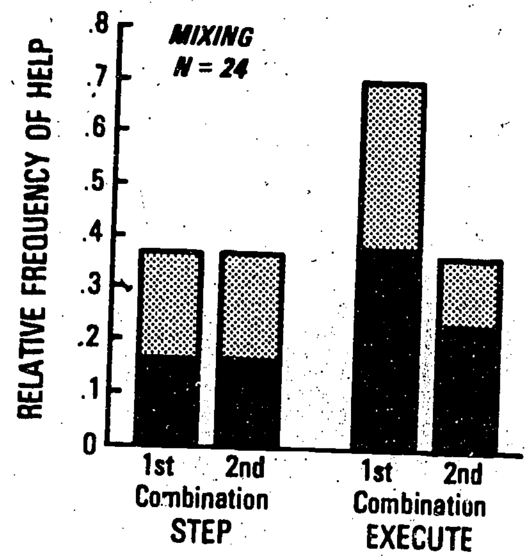
If children need less help to get a problem done the second time they do it, then we and the teacher may certainly feel that they have learned something. We coded the lessons with respect to whether or not the children received help from the teacher at various points in the mixing and recording part of the lesson. We started our coding after the teacher's initial instructions just as she distributed the chemicals. At the most macro level we were concerned with differences between the first and second task, that is, between the child's mixing his chemical with the first indicator (and then recording the results) and his mixing the chemical with the second indicator (and recording). Within the first and second task we coded the Mix and Record phases separately. We expected that the kinds of problems encountered with respect to choosing the two chemicals and mixing them in the test tube would be quite different from the problems encountered in recording the chemicals and results on the worksheet.

We also wanted to code the usefulness or importance of the help because it was intuitively clear that some of the help the teacher gave was somehow more significant than other help. This proved very difficult and we were unable to attain reliability on our initial attempts. The utility of help is, of course, an interaction between what the teacher says and what the child already knows. For example, explicit detailed instructions constitute a high level utility only for a child who does not know what to do. We return to this issue later because it is central to the interactive model of assessment. Our first partially successful solution to the "utility" problem keyed off a distinction the teacher, herself, made when we interviewed her about the help she was giving. She distinguished between "low level" and "high level" help by which she was referring to whether she told them simply that they should do the phase or whether she explained how actually to do it. We labelled these two aspects of each phase "Step" and "Execute." As it turns out, the patterns of results are quite different for these two aspects of the problem.

For each child there were eight points to be coded as to whether or not the teacher provided help. The authors assessed the reliability of this coding procedure by coding one of the lessons independently. They agreed on 91% of the cases.

Figure 5 shows the results for each of the eight coding points. For the moment, consider the whole bars ignoring the fact that there are grey areas on each bar. The patterns for Mixing and Recording are quite different. For Mixing there is a decrease in the amount of help from the first to the second combination. This difference occurs only with respect to the Execute aspect. This decrease in help for the execution of Mixing is found separately in each of the 5 small groups and is significant at the $p<.05$ level when tested by the McNemar test for the significance of changes. The children continued to get the same low level of help throughout the lesson on the Step aspect.

The results for the Recording phase of the tasks are quite different. Here there is no difference between the first and second combination with respect to either aspect. The teacher help stays at a relatively constant high level throughout the lesson. The results suggest that the children were learning something about how to do the mixing over the course of the lesson but that they did not learn anything about how to record the chemical combinations. But another interpretation is just as plausible. It could be that the


MIXING
N = 24
RELATIVE FREQUENCY OF HELP
.8
.7
.6
.5
.4
.3
.2
.1
0
1st
2nd
Combination
STEP
1st
2nd
Combination
EXECUTE

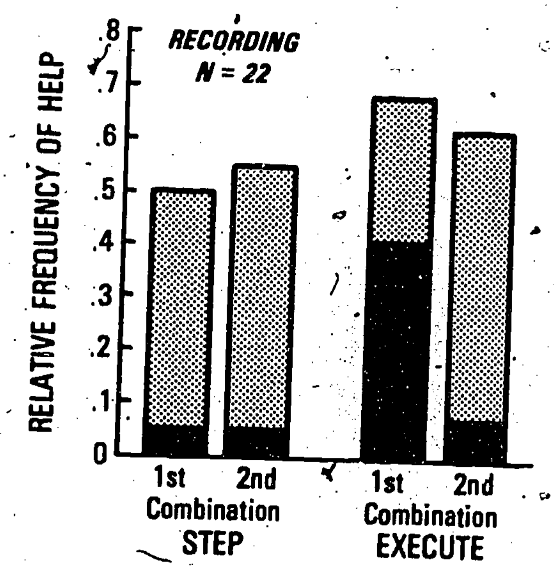

RECORDING
N = 22
RELATIVE FREQUENCY OF HELP
.8
.7
.6
.5
.4
.3
.2
.1
0
1st
2nd
Combination
STEP
1st
2nd
Combination
EXECUTE

Figure 5. Relative frequency of teacher help for each of eight coding points. "Grey areas" of each bar indicate help that could not be determined by the coder to be needed.

children did not learn anything at all. It could be they already knew what to do, but the teacher went ahead and told them what to do at first anyway.

Was the Help Needed?

This gets back to the interactive nature of the help. Once we coded whether or not the teacher gave help (and what phase and aspect it was given in) we returned to considering whether or not the children needed the help the teacher gave. We applied three coding categories to each of the eight coding points. Reliability of the authors' independent coding was 87%. The categories were:

1) Needed help. We had no trouble identifying many cases of the first category where children needed help. Children often asked for help in a question directed to the teacher or they sat doing nothing until the teacher told them what to do.

2) Did not need help. We also identified many cases where the children did not need help to complete the procedure successfully and, in fact, got no help. There were, however, a few cases where children got help but clearly did not need it, e.g., they were already doing the step when the teacher told them to do it.

3) Cannot tell whether help was needed or not. The third coding category was more problematic but turns out to point to an important difficulty with assessing children's abilities within supported interaction. There were a large number of cases where we could not tell whether or not the children needed the help they were given. These were not cases of inadequate data collection; the teacher-child interactions were recorded clearly enough. Rather

they were cases where the teacher gave help <u>before</u> it was clearly needed. For example, many of these cases were ones in which the children asked the teacher about how to describe the color of the resulting reaction. The teacher would answer that question and immediately go on to tell them to write it down. As researchers, we do not know if the children would have recorded the reaction on their own if they had not been given help.

The grey areas in each of the bars in Figure 5 indicate those cases for which we could not tell if the help was needed. This Figure makes it clear that the interventions directed toward the problem of mixing the chemicals were relatively more responsive to the children's problems or questions than the interventions around recording. A closer look at the Mixing data indicates that, excluding the grey areas, we have the same pattern of results as we found when those areas were included. That is, the Step aspect shows no change but there is a decrement in the help with the second combinations for the Execution aspect.

Looking now at the Recording data we find quite a different pattern when we exclude the grey areas. Here a far greater proportion of the teacher's interventions did not follow a child's question or problem. While the Step aspect stays the same from the first to the second combination, the Execute aspect shows a decrease in the amount of help that we can be sure was needed. That is, we do find a decrease in the difficulties and questions the children had. The teacher, however, continued to give a high level of help.

<u>Teaching and Assessment</u>

From our point of view as researchers, the teacher seemed to be obscuring our view of the children's competence. The decrease in requests for help suggests that the children were learning something about what they were supposed to write on their worksheets. But other interpretations are also plausible. For example, the teacher may have believed that the children did not know how to Execute recording so began giving help a little sooner the second time in order to head off the difficulty. The point is that because the teacher gave help before it was clearly needed we can not be sure whether or not the children needed the help.

The teacher also coded some of the lessons and discussed with us her perceptions of her interventions. These interviews provided us with several plausible explanations for the differences in the patterns of teacher help for Mixing and Recording. First, she points out that she actually provided specific instructions about mixing in the first phase of the lesson but gave far less explanation about using the record sheet. Thus the greater level of help for recording may be partially a result of attempting to provide mini-lessons on recording during the "hands on" phase. Second, the teacher had to make extra effort in the second phase of the lesson to assure the records were kept. If the children did not know what to do next as far as mixing is concerned, they would be stuck and would stop or ask a question. But, it would be very easy for a child to mix a chemical and indicator, examine the result, replace the test tube in the rack, and then go on to the next combination without recording the results. This would be an easy mistake for the children to make because the purpose of the record could be found only in the third phase of the lesson in which the 12 chemical combinations were to be discussed and which only the teacher knew about. Finally, she noted that many of the interventions that we had coded as category 3 (cannot tell) were cases in which she considered herself to be just reinforcing the actions she presumed the child would probably carry out anyway. But she knew that subsequent lessons in the unit would make use of very similar record keeping skills and she wanted to use whatever opportunities she had to reinforce the record-keeping habit.

The teacher's comments point to an important way in which teaching and assessment can be in conflict. Giving too much help is usually not a critical problem for teaching. If the children get help with a problem when they do not need it, the worst that can happen is that they will become a little bored and perhaps want to get onto something new or into something inappropriate. A teacher can afford to err in the direction of giving too much help, but the consequences may be far more disturbing if too little help is given. The teacher's assessment of the children's progress in being able to solve a problem requires withdrawing support to the edge of the children's abilities. This kind of brinksmanship requires that the teacher be there to quickly pick the children up when they do slip over the edge of their competence.

These observations make it clear that, for the teacher, assessment <u>per se</u> must often take second place to other demands. The teacher must often interact with the children in ways that make assessment impossible. In this case, for example, as researchers attempting to assess the children, we could not tell which children used record keeping from the start or picked it up quickly, and which children were slow to pick up record keeping. As Brown and

Ferarra (in press) illustrate in a laboratory setting, a one-to-one tutorial does make dynamic assessment feasible and produces results interestingly at variance with standard techniques. The results of the current study indicate, however, that dynamic assessment may not provide a viable alternative to the process-product paradigm in classroom based research.

We assume that assessment is a continuous process in the course of lesson interactions. It may not be as precise as is possible in a one-to-one situation, but it is certainly a necessary part of effective teaching. We have suggested that a model for the kind of assessment that is possible in the course of lessons can be based on the gradual reduction in the amount of support the teacher needs to give as she goes through a sequence of problems. The basic idea is to make use of the supportive social interactions which characterize teaching situations rather than trying to eliminate those supports as in standard testing procedures. For this kind of assessment to happen the activity does not have to stop for the child to be tested; the assessment goes on as an integral part of the teaching process itself. But since the process is embedded in the ongoing lesson activity it is very susceptible to variations in the teacher's priorities and to limitations in the resources the teacher has available.

CHAPTER 5:

BUT IT'S IMPORTANT DATA!:

MAKING THE DEMANDS OF A COGNITIVE EXPERIMENT

MEET THE EDUCATIONAL IMPERATIVES OF THE CLASSROOM

Marilyn G. Quinsaat

Oceanside Unified School District

As a relative newcomer to research on children, I have noticed a trend in the titling of research papers. Authors have found a creative outlet in using cute phrases from children who are their subjects to exemplify the intent of the paper. I have chosen a cut phrase, but this time the saying is from the classroom researchers "But it's important data." This paper is intended as a reflection on the difficulties encountered, and how consequent decisions were made, while I was the teacher in a classroom where psychological research was being done. It is also intended as a comment on the difficulties encountered by the practitioner among researchers.

The research described in this paper took place in my 3rd/4th grade classroom. The three-year project (two years in the classroom have been completed, one year of analysis remains), sought to study the cognitive demands children are faced with when learning to deal with the "same task" in different classroom situations. Videotaped data were designed to trace specific cognitive tasks through different settings: large-group lessons, small group lessons, one-to-one tutorials, children-only school interactions, and after-school clubs. A set of lessons incorporating all of the settings within a curriculum-cognitive task unit was called a "cycle." A more complete description of the project from the researchers' point of view is available in Griffin, Cole and Newman (in press).

It was extremely important that the teacher work closely with the project to help with the planning of cycle lessons, documentation of decisions which might affect the kind of data collected, and analysis. In many respects the practitioner and observers had much of the same relationship as others who had been involved in classroom research. (Florio & Walsh, 1976; Mehan, 1977). Florio and Walsh labeled the teacher's role "Observant Participant," giving the impression that researchers and practitioners collaborated in finding and making observations about the classroom. However, while in previous classroom work researchers were primarily observers, in this project, researchers set up and participated in specific tasks in order to systematically explore the ways in which cognitive tasks are influenced by the interactional and curricular variations necessary to run a classroom. Researchers sought to understand the context of cognitive tasks, and the teacher had a more responsible role in the project. The problem of coordinating the needs of cognitive research with the ongoing business of teaching and learning in the classroom had to be confronted continually.

Background

At the beginning of the project, I had two years experience teaching in public schools. Prior to that, I had been a Sociology major and had graduated from the same university and the same teacher-training program with which the research was associated. Much of my upper-division work emphasized learning about current educational research, considering the teacher as ethnographer, and using video-tape equipment to study classroom interaction. When Bud Mehan contacted me about participating in this research I thought it might give me a chance to build on my undergraduate background, allow me to get a glimpse of what graduate work would be like, and perhaps show me something about my teaching. But I considered self-improvement to be an indirect object of my involvement in the project, since the project was not directed at changing my teaching.

It is important to note that I had some prior experience which put me at an advantage over many teachers who might find themselves in such a situation. I have been video-taped while teaching as an undergraduate. I knew that video-taping could be an extremely important and beneficial means of gathering data about teaching. Despite the fact that I had this experience, I still felt somewhat uncomfortable about the prospect. At the outset, the researchers assured me that they were not interested in looking at my <u>teaching</u> as data. The <u>students</u> were the "subjects"; aspects of "how they learned" were the data.

I soon began to understand the design and interests of the project, and realized that, although I was not primary "subject," my role as the teacher, and the way I taught, were extremely important to the analysis. Although the study was not focused on teachers, knowledge about the teacher's role in designing lessons, making decisions about what and how tasks should be learned, and his/her actual implementations of plans would be essential to specifying what the task was and how the children perceived the task. These considerations were central to claims about social organization and cognition. As the teacher, I clearly had privileged sources of knowledge. As I came to understand my role in the project as a mediator between abstract research plans and concrete classroom reality, meeting the demands of both teaching and the process of doing research became more difficult.

Problems in Doing Classroom Research in General

Before proceeding to the specifics of our research, I want to review p. blems that may arise when teachers become involved in classroom research in their own rooms. Although it is rarely addressed openly, the first hurdle to doing classroom-based research is the difficulty in finding educators willing to participate. In principle, it should be expected that educators would be interested in keeping up with educational research because of its implications on how teaching should go on in the classroom. However some teachers feel an unwillingness to cooperate in classroom research, afraid of work disruption, and especially of accusations of failure to keep abreast of new trends in their field. Fear of such criticism is, in fact, central to the reluctance of teachers to participate in such work.

Many teachers I know assume that educational researchers end up exposing and criticizing the practitioner and/or the educational system. It is easy to see how teachers might get this impression from the kind of research that is published about teachers and schools. Aside from curriculum research, teachers usually hear about work that shows how teachers are doing it all wrong. Pygmalion in the Classroom is a good example. It points out that a teacher can make or ruin a student's academic potential without even knowing how the influence was accomplished.

Why, one might ask naively, should a competent teacher worry? If everything was going alright, there would be nothing to hide. This point of view really is naive. I am willing to admit that things go wrong in my classroom more often than I would like, as would any honest professional. And if video-tape equipment recorded what was going on, it would be extremely easy to find cases which could be embarrassing.

When observers are in the classroom, especially observers who are presumed to be experts on the teaching/learning process, teachers experience an unpleasant role reversal. Under ordinary conditions, the classroom teacher is regarded as an agent of benefits for the children. S/he is responsible for helping them acquire the academic skills necessary for success in their everyday lives, a responsibility that extends beyond textbooks to the social organization of the classroom as well. Once an observer/researcher enters the classroom, the teacher begins to feel his/her role change. The researcher is there to improve classroom effectiveness. The researcher is an advocate for the children, even if s/he does not know their names or their academic histories. The researcher's advocacy may result in recommendations for changes may stem from an evaluation of the teacher, viewed as part of "the problem," instead of as a beneficial agent.

Many educators I know are discouraged with their work, and have good reason to be. Complications with the demands of the public, bureaucratic organization, high student-teacher ratios, and other constraints all add to the stress of the teaching profession. Given the opportunity, they would like to talk about the difficulties of teaching in addition to the difficulties that face the children. Yet such conversations rarely happen as a part of the research process because to enter such a conversation is to undermine one's own authority with little hope that the risk will pay off in terms of improved classroom conditions.

Cognitive Experiments in the Classroom.

These very general remarks about classroom research are intended as an introduction to the special problems of the project that I engaged in. I did not simply agree to have someone observe in my classroom over a two-year period while I went about my own business. Instead, I agreed to participate in a project that would, from time to time, involve me in the planning of lessons that were motivated by the researcher's focus on specifying the way that the children processed information at each step in the lesson. Based on my past experience, I had ideas about what kinds of lesson content and structure would work well with my room full of 4th graders. But my ideas didn't always fit the requirements of the research.

The project conducted in my classroom was focused on the ways that the social organization of a learning task influences how well children master the material. Intuitively it seems that some children learn best when left with paper-and-pencil work; others respond well when working with a small group of other children; still others can't seem to understand the material unless the teacher is working with them on a one-to-one basis. These intuitions are part of classroom folklore, but they are very difficult to pin down because so many aspects of the lesson change from one kind of teacher-student interaction to the next. Our research tried to find a way to evaluate such ideas.

The basic idea was to present the kids with the same basic material in lessons structured in very different ways. We had large-group lessons where I presented material to the whole class at once. We had some lessons where a small group of children worked with the teacher, and others were the same small group worked independently. Finally, we created "tutorials," one-on-one reviews of a whole unit, that were supposed to evaluate what the child had learned--while teaching the child as much as possible by way of a lesson wrap-up.

This systematic variation in the way that lessons were organized was the first source of problems for me. I like to organize my classroom so that I am usually working with a small group, while other groups are working on their own, rotating these groups throughout the day. My classroom was not organized in such a way that large group lessons would be easy to do, so we had to make arrangements to accommodate that need. Whenever the research was in progress, my normal routine occasionally had to be modified to allow for the scheduled kinds of lesson organization.

A second area where I had to modify my usual procedure was in the forming of lesson plans. The research sought to evaluate the influence of different kinds of social organization on the performance of specific cognitive tasks. This meant either finding a ready-made curriculum unit that fit our needs, or developing our own. In many cases we had to work quite hard to find ways to implement research ideas in the classroom. It was in this area that the research team relied most heavily on the teacher. I was regarded as the expert on presenting curriculum to 4th graders, so in the translation between abstract research goals and practical day-to-day activities I had to be the translator or at least arbiter of translations. For example, we decided to teach a cycle on Household Chemicals. The unit had the potential of being a success, especially if the lessons included some "exciting" experiments. It also had the potential of being a disaster, if the content or the cognitive task was too difficult. I had to insure that the materials used were interesting and accessible to 4th graders. Abstract formulations from a college text wouldn't work.

These goals were not completely incompatible. The researchers accepted my goals and I accepted theirs. I, too, wanted the children to master the cognitive skills underlying the curriculum. But implementing these two goals simultaneously turned out to be one of the central difficulties of the project. It didn't take me long to learn that whatever areas the researchers might be experts in, tailoring classroom lessons to the needs of cognitive psychological analysis was not one of them!

A useful example of conflicting goals occurred soon after the beginning of a cycle on Mapping. The children were given areas to measure and then were instructed to draw an accurate map of the area, given the measurements they collected. As the lesson progressed it became clear to me that many of the students were eager to do something with their measurements, but didn't quite know how to go about doing it. I felt that a lesson on scaling was in order, but that lesson wasn't planned to occur until later. I got together with the research team and negotiated a change in the cycle. Since I was interested in teaching the concept of scaling, I was made responsible for writing up the lesson plan. This aspect of the cycle had previously been guided by the researchers' notions of the structure of the topic. During the course of this replanning, it was also decided that the lesson would be done as a tutorial instead of a small- or large-group lesson. This procedure was different from past tutorials, which occurred at the [illegible] of cycles in order to serve as assessments of what a child knew. For the mapping cycle, the tutorial was in the middle of the cycle, and definitely oriented toward teaching.

Implementing this new piece of research/curriculum produced a new kind of conflict. I viewed the tutorials as an opportunity to teach the concept of scale. I believed that this was what the children needed to know in order to get on with the upcoming lessons on mapping. The research team, on the other hand, viewed this tutorial like the others, as an opportune time for the teacher to do some careful assessment of what the children knew, while incorporating good teaching. What constituted "important data" for them was a chance to look carefully at the levels at which children were able to do this scaling task. This conflict led me to believe that even the idea of doing tutorials, or individual evaluations on my students, was a luxury which I couldn't possibly engage in during regular classroom instruction. The researchers needed tutorial situations in which children were taken to the limit of their abilities in order to determine exactly the level at which they could process the information from previous lessons. Given my time constraints, I certainly didn't need that precise an evaluation. More general evaluations of my students would have been enough for me to see how to go about teaching them.

The conflict is in the fact that, as a teacher, it is important for me to find ways in which children can succeed as well as possible in their academic work. Yet this was not necessarily the goal of the researchers since they were also interested in the ways and situations in which children were having difficulties with cognitive tasks. Sometimes situations would occur that could only be "negotiated" while I was in the process of teaching. I took it as my responsibility to make certain that lessons went as well as possible once the planning phase was over, no matter what the logic of the research demanded. Sometimes I would modify what I should have said or done in lessons, using my intuitions about the needs of individual students.

My modifications during the lessons complicated life for the researchers. It would have been convenient, from their viewpoint, for my lessons to be uniformly structured. They weren't, of course. But the changes eventually became part of the data since we wanted to know when the requirements of classroom goals would require changes in the cognitive demands placed upon the children. This simply alludes to the idea that research, as well as teaching, often needs to be modified as the process under observation unfolds.

It is important to note that the primary reason I was willing to negotiate changes in the lesson plans was not to improve data collection, but to act as a guardian for the children. This advocacy was carried on simultaneously on several grounds. Research is intended to be a benefit for the children in the long run. But in the immediate circumstances, it is up to the teacher to protect the child from research situations which might violate their rights. For example, it is well-known that classroom research involves possible invasion of the subjects' privacy as well as the potential disruption of classroom activities.

All participants in this project were covered by a Protection of Human Subjects Declaration. The criteria for protecting the rights of the children while collecting data were quite stringent. Yet knowing when a child's rights were violated remained rather ambiguous. For example, one part of the Human Subjects Protection Declaration required that video-tape and camera equipment remain as "unobtrusive as possible" so that regular classroom business could continue. "Unobtrusive as possible" is a difficult phrase to translate into classroom reality. I was left as the agent for the children in deciding what equipment got in the way, and in negotiating how equipment could be set up to obtain proper sound and camera angle for data collection purposes.

Conflicts were minimized by spending energy educating each other. I often felt that I was the student. For example, at the beginning of the project, it was unclear to me why the tutorials for each child were necessary. I welcomed the opportunity to teach one-to-one lessons in the classroom, but the idea of teaching 27 "identical" tutorials per cycle, some lasting an hour, while the rest of the children went about their business, promised a lot of strain on my part, not to mention the effect it might have on classroom management.

The researchers carefully explained the importance of doing tutorials in the way they had in mind. I was given recently published research to read on new methods of mixing evaluation and teaching that the tutorials were designed to model (Brown & French, 1979). I found the ideas interesting and we had several discussions about how we could organize such extensive one-on-one work.

Over the following two years, the research team worked to help me understand all facets of the project. They provided large amounts of background reading, made themselves available for questions and discussion, provided access to helpful consultants, and invited me to participate in Laboratory meetings where our own and other related projects were being discussed. This program of education, centered on the research, provided me with the information needed to make intelligent decisions about what needed to get done in the classroom.

As the project continued, the goals of the research became clearer to me, and to the researchers as well. I began to understand that research is a continually changing process. I was given more responsibility in the planning of the lessons as my interest and understanding of the research grew. One of these areas was in the planning and teaching of a Division cycle.

Division cycle was an ongoing activity throughout the second year of data collection. Since division is a standard part of the 4th grade curriculum, and children were seen to do the calculation in other lessons, it was decided to tape occurrences where children were trying to solve problems involving division.

At first I thought that this cycle would be much easier for me. There would be no long hours of planning and lesson preparation. However, in a sense, what occurred was even more difficult than the specially planned lesson. It was important to the researchers to have a very detailed specification of what each lesson entailed. This specificity was normally accomplished by the preplanning of each regular cycle. In this case, the information was contained in my notions of what I thought the lesson was and how I thought it should be taught. I found myself being questioned about every aspect of the division process. Why did I choose the algorithm I taught? What were the steps involved? What did the child need to know in order to do each step? How did it help some children and not others? How did I come to learn algorithm? These are all good questions, but they are not the kind that I ask myself when I teach division. I began to feel defensive about my work, feeling that the researchers might now be investigating me!

Understanding Why It's Important Data

The division cycle provided another example where the everyday demands of the teacher's job come into conflict with that of the researchers. To a teacher, it is not necessary to be able to specify all aspects of a lesson. It is enough to be able to find or create lessons which serve the purpose, are appropriate to the class, and are manageable. If a teacher were to work on it, s/he could spend the time figuring out the specifics of the lessons in the way that the research team needed it, but it would demand a great deal more time than the competing demands of the curriculum permit.

But, to the researchers, that very specificity of lessons is what enables them to understand what the children are doing. As one of the researchers pointed out, the teacher's specific notions about the lessons were important data, because they shaped the way that the children experienced the curriculum. I began to understand better that everything that happened to shape classroom lessons was important. The students alone were not the subjects. Interaction was the "subject" also. And in the sense that interaction was the subject, the teacher became a subject, too.

I recall several occasions when I made a casual observation. A researcher would stop me and ask me to clarify my statement. At that point, the researcher would mutter, "We've got to remember to write that down." No one could specify ahead of time all that constituted good data, so at any point anything could be important.

In reflecting generally on the past two years of data collection, it is difficult to know exactly how the research has affected the children or their ability to do schoolwork. One hopes the children gained some knowledge from the curriculum areas taught. I know from being with them that they found the cycles to be interesting as well as fun.

However, I feel that I probably was affected the most. I spent hours working on the project, to the point where it seemed like a second job. Those hours often included negotiations which were made difficult by the ambiguous, paradoxical conditions of advocacy. Yet I felt that I had emerged after two years from the best teacher-training inservice program I had encountered.

The experience I've gained from having been involved in research continues to have a great impact on my work. Designing curriculum for the cycles and the amount of specificity involved in doing that made me more aware of the quality of materials that I was coming in contact with in my classroom. Getting to understand better the theories behind our research project and learning how to be critical of theory taught me how to analyze the vast number of educational curricula that I encounter. The analysis of my classroom thus far reveals that I do plenty of things I wish I could do better. But I think in the long run, it also reveals that I am learning how.

CHAPTER 6:

LONG DIVISION OF LABOR:

IN SUPPORT OF AN INTERACTIVE LEARNING THEORY

Andrea L. Petitto

Graduate School of Education and Human Development

University of Rochester

This chapter presents a process oriented study of teaching and learning. Small group lessons in elementary school classrooms, where groups are stratified by achievement levels in arithmetic, provide a set of contexts in which to investigate learning processes in relation to naturally occurring variations in the constraints on expert/novice interaction. The analysis and discussion draws from two major areas of learning research: educational psychology concerned with learning among children of different academic abilities; and cognitive psychological studies of individual learning processes. The analysis demonstrates that in important respects, the teaching/learning interactions cannot be reduced either to direct instruction or to individual learning processes.[22]

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22. The use of the expression "teaching/learning" refers to a concept best expressed by Sutton's definition of the Russian word "obuchenie" which means "both teaching and learning, both sides of the two-way process, ... well suited to a dialectical view of a phenomenon made up of mutually interpenetrating opposites." (p. 169, 1980)

How to deal effectively with a heterogeneous student population has long been a major problem for educators. In classroom practice in the United States, this problem has most often lead to ability grouping--dividing students into small working groups according to a teacher's perception of the students' academic abilities. Teachers use small group instruction to promote student/teacher interaction and to increase student attentiveness during lessons (Barr, 1975). Children of similar academic ability are grouped together to facilitate the adjustment of teaching techniques to instructional needs. For pragmatic reasons such as these, the practice of ability grouping is well established. This practice, however, raises several theoretically important issues which are the continuing subject of research and debate. Primary among these is the role of group interaction in learning, and how psychological processes important in group interaction are related to variations in student ability.

Process from Product

The acquisition of new cognitive skills has long been studied inferentially by assessing learning outcomes related to a variety of curriculum manipulations (Gagne, 1968). More recently, cognitive science has developed detailed models of the process of skill acquisition by examining in-process transformations of individual problem solving behavior (Anzai & Simon, 1979; Anderson, 1982; diSessa, 1982; Resnick, 1982). But processes which produce individual learning are internal, inaccessible to direct observation. Investigation of such processes must infer the nature of those processes from their products--however fine grained that sequence of products might be.

Researchers who have studied learning through small group interaction have also assumed that all the important processes which produce changes in problem solving skills and strategies occur inside each individual's head, though facilitated in some way by dynamics of the interaction. This assumption has led to the predominance of research methods which rely upon end-sate analyses--in the form of pre and-post tests--from which to infer intervening processes. These studies have not provided definitive answers about the relative benefits of small group vs. whole class nor heterogeneous vs. homogeneous ability grouping much less explain the psychological bases for those effects which <u>are</u> found (Kulik & Kulik, 1982; Mehan, 1979). Some recent studies have begun to assess interactive mechanisms that might be important, but evidence to date has not been sufficiently consistent to demonstrate strong relationships between interaction patterns and cognitive learning processes (Webb, 1982; Swing & Peterson, 1982; Peterson, Janicki & Swing, 1981).

The research presented here will show that there are processes which must properly be characterized as <u>intersubjective</u>--arising from the interaction between people--which play a major role in producing changes in problem solving behavior among the participants. These processes, being external, are more accessible for observation and analysis and can provide an important link to explain relationships between interaction and individual learning.

<u>The Social Context</u>

When investigating cognitive learning in socially organized contexts, as in classroom lessons, the investigator is forced to consider cognitive and social issues together as two aspects of a single phenomenon (Griffin, Cole & Newman, 1982). This reformulates the theoretical question from: "How does an individual construct the necessary productions and flow of control for acquiring and refining a cognitive skill?" to "By what mechanism and in what form is a teacher's competence in a cognitive skill transferred to a novice?"

Cognitive psychology has long since abandoned the model of the passive learner. Psychologists have argued that teaching cannot be construed as "telling," i.e., direct transmission of knowledge. This is particularly true in procedural learning. Anderson (1982) points out that a major difficulty with direct procedural instruction is the necessity to specify new productions that will be adequately integrated with the student's "complex existing flow of control." Gagne (1968) expressed similar caution about the generality of his learning hierarchies, stating that the optimal hierarchy for any individual depends upon his current configuration of cognitive skills. Resnick and Glazer (1976) have argued that learners must actively "fill in" gaps in instruction, making connections that are only implicit in the teacher's presentation.

In cognitive studies, however, the role of the teacher as active participant in the learning process has been generally neglected. Researchers usually construct learning and problem solving situations in which instruction follows standardized procedures and which adjust for variations in subjects' learning rates and styles in predetermined, formal ways. This contrasts with most every-day teaching/learning situations. Though a teacher usually begins with a more or less well formulated lesson plan, the teacher's interactions with individual learners can vary in many ways along multiple dimensions. This variability is not constrained by a need for experimental controls, but by such considerations as a desire to promote learning and the teacher's ability to recognize correct performance of all or parts of the skill to be learned, in any of its possibly many valid forms.

Newman, Griffin, and Cole (in press) point out several important differences between tasks which occur in laboratory settings and those observable in regular classroom lessons. In either instance, participants may have many goals other than the one the researcher or teacher have in mind. In the relatively loose constraints of a classroom setting, students produce more visible activity related to those "alternate" goals than is possible in most experimentally controlled situations. Many of these alternative activities enter into the teaching/learning process in important ways. Newman, Griffin and Cole also argue that both laboratory and classroom tasks are always socially constructed, though in classrooms social constraints are more flexible and shifting. They show that changing social constraints produce immediate changes in the nature of the task at hand, in the procedures used, and in their ultimate products.

These issues have been cogently illustrated specifically in the area of mathematics lessons by Bauersfeld (1980). Making use of current sociological theories, (e.g., Mehan, 1979, 1978) Bauersfeld describes four "hidden dimensions" in the classroom which have been neglected in instructional research. The first of these, and the one most immediately relevant here, is the "constitution of meaning through human interaction." Bauersfeld describes classroom lessons as episodes in which "...each participant's view of the actual task to be done is different and varying during the course of the episode. The task must be understood as a function of the situation" (page 121).

Since each participant--teacher and students alike--have a different view of the task, then when investigating the processes by which people learn from other people, the unit of analysis must be larger than the individual. Further, not only the unit of analysis, but the method of analysis must change. Since the constitution of meaning cannot be ascribed to a single individual, Bauersfeld eschews the use of simple, linear models to describe such learning events. He states: "...as a matter of principle, there is small chance of predicting the outcomes of such episodes at their beginning." While we agree that there can be no simple mapping between either the child's or the teacher's entering system of knowledge and the educational outcome for the child, there are constraints which limit the likely outcomes of this learning process. What these constraints are and how they work is the subject of this paper.

Bauersfeld's critical argument points to the need for an interactive theory of learning. Members of the Laboratory of Comparative Human Cognition (1982) have developed an interactive learning theory through the synthesis of current cognitive theory in American psychology (McClelland & Rumelhart, 1981a,b; Norman, 1980) and Soviet theories of learning and development (Leont'ev, 1981; Luria, 1979; Rubinshtein, 1957; Vygotsky, 1978). This theory views the teacher and learner in their joint activity as as single, functional system. This functional system is treated as a fundamental unit of analysis of the same kind as an individual acting independently. As in more traditional versions of American cognitive psychology, goals serve to coordinate the actions within the system. In the case of an educational activity, the educational goal is treated as the primary one which sustains the unity of the functional system, although the various individuals participating in this system each have different versions of this overall goal. There is also a multiplicity of goals--an issue raised by Neisser (1976)--existing simultaneously, any of which may or may not be related to the educational goal. It is up to the teacher to organize the actions of the participants with respect to the educational goal.

A Study of Learning Long Division

With this theoretical view we approached the analysis of the teaching/learning processes that took place in several small-group sessions in a fourth-grade public school classroom. The overall educational goal in these episodes was for the children to learn to do long division. This goal is institutionally defined and is understood and accepted in various ways by the teacher and students. This leads to a more immediate and locally defined goal, to carry out long division problems. Learning new procedures by demonstration and practice is one of a limited set of activities that regularly occurs in small group sessions such as these, and is confirmed by the teacher's introductory remarks, e.g., "let's try a few." As each problem is presented, the current goal is to divide, using the long division procedure. At the outset, only the teacher has a clear idea of what kinds of actions adequately satisfy this goal. The teacher has a relatively well developed theory of long division which consists of a hierarchy of goals and subgoals implemented by arithmetic routines which satisfy them. This is what the students must acquire in the teaching/learning processes observed here.

But how can the students acquire goals they do not already have? Simply stating the goal of long division to students who are not already familiar with it would certainly be cryptic: e.g., "Find an approximate integer quotient less than the precise quotient but greater than any other integer quotient which is less than the precise quotient. Then determine the undivided remainder." Since statements such as this one would be uninterpretable by the average fourth grader, goals are expressed in terms of the procedures which satisfy them. We shall see that in long division, as has been shown for other kinds of everyday arithmetic (Lave, Murtaugh & Rocha, 1983), one particularly useful and effective procedure utilizes successive approximation. This procedure is important because some kind of successive approximation strategy is necessary for human expertise in long division in its more complex forms. But processes of estimation or approximation are not precision operations as are, for example, multiplication and subtraction which can be carried out mechanically. Estimations are inherently goal directed. How is it possible, then, for a novice unfamiliar with the goal to learn such a procedure? The interactive learning theory includes the notion of a medium of interaction, or context. This provides for intermediate goals that are within reach of the students and so can be shared between teacher and student. Such a context will be identified in this analysis.

How do the students in the functional system move from their initial understanding toward one that is consonant with that of the teacher? The analysis presented below will reveal several aspects of this process. First, in initiating the lesson, the teacher presents a precise procedural description which serves as a medium of interaction between herself and the children. In the process of the teaching/learning interaction, the form of the procedure which the students learn changes from the procedural description originally presented by the teacher to alternate but equally valid procedures, including successive approximations among others. As will become clear in the analysis, these changes led to different final versions of the procedure from student to student. Yet these variations are neither inventions or 'discoveries' by the students nor are they planned in advance by the teacher but arise through the interaction between them. Variations in the form of the student-teacher interaction are indistinguishable from variations in the form of the long division procedure. These variations follow certain characteristic patterns some of which are associated with achievement levels of individual students.

These observations serve as the basis for an interactive learning theory in which the teacher and learner are viewed as parts of a single system. This system serves to transform information using operations, cognitive resources, and constraints in much the same way as individual internal processing theories do. For the purposes of this investigation, the fundamental unit of analysis contains teacher and one or more learners. It is on this level of analysis that observable changes in the problem solving process take place. Since the smallest meaningful unit of analysis for this kind of teaching/learning process must be larger than the individual, our theory is an attempt to extend the domain of cognitive analysis from individual processing to intersubjective processes and to show an essential continuity between them. Such an enterprise is necessary if we wish to understand the maintenance and transmission of cultural knowledge--the primary function of instruction.

The Setting and the Lesson

The serious consideration of learning as an interactive process leads to a redefinition of the task itself. It brings up the possibility that what the task is and what is being learned is different for different children and that these differences have educational consequences (Hood, McDermott, & Cole, 1980).

We studied the teaching/learning process as it unfolds in a regular fourth-grade classroom in a public elementary school in a medium sized, working class town on the West Coast of the United States. We observed a sequence of eight arithmetic lessons on division. The analyses presented here concentrate on only one lesson, the fifth in a series of eight. This was the lesson in which the long division algorithm was first introduced. It had been preceded by several lessons which used manipulable materials to illustrate the notion of division and remainders.

For the purpose of arithmetic lessons, the teacher had divided the children in the class into five small groups on the basis of tested arithmetic achievement in computation skills. These were routinely administered paper-and-pencil tests developed by project TORQUE. They included two tests on number lines and one addition, one subtraction and two multiplication tests. Though these test results formed the basis for assigning children to groups, the teacher did not strictly adhere to them. In a few cases she placed children into groups higher or lower than their arithmetic test scores would have indicated. The teacher justified these adjustments noting that those who had been placed above their tested scores showed "systematic rule errors" in their written work, a fact which she interpreted to mean that their difficulties were not in "understanding" but were mechanical. The teacher felt that the two children whom she dropped to a lower placement generally "didn't seem to understand things." Our analysis suggests that the teacher's perception of a child's understanding of the lesson content can be effected as much by the child's interactional difficulties as by actual cognitive skills. Nevertheless, we also conclude that difficulties in social interactional skills can lead to diminished ability to learn from instruction.

The average arithmetic test scores for each group are summarized in Table 1.

The resulting groups consisted of four to six children each. The <u>number</u> of groups formed was not determined by the distribution of test scores but by the teacher's organizational plans for the classroom. The teacher's purpose in forming these groups was to provide an opportunity for regular individual contact in arithmetic lessons. She used homogeneous ability grouping to facilitate teaching practices, including remediation and other forms of support. Despite differences in skill levels, the teacher used the same basic lesson plan for all groups, expecting to make in-process modifications in response to the children's performance during the small group sessions.

At the outset, our primary concern was to describe the the effects of differences in students' entering arithmetic skills on the interactions that constituted the teaching/learning of new material. The analysis of cognitive processes, already difficult in laboratory settings with controlled conditions, is problematic in observational studies. However, we were able to exploit the teacher's pragmatic structuring of the classroom and the well defined nature of the lesson content to structure the observation of social

Table 1

Re[illegible] of Arithmetic Pretests
fo[illegible] [illegible]ive Achievement Groups

		Average Score (max=28)	Std Dev	Number of Children
Highest Achievers	Group 1	26.8	0.75	6
	Group 2	25.6	0.89	5
	Group 3	22.8	4.1	6
	Group 4	14.2	4.9	6
	Group 5	15.8	3.8	4

Scores are the number correct of 6 addition, 8 subtraction, and 14 multiplication problems. Averages shown here are from the final group compositions which are not strictly in line with arithmetic scores. The teacher placed two children in groups higher than their scores warranted - one from Group 4 to Group 3 and one from Group 5 to Group 4. She also placed two children into groups below that which their scores alone would have indicated, both from Group 4 into Group 5.

interactions. The classroom setup was well suited to this purpose with its five small groups ranked on the basis of achievement in arithmetic skills. The institutional setting and classroom routine provided constraints on kinds of social interactions that were likely to occur and prescribed legitimacy within this restricted range of possibilities. Conditions for field observation were nearly ideal. Ethnicity and social class composition were equivalent across all five groups. We had arithmetic pretest scores, videotapes (from two camera angles) and field notes for all small group sessions, access to the children's written work, and the results of a division posttest.

The lesson content was long division with two digit dividends and a one digit divisor. Long division in this lesson is viewed as a standardized procedure for doing division problems with remainders. The procedure generates a quotient, a number which is the multiple of the quotient and the divisor, and a remainder which is the dividend minus the multiple (see Figure 1). 2): first, finding the quotient then checking the quotient. Finding the quotient is treated as a simple lookup for the missing member of the multiplication triplet (a x b = c, where either a or b is unknown). Checking the answer amounts to a justification in which a multiplication is expressed in its usual complete form (a into c equals b because a times b equals c).

MQ introduced long division as a variant of the simple division procedure followed by a new step to find a remainder. She first presented the long division problem, "seven into forty-six",[2] to the group, then presented a

2. MQ used different numerical examples in each group. The one presented for explanatory purposes here is from the second highest achievement group, but all others follow roughly the same course.

```
  QUOTIENT --->     6 R 4  <--- REMAINDER
DIVISOR --->   7 ) 46      <--- DIVIDEND
                   42      <--- MULTIPLE of Quotient and Divisor
                    4      <--- REMAINDER
```

Diagram indicating portions of the long division layout and corresponding terms.

Figure 1. The long division layout and corresponding terms.

Simple Division	Long Division Introduction	Extended Precision Procedure
q x)y	q R r x) y y′ r	q R r x) y y′ r
Simple Division	Long Division Introduction	Extended Precision Procedure
	Find a "nearby" simple division y′ close tó y y′ < y	Find a "nearby" simple division Find q such that q * x = y′, y′ = y, and y′ < y Generate an ordered list of multiples of x: x * q = y′ from q = 1 ... 9 Select y′ close to y (on magnitude continuum, no y′ between y′ and y) Check: is y′ < y? If no, go back to select y′ If 'yes' then do Simple Division
	Simple Division	Simple Division
Quotient Reverse multiplication: find q such that q * x = y Write q above division bracket	Quotient Reverse multiplication: find q such that q * x = y′ Write q above division bracket	Quotient Reverse multiplication: find q such that q * x = y′ Write q above division bracket
Check multiply: q * x = y	Check multiply: q * x = y′ Write y′ below y	Check multiply: q * x = y′ Write y′ below y
	Remainder Subtract: y - y′ = r Write: 'R' r above division bracket to the right of q	Remainder Subtract: y - y′ = r Write: 'R' r above division bracket to the right of q

Figure 2: Long Division Structure

closely related, "nearby" simple division, "seven into forty-two," writing both of them on the blackboard. She solved the simple division, then returned to the long division saying that it is done "the same way," by searching for a number which when multiplied by the divisor (seven) would result in a multiple close to but smaller than the dividend (forty-six): "What number times seven has an <u>answer</u> that's close to forty-six? ...but it doesn't go over. If it's bigger than forty-six, then it wont work." At this point, after seeing the "nearby" simple division worked out, the children in all groups quickly filled in the correct quotient. MQ then complete the problem by carrying out the multiplication as in the checking step "...because six times seven is forty-two," then demonstrating the subtraction step to find the remainder "We subtract...this number [pointing to 42] from that number [pointing to 46] to find out what the difference is....This is your remainder."[3]

The middle column in Figure 7 shows the overall structure of the long division procedure at this point in the presentation. By indicating this relationship to simple divisions, MQ has established a subgoal hierarchy for the long division procedure: first, find a nearby simple division; second, carry out the simple division; third, find the difference or remainder. Simple division is an already established routine consisting of two parts, reverse multiplication and check. Finding a remainder is a goal which has also been previously established through other instantiations of division with remainders using other media (manipulables of various types) and other procedures. But the goal of "finding a nearby simple division" is entirely new.

3. The children had all been introduced to the idea of remainders as "left-overs" that could result when a quantity is not evenly divisible. This had been covered in lessons using various manipulables and some paper and pencil division procedures other than the standard numerical algorithm.

It is this step in the procedure that will be the focus of attention because of its unfamiliarity (for the students) and because of its potential for successive approximation.

As it has been presented so far, it is not clear what the criteria for "nearby" should be nor what procedures might be applied in the search for such a simple division. MQ dealt with these ambiguities by re-solving the same problem, this time filling in the ambiguous procedures with a sequence of precision operations. The resulting procedural sequence is presented in the third column in Figure 7.

MQ's filled in procedure begins by generating all the multiples of the divisor and scanning them for the one with the needed properties. In her presentation, she wrote out a list of multiples of the divisor on the blackboard, commenting that this step is normally done mentally: "So, that's what you would be doing in your head--trying to find all the answers that are times." Using this method, MQ demonstrated the process of making proximity and relative magnitude judgements based on the sequence of multiples (35, 42, 49, etc.):[4] "Find an answer that's close to forty-six but doesn't go over. Forty-nine is close but it goes over [pointing at the written list of multiples on the blackboard]. So, forty-two is the closest one that does ... that isn't bigger." This completes the process of finding a nearby simple division.

4. Rather than the sequence of multipliers (5, 6, 7, etc.)

Subsequently, the simple division is carried out in its original form, reverse multiplication and check: "What times seven is forty-two? Six." The checking step follows all of the above procedures with the multiplication, "Six times seven is forty-two," although this result had already been found within the procedures for finding the nearby simple division. MQ completed the example by finding the remainder: "Subtract and find your remainder. Remainder is four. The answer is six remainder four."

This is the Extended Precision version of MQ's long division algorithm as presented to the children in each small group. The procedure as presented sacrificed elegance for precision and completeness. No operations are unspecified, assuming that multiplication and subtraction do not require explanation. A child who remembers this sequence of steps in the proper order and who can execute each operation accurately is assured of success. Further, the Extended Precision sequence preserves intact the derivative relationship between long division and simple division.

However, the operations involved in identifying a nearby simple division put a great burden on working memory by including steps which generate and search a long table of multiples. The checking step is redundant--repeating a result already found in earlier operations. These characteristics make it unlikely that an expert would actually use this method to do long division. Nevertheless, this [illegible] of the long division algorithm served as a medium through which the teacher and children negotiated new and more efficient procedures such as successive approximations. The following discourse analysis traces this development.

Interaction and Transformation

As the teacher and children cooperated to solve the demonstration problems, and when they interacted in solving the worksheet problems, the actual procedures by which the problems were solved were changed from the Extended Precision version that MQ originally presented. These transformations produced abbreviations and reorganizations, tending to shift the procedure from a tightly specified sequence of precision operations to more cognitively efficient processes which can include some elements of estimation.

The resulting new versions of the long-division algorithm appeared to be neither an explicit part of the teacher's lesson plan nor inventions or discoveries made independently by the children. Nevertheless, the teacher's lesson plan, the children's understanding of it, and the current state of the children's arithmetic skills all entered into the process. The present analysis takes into account the relationships between variations in this transformation process and cognitive resources, i.e., skills and knowledge that each participant brings to bear on the current problem.

Alternatives to the Extended Precision Method

Transformations followed two different routes drawing upon different aspects of the children's arithmetic skills. One route relied upon the children's knowledge of an ordered set of multiples of the divisor and produced an abbreviated version of the original algorithm in which the first two subgoals are merged. This will be called the "Precision Multiples" procedure. A second route relied on the children's ability to perform single multiplications but did not require familiarity with ordered sets of multiples. This second route led to the procedure termed "Successive Approximat. ." It introduces an estimation strategy into the first two subgoals and recruits the remainder procedures to serve a checking function quite different from the original checking subgoal. As discussed above, this procedure itself implies the active existence of the long division goal which guides it. The following paragraphs present and analyze examples to illustrate the transformation processes.

Precision multiples: Of the two kinds of transformations observed, Precision Multiples represents a relatively small--but nevertheless significant--departure from the Extended Precision form and often required considerably less teacher/child interaction for its formation than did Successive Approximations. One example in which this transformation did involve an extended interaction sequence is presented here to demonstrate the interplay of elements in the interactive process.

Sometimes transformation processes took place within one problem and between one child and the teacher; sometimes a series of problems and several children were involved. The following example occurred over three problems solved in sequence by three different children, Jorge, Jénny and Tracy, interacting with the teacher during the demonstration phase in one small group session.

MQ: Alright Jorge, your problem will be ...[writes the division problem "9)49" on the blackboard]

: Forty-five. Five.

[writing 5 above the division brackets] Five times nine is ...?

Jorge: Forty-five.

MQ: [writing 45 below the 49] Ok, and then what?

Jorge: Four. Remainder four.

Jorge did not overtly carry out all the steps in the Extended Precision procedure, but he did report the results of each step; first the closest smaller multiple (forty-five), then the corresponding multiplier (five). We cannot say whether Jorge mentally generated all the multiples of nine, though it is likely that he somehow abbreviated this part of the procedure. The teacher acted to maintain the Extended Precision form by writing in only the quotient, "5," and demanding the redundant multiplication step. Jorge complied (the second "forty-five"), then finished by producing the results of the subtraction and labeled it the "remainder." Here, the overall form of teacher's original sequence of steps remained intact, though not all of it is overtly carried out.

In two subsequent problems, this procedure was abbreviated and reorganized to eliminate the redundant multiplication. In the first of these, Jenny's answer was roughly the same form as Jorge's had been. MQ then asked for further specification of the roles of these numbers in the algorithm sequence, this time by asking for their placement. Jenny's answer specified the placement not of the quotient but of the multiple--obviating the need for recalculating the multiplication. Thus, we see the first step toward eliminating the redundant multiplication. [MQ has written "7)51" on the blackboard for Jenny to solve] .

Jenny: It's forty-nine. Seven times seven.

MQ: Here? Here? [pointing to positions above and below the division bracket]

Jenny: The forty-nine goes down under the fifty-one. It's supposed to be seven. [MQ writes in the forty-nine and seven in their proper places]

In the third problem, Tracy began by specifying only the multiple and not the quotient (or multiplier), specified its placement below the dividend. The teacher accepted this placement before any quotient was given. Only subsequently--and with a little difficulty--did Tracy determine the quotient. [MQ writes "8)60" on the blackboard for Tracy to solve]

Tracy: Wait a minute. Fifty-six.

MQ: Here? [pointing above the division bracket]

Tracy: There, on the bottom. [MQ writes in the fifty-six] Um. Six.

MQ: Six times eight is fifty-six?

Tracy: [other children laugh] Wait. Seven! Seven ... and four.

MQ: [writes in the seven and the four in their proper places] Ok?

At this point, the Precision Multiples form of the procedure has emerged. The redundant checking step is merged with the procedures for finding a nearby simple division, and is completed before the quotient is completely determined. This sequence demonstrates that the transformation process is as much a process of novices preparing the teacher to teach to their particular understanding of the task as it is the teacher preparing the novices to learn. The Extended Precision procedure called upon children's knowledge of multiplication of single digit numbers. The children's adeptness at finding such multiples--once called upon to do so--allowed them to abbreviate this sequence of operations and adopt the Precision Multiples solution. But only through collaboration with the teacher in solving long division problems could these children demonstrate their ability to apply these multiplication skills in this way. The demonstration of readiness and the development of the new procedural sequence developed together.

In this way, one procedure led to another. The old procedure, Extended Precision, served as a starting point and a medium of interaction between teacher and child. Through it, the teacher and children negotiated a new form of the procedure appropriate to the children's current arithmetic skills and level of understanding.

Successive approximations: In the above example, the children drew upon knowledge of multiples of single digit numbers to specify multiples of the single digit divisors. Nor all children effectively access knowledge of multiplication facts in this way, however.[5] Some of the children showed a tendency to start with a likely quotient rather than a multiple. This tendency resulted in a different kind of reorganization. Successive Approximation. The example below is from the same session as the preceding examples. Here, Thomas solves the problem "seven divided into forty" as follows:

> Thomas: Seven times four? Wait...That's not the closest. Ok, it's supposed to be seven times five. Thirty-five...Four? Remainder four? Or, remainder, uh, five.

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5. In this particular classroom, the usual method of practicing multiplication facts was to drill for speed and accuracy on randomly ordered multiplication triplets: axb=c. Thus, many children may not have had practice with ordered sets of multiples.

MQ: Ok, you got that.

Thomas started by stating a multiplication--mul[illegible]lying the divisor by four. Then without overtly stating its result, he ma[illegible]s a judgement about its adequ[illegible]y: "That's not the closest." Finally he adjusts, picking a larger multiplier. From his treatment of this multiplier, we must assume that it is intended to be the quotient. Thomas's overt responses suggest a new process, S[illegible]e Approximation, in which the first precision operation is the multipli[illegible]n in the checking step which follows an estimation--finding an approximately correct quotient.

We cannot determine precisely what mental processes resulted in these verbal products. Thomas's problem solving is mainly internal and individual. However, similar transformations arose in extended teacher/child interactions which are more open to analysis. In one such case, Jackie had written "10 R 1" for the problem "nine into eighty-four" on her worksheet.

Jackie: Oh!

MQ: Ok, so I think maybe you went too high.

Jackie: Eight. What's eight times eight? Eight times...seventy-two.

MQ: R5. Oh, eight times nine? Can you go higher than that?

Jackie: Eight times nine is 72? Just nine times nine...Oh! [She erases and begins to redo the problem. The teacher turns her attention to someone else.]

When interacting with MQ, Jackie clearly chooses multipliers without first deriving them from multiples of nine, note her hesitation after specifying the multiplication by eight.[6] This characteristic of Jackie's approach interacts in complex ways with MQ's instructional techniques [illegible] with MQ's version of the long division algorithm. Jackie's multiplication was accurate and her multipliers were within a reasonable range, and so MQ provided feed-ba[illegible] on relative magnitude: "too high," "can you go higher?" MQ's judgements are based on the relationship between eighty-four and multiples of nine, consistent with the criteria for finding a nearby simple division. But Jackie acted on the highe[illegible]ower fe[illegible]k by adjusting the [illegible]ne instead of the multiples. The net result is Successive Approxim[illegible], in which quotients are estimated and tried as multipliers of the divisor and subsequently checked.

As noted above, processes of estimation or approximation are inherently goal directed. Jackie's incorrect solutions are sufficiently reasonable to be interpreted in terms finding a nearby simple division. MQ's responses derive from a more tightly constrained version of that goal than is available to Jackie alone, though Jackie's and MQ's goals overlap in their attention to magnitude relationships between multiples of the divisor and the divided. Because of this overlap, MQ needed only to express relational moves, providing external guidance which monitored relationships between the dividend and the outcomes of Jackie's actions. In this way, the goal itself is made clear through the procedure to attain it. This procedure, however, is Successive Approximation, not the Extended Precision procedure.[7]

6. As noted above, processes of estimation or approximation are inherently goal directed.

7. Looking at the beginning of this interaction, we can see possibilities for further reorganization regarding this checking procedure. Jackie had already written out a complete, though incorrect solution. In it she had made an error

In this and other examples observed throughout these sessions, a transformation to a Successive Approximation procedure began with a child's tendency to specify a quotient at the outset which, if not correct, is within a reasonable magnitude range. Errors by children using this approach led to correction efforts by either the child or the teacher which focused on relationships which specify the goal of the exercise.

These results illustrate that the form of the teacher-child interactions vary with different children and that these variations depend as much on the child's approach to the procedure as on the teacher's initial presentation and follow-up. The development of these interactional forms takes place through a complex interplay of factors involving division of labor on the task and mutual interpretation of responses and directives. These variations in the form of interactions are indistinguishable from variations in the form of the procedures which are the content of the lesson.

Group Differences in Interaction

Our analysis of the teacher-child interactions showed that there were important differences in the form of these interactions across groups. These

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in a presumably familiar operation, subtraction, which masked an error in the Quotient step where her multiple violates the "smaller than" criterion with respect to the dividend. MQ pointed out the subtraction error in order to unmask the division error. This moved the process of checking the adequacy of the multiple, which was originally part of the Quotient step, to the subtraction in the Remainder step. Subtraction now takes on a new functional significance within the long division procedure. It has become part of the check for the quotient as well as a way to find the remainder. This use of subtraction is not exploited further in this sequence, but the [illegible] possibility for doing so is clearly present.

Table 2

Solution Processes Characterizing
Observable Teacher-Child Interactions

Groups -->	(highest) 1	2	3	4	5 (lowest)
Solution Processes					
Extended Precision	3 25%	0	0	2 17%	4 40%
Precision Multiples	5 42%	1 25%	6 43%	10 83%	6 60%
Successive Approximation	4 33%	3 75%	8 57%	0	0

Absolute frequencies of each observable occurrence each solution procedure are shown in the upper portion of each row. Percentages shown below each frequency are calculated by dividing the frequency for each category by the total number of observable solutions for that category. Only those solutions achieved through teacher-child or child-child interactions are included in this table.

Insert Table 2 about here

differences are displayed in Table 2. The Precision Multiples solution was observed in all ability groups, though not for all individuals in any one group. The Successive Approximations solution was observed only in the three groups highest in arithmetic achievement. Finally, the Extended Precision form of the long division algorithm as it was originally presented often reappeared in the teacher-child interactions in the lowest achievement groups, but very rarely in the highest ones (after the teacher's initial presentation).

In all groups, some children showed sufficient familiarity with arithmetic facts and the long division algorithm to provide appropriate and efficient sequences of numerical responses similar to those presented above as examples of the Precision Multiples solution. Children in all groups made some errors, however. It was the teacher's and children's efforts to resolve these errors which produced variations in the form of the problem solving interactions across groups.

The Successive Approximation solution is an example of error resolution which occurred with relatively high achieving children. As shown above, the errors that high achievers produced usually bore a sufficient resemblance to the correct answer to be interpretable, and so correctable by the teacher. That is, the teacher could specify some parameter by which the child's solution procedure could be corrected: try a lower number, get closer, etc. With the lowest two groups, however, children who did not produce correct answers either remained silent or gave answers that were not readily interpretable in terms of the goal structure of long division. When this happened, the teacher resorted to the original form of the presentation of the algorithm, guiding the child through it step by step. The following examples illustrate this process.

In the second to lowest achievement group, three of the five children whom the teacher called upon were able to provide precise numerical solutions with little or no discussion. Two other children had some difficulty. Joel's attempt illustrates the form that the teacher-child interaction took when the child provides no initial input. [MQ writes "7)51" on the blackboard for Joel to solve. Joel is silent for some time. Other's occasionally mutter that they know how to do it.]

MQ: Seven times what has an answer that's close to fifty one? [no response] Try a number. How about seven times three?

Joel: No.

MQ: Seven times four?

Joel: No.

MQ: Seven times five?

Joel: No.

MQ: What's seven times six?

Joel: No.

MQ: Ok, how about seven times seven?

Joel: Yes.

MQ: ...or seven times eight?

Joel: Yes.

MQ: Which one do you think it should be?

Joel: Seven times eight.

MQ: Ok, what's seven times eight?

Joel: Fifty-six.

MQ: Fifty-six. Is that too big?

Joel: Yes. Forty-nine. Seven times seven.

MQ: Good. Seven times seven is what again?

Joel: Forty-nine.

Here, Joel's yes-no judgements and his numerical responses indicate that his multiplication is adequate to carry out the steps of th procedure once the teacher specifies them, but he contributes almost nothing that is not asked for. Though MQ began by using terms which suggest an estimation strategy, "Try a number," the interaction results in the complete Extended Precision procedure close to its original form. Joel's yes-no responses to MQ's "How about..." questions show that he does have some grasp of the criterial relationships between the multiples and the dividend, but he failed to establish this as an area of agreement between himself and the teacher at the outset.

This performance may have affected other children in the group. The next child, Candy, began the division "four into thirty" by stating the multiplication "four times two equals eight," apparently initiating the full form of the Extended Precision procedure. The teacher then followed along by helping her through the entire sequence of multiples of four.

The low achieving children sometimes made initial responses that were not easy to interpret. In the lowest achievement group, during the worksheet phase of the session, Eric had made some calculation errors and an error in the placement of the results of his calculations. Because of these errors, he had written "sixteen remainder one" as a solution to the problem "three into seventeen.".

MQ: What number times three is sixteen?

Eric: Hmmmmmmmm.

MQ: I think you better think this one again. [The teacher erases the sixteen.] Think of your three's tables. What number times three has an answer that's close to seventeen?

Eric: [No answer.]

MQ: Let's go for our multiplication tables. Three times one?

Eric: Three. [said with a sigh]

Eric and MQ then proceed through the entire multiplication table to complete the Extended Precision form of the algorithm. We have seen repeatedly that MQ resorts to this extended procedure when children provide no interpretable responses in approaching these long division problems. What is the functional significance of this procedure that the lower ability groups are so often exposed to?

Differences in the procedural transformations across achievement groups consisted of the uneven distribution of Successive Approximation which appeared only among the higher achievers, and the relatively greater frequency of the Extended Precision form among lower achievers. Though groups had been formed primarily on the basis of arithmetic computation skills, difficulties with multiplication facts cannot entirely account for these differen in the form of the interactions Higher achieving children were not always very accurate in their arithmetic, but they often showed a concern for monitoring the critical numer relationships within the algorithm. One striking example was a sequence with Matt, one of the children in the highest achievement group. The following excerpt from the demonstration phase of one small group session shows that, though Matt's multiplication skills were demonstratably weak, he managed to present effect goal directed behavior as well as, to suggest competence in multiplication, by expressing relational judgements. [MQ writes 7)52 on the blackboard for Matt to solve.]

MQ: Fifty-two divided by seven?

Matt: Seven times ...eight?

MQ: ...is what? [shushes the other children] Come on, you guys. Let him try to figure it out.

Matt: [pause] It's over. [pause] Seven times six.

MQ: Seven times six is what?

Matt: Forty-eight...forty-two?

MQ: Forty-two. Is that as close as you can get?

Matt: [shakes head "no"]

MQ: Can you get closer?

Matt: Uh huh. ["yes"]

MQ: Let's try to get closer.

Matt: ...can have six, eight times six but that's /???/

MQ: /It's gotta be/ times seven. It's gotta be times seven. What times seven?

Tony: It's closer to nine.

MQ: Seven times ...six times seven was forty-two. Let's try the next highest one.

Chld: Seven

MQ: What's seven times seven?

Matt: Don't know.

MQ: /Forty-nine/

Chld: /Forty-nine/

MQ: That's as c as you are going to get. If you g eight times seven is fi six and that's too big. [on the bla oard, writes in the seven as the answer and forty-nine below the fifty-two]

In spite of his difficulties with multiplication, Matt nevertheless establishes the Successive Approximations transformation. The interaction which achieves this, however, is quite different from the sequence with Jackie, presented above. Jackie had supplied numbers guided by MQ's directives concerning relative magnitude. Here, Matt does most of the monitoring of relative magnitude while MQ and other children supply most of the numbers. Matt's "It's over" establishes the "nearby simple division" goal, permitting a cooperative effort with others who shared overlapping versions of this goal. With the goal well established in the interaction, Matt's "eight times six" is also interpreted as an erroneous variant of this search, and MQ simply brings him back to the correct procedure.[8]

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8. Note also that the sequence with Jackie took place during a worksheet session in which her own written work included an erroneous subtraction, making possible further transformations of the procedure. Note that such a subtraction would not have arisen in the demonstration phase of the lesson where the teacher characteristically would not write incorrect responses. The point is that many of the seemingly incidental aspects of a setting can affect the dynamics of an interaction leading to significant differences in cognitive outcomes.

In spite of M[illegible]'s obvious difficulties with multiplication, MQ never resorts to the full sequence of multiplication of the Extended Precision procedure. The function of the multiplication sequence in the Extended Precision procedure is not simply added practice in multiplication tables, nor is it necessarily presented as a fool-proof way of doing long divisions. Its function is explicative, demonstrating important functional relationships between multiplication and division. Matt has already established the consideration of those relationships by his initial responses.

Discussion

In this analysis, the teacher and students are seen as embedded in a functional system which itself constitutes a fundamental unit of analysis. The observed transformation processes described above characterize these functional systems as self-modifying--altering their own functional properties through processes internal to the system, though not *entirely* internal to any one individual within it. This conceptualization points to alternatives to the usual way of dividing up lesson episodes. While we recognize the importance of studies which analyze individual cognitive processes and learning, this discussion explores other modes of analysis to reveal new aspects of the dynamics of instructional interaction. How can we characterize these functional systems in order to capture at least some of the essential principles by which learning occurs?

The interactive learning theory identifies a lesson episode as a functional system contained within an institutionally organized setting: i.e. our lesson on long division in a classroom in an elementary school. The functional system produces the performance we observe while the setting provides a general specification of the goals which coordinate its actions. This relationship between setting and shared expectations and goals is developed by Murtaugh et al (Lave, Rocha, & Murtaugh, 1983).

The role of goals is critically important here. The setting provides goals which are held in common by the several individuals within the lesson episode. By holding common goals, the various participants are able to communicate. That is, the institutional setting "sets up" individual cognitive processes in a way that affords them access to each other. At the outset of the lesson analyzed above the institutionally established goals of learning long division by demonstration and practice are in some general way guiding the children's and teacher's interpretation of each other's products.

Within the functional system, three main components can be identified: background knowledge, thought of as a pool of multiple competencies brought into the episode by the novices and/or expert; products which are writing, aural statements, actions or other presentations offered by the various participants, and a continuous process of interpretative interaction between novice and expert which relates old knowledge to new procedures. Though we make these distinctions, the three components are not equivalent types. Either the background knowledge or the products can exist independently without the support of the current functional system. But the interpretive interaction is dependent upon the availability of the other two components as well as the fundamental organizing power of the setting.

Our analysis reveals a cyclic relationship among the three components. Background knowledge and products both enter into the interpretive interaction and are modified by it. Since it is distributed across individuals, the whole body of the available background knowledge is not immediately accessible by any single individual, though pieces of it are made visible by being drawn into the interaction. Products arise within the interaction and once produced are available to all participants as objects of discussion. In modified form, both background knowledge and products re-enter the interaction in continuing cycles. We have seen that MQ's Extended Precision procedure is the key product which initiates the lesson sequence. It depicts a procedure which embodies important relationships and constraints while drawing on routines familiar to the students. But the Extended Precision procedure cannot not be taken literally as a definition of long division. It functions as a starting point or a context, specifying intermediate goals and routines from which higher order goals and new procedures which serve them are derived.

The critical processes for change occur in the interpretive interaction. Here, participants interpret each other's products in terms of their own versions of commonly held goals. But since individual versions of these goals do not overlap completely, such interpretations are often askew. When this happens, individual participants may try to adjust others' actions to bring them in line with what he perceives as the common objective. The nature of these adjustments provide information for the otherwise inaccessible goals of the individual doing the interpreting. This combination of interpretation (internal and individual) and adjustment (external) has been termed "appropriation" (LCHC, 1982). It forms the basis of the mechanism by which individual goals are brought into closer correspondence.[9] When such adjustments call upon the background knowledge of other individuals, then this process also results in the reorganization of that knowledge.

We have documented numerous instances of appropriation in these small group sessions. When a child's actions can be interpreted as an attempt to achieve the proper goal, the teacher acts to adjust these actions by maintaining higher order constraints. The teacher's higher order goals coordinate the child's products and bring familiar background knowledge into new functional relationships: for example, multiplication becomes structured as sets of ordered triplets, integer multiples take on significant magnitude relationships to other integers, and so on. This results in viable long division procedures which are modified by the interpretive interaction to fit the particular characteristics of the student's background knowledge, while at the same time imposing new organizing principles on that background knowledge.

The importance of the student's actions is brought out by the instances observed where students gave no products or uninterpretable ones. At these junctures, the teacher reverted to the Extended Precision procedure to re-establish a basis for interaction--an intermediate context based on familiar routines and goals from which to work. This move suggests that more instruction time will be required for such students. It is important to realize that this is not necessarily an error on the part of the teacher. Nevertheless, it is also important to understand that there can be many reasons for a child's failure to provide adequate feedback to the teacher. Such reasons could

9. This is the way it is supposed to work. The process can break down in a multitude of ways, however, possibly leading to ever diverging goals. This results in such remarks by educators as "I'm loosing that student."

involve background knowledge, mental capacity, emotional prob ms, or matters which are social or idental--as for examp a temporary misunderstanding. In any case, without interpretabl productions by the student, the teacher can only guess at the appropriate ne ove.

Conclusions

We have depicted functional systems as information processing systems which contain individuals within them. These are nested units of analysis. The functional system is nested within the setting (which is nested in turn in larger cultural units), and individuals--proper units for other analyses - are nested within the functional system. What is important is the continuity between nested levels. The way the functional system processes information is critically related to the processes going on inside the individuals, and the way that information is processed by the functional system as a whole modifies, sustains and adjusts processes going on within the individuals. In an important sense, then, intra-subjective and inter-subjective information processes are continuous, though the physical mechanisms which sustain them are not.[10]

10. These arguments make it clear that this kind of learning is interactive in two senses. It occurs in interaction between individuals, and it consists of an interaction between top-down and bottom-up processing. The top-down processes are supported by the setting which makes possible the agreement upon common (or overlapping) higher order goals, in this case, to learn some kind of arithmetic called long division by demonstration and practice. Prerequisite elements - intermediate goals and component routines - are assembled in a bottom-up way though coordinated by higher order goals. All of these processes are sustained and synthesized in the interpretive interaction.

We have seen that the process of instruction cannot be reduced to direct transmission of knowledge, nor are creative learning processes necessarily entirely internal to individuals. This study substantiates Anderson's (1982) conclusion that procedural knowledge is not acquired directly. Instruction in either declarative form--as in Anderson's study--or in procedural form--as in the present study requires interpretive processes in which previously existing procedures participate. However, the current study shows that a great deal of this interpretive work is done inter-subjectively and results in the acquisition of new goals as well as new procedures by the novice. The observed instructional episodes, analyzed with reference to the Interactive Learning Theory, show a constant interweaving of internal, individual cognition and inter-subjective processes in which the form of what is learned and process of learning are mutually constituted between teacher and student.

This process, however, is critically dependent upon some level of shared, overlapping goals, for it is these that allow individual's to interpret each other's externalized products. This coordination is initiated and sustained by institutionally specified goals. That there can be roughly corresponding goals defined by institutional settings depends, of course, upon the effectiveness of socialization and aculturation processes in the histories of the individual's who meet there. Thus there is a continuity between cultural history and individual cognition which cannot be ignored in any instance of instruction. The teacher and students simply must have some idea of what they are all doing together.

A system this complex is bound to be richly endowed with possibilities for breaki... down. Sev... l of these possibilities ...e currently under investigation by the LCHC team (see LCHC, 1982). Their ...stigat... of learning disabilities has shown the importance o... socialization and social skills for the ability to learn from oth...s. It is hoped that this paper can provide a framework ... structuring ... integrating investigations into the great variety of loci ...r possible learning difficulties, as ...ll as to shed light on normal learning process.

CHAPTER 7:

CONCLUSIONS

This report, addressed to the broad audience of cognitive scientists, takes an approach that is fundamentally different from the mainstream of that discipline. Because our topic is education we have not isolated the mind of the learner from the cultural tools and the culture members involved in the activity of instruction. Instead, we have located the process of learning in the interaction between the learner and the cultural elements that are both the means and the topic of learning. Our thesis is that an explanation of learning must include both an account of the changes in the social interpretation of the child's initial responses and an account of the transformation of cognitive activity from the inter- to the intrapsychological planes. Our method in the project we have reported was to create learning environments in a variety of social settings in which we could model the process of change. Putting tracers in each of the settings helped us to make the cross-social-setting comparisons that are essential for understanding the interactive learning processes.

Implications for a Cognitive Science of Education

Our observations and analyses of activities in the laboratory and classroom settings lead us to three conclusions. First, learning in interaction involves a process of appropriation in which the teacher interprets the child's responses in terms of her own analysis of the task. This process works off the assumption that the same action or object can be simultaneously from two different points of view. The appropriation of nonuniquely analyzable objects is both a source of creativity and a problem for researchers attempting to make statements about cognition. Second, learning in interaction involves a zone of proximal development in which the teacher and student collaborate in undertaking the task. The zone provides for many divisions of labor and sequences of instruction. Third, designing instruction is a matter of creating systems of social interaction.

Appropriation and Multiple Analyses

We have seen many cases in which two people in interaction have different understandings of the task or situation. Multiple realities are not necessarily an occasion for miscommunication but a necessary part of any social encounter. The limits on successful communication are not determined by the participants having identical analyses of the situation (if that were the case communication could never occur) but are determined by the possibility of the participants appropriating each others' actions. The appropriation process does have important limits, which have an important impact on both research and instruction.

The limits of appropriation can be seen most clearly when a child gives an "inappropriate" response. Recall the difference between Jackie and Eric in the long division lesson discussed in Chapter 6. Jackie, the successful student, made an error in computation but one that was interpretable as an wrong answer to the task at hand. Eric, a student in the bottom math group, wrote down an answer that was so entirely out of the ball park that the teacher had no recourse except to back up in the procedure to a point on which she had some hope of finding common ground with Eric. When the child makes a mistake on the task, the teacher can work with it and show the child how it is an error. When the child is doing some task other than the one the teacher expects the children to be working on, the teacher cannot show the child how his responses could be improved.

The teacher's capacity to assess the child will depend upon her ability to appropriate the child's responses. A teacher may, of course, be mistaken about the child's response. Eric, for example, might have accidentally produced an answer that had the appearance of an interpretable mistake. The teacher's appropriation of that response, however, would not be interpretable to Eric and the interaction would break down or be otherwise unsuccessful. Working such an interaction through to an ultimate success would require considerable concentration and individually focused effort, commodities that teachers seldom have in a classroom filled with 25 other children. Consequently, the mainstream children who are doing the task in the "appropriate" manner, receive instruction and the children like Eric are left behind. The teacher's coding scheme necessarily breaks down in the face of children who are not doing the task as the teacher understands it.

Researchers attempting to code classroom processes are in precisely the same dilemma. Coding schemes, especially those which are done online, favor the children who are analyzing the task in the same way as the researcher and teacher. As we show in Chapter 3 standardized coding schemes appear to give an valid picture only for some of the children. In this respect, however, teachers have some important advantages over the researcher attempting to code the children's behavior. The teacher can interact with the children and thereby find out if her appropriation of the child's response is interpretable to the child. The researcher has no such check on the outcome of his coding. The coding scheme necessarily assumes that the behavior is uniquely analyzable, an assumption that can lead to dangerous misappropriations of children's behavior unless s/he can arrange experimental conditions which help to check on what the child is really doing. The teacher also has a longer history with each child than does the typical researcher. Throughout our work in the classroom we were continually impressed with the richness of the knowledge that a teacher builds up over the course of daily interactions with the child. This vast knowledge of individual patterns considerably increases the range of her well-grounded interpretation of the children's responses. Without this knowledge (for example, at the beginning of the year or in cases of rapid student turnover) the teacher is in a position similar to that of the researcher: she is far more dependent on normative expectations. Those expectations almost invariably favor the children from the mainstream and majority culture and render the other children's responses uninterpretable (or, incorrectly, "wrong").

Appropriation is not limited to cases in which the teacher and child have the same understanding of the task and its solution. As the examples throughout this volume have shown, children can learn new goals and ways of doing things when their responses are appropriated into a system of which they were not previously aware. Because the teacher interacts with the child (unlike the researcher who simply miscodes the behavior and leaves) the child can learn retrospectively what his response counts as in the system as understood by the teacher.

In education there is an attempt to teach children to identify and solve tasks when they arise in contexts outside of school. We suspect that the process of appropriation is instrumental in achieving the creativity necessary for tackling what we have called the "whole task", that is, being able both to formulate the goal and to come to a solution. For example, the providing opportunities such as found in the combinations of chemicals task in which children were allowed to discover a task in the course of doing some self motivated activity is an important kind of experience for children to have if they are going to learn how to apply what they know to new situations. They will not learn to transfer if they are always presented with a ready-made task. A teacher's retrospective discussions are also a crucial part of that experience. For the children who did not formulate the task themselves, such discussions are an opportunity to see that a task had been potentially in the activity. The process of appropriation stands in for the child's self discovery and displays for the child how the task and his response to it looks from the perspective of the teacher's analysis. We believe that appropriation is a quite general process that can account for the emergent creativity of social interactions and the growth of flexible expertise in learners.

The Sequence of Instruction in the Zone of Proximal Development

The essential counterpart to appropriation is the zone of proximal development as formulated in the work of Vygotsky and his students. Throughout this report we have shown examples of teacher-child interaction in which the task was divided between the two participants and in which over the course of the interaction, the child came to understand the task and to do it more competently and independently. Our conclusion from these observations concerns the tremendous flexibility that we find in the system. The ZOPD (as we call it) is in no way a mechanical transmission of predefined task components from the teacher's role to the child's role. The appropriation process, for example, makes clear that the child's role may become reorganized during the course of interaction as it becomes more and more under the control of the teacher's interpretation of its significance.

The flexibility of learning within a ZOPD extends to the sequence of tasks that defines a curriculum. There is a strong tradition in developmental psychology that is reflected in the assumptions of many educators as well that cognitive change in any domain can be specified in terms of a hierarchy of levels, stages, or tasks. The notion of a learning hierarchy as popularly interpreted[11] implies that educators can construct a curriculum consisting of a single best sequence of tasks going from simple to complex that will optimize transfer and not leave any gaps in the skills required for later tasks. The ZOPD notion, however, provides an interesting alternative to that assumption. Where a task is being carried out interactively between an expert and

11. Gagne (1968) is careful to deny that his experimental findings imply that there is any generally applicable single best sequence of tasks.

novice, the components that the expert takes responsibility for may be "higher level" or "lower level". The expert may take charge of the executive decisions leaving the lower level operations to the novice or, alternatively, the expert may allow the novice to make the difficult decisions and give support by handling the mundane details that might otherwise distract the novice from the higher level thinking. The latter approach has been suggested as a method for teaching writing (Bruce, Collins, Rubin & Gentner, 1982) through tasks which involve ordering sentences and paragraphs. The teacher (or in recent implementations, the microcomputer) provides the sentences and the child's role is to consider the higher level text structures involving topical coherence.

Our own observations suggest that in many cases the notion of higher and lower levels may be misleading. Take, for example, learning long division a prerequisite for which, it is commonly assumed, is mastery of the multiplication facts. Children in the lowest math group entered the set of division lessons with little command of the basic facts. In Chapter 6 we saw that the expert successive approximation strategy did not emerge in their interactions with the teacher. The relationship between the lack of math facts mastery and their subsequent failure to learn long division is far from straightforward, however, as Chapter 6 makes clear. Two anecdotes reveal further dimensions of this relationship. One member of the lowest group, Margaret, discovered that the multiplication tables printed on the inside cover of her folder provided a very effective substitute for her memory of the facts. The tables were particularly effective when working on long division because they were ordered by multiples allowing her to scan down the table to find the particular multiple that was "close to but not bigger than" the number in the question. Using the table, she was able to complete long division problems. In the process, she also learned something very important about the structure and function of the multiplication tables. Another child in the same group, Mark, found the long division task very difficult. One day at recess after he had been working on a seat work assignment the teacher found him very upset about the fact he did not know his multiplication facts. He could see the relation between the doing the division algorithm and knowing the facts and, for the first time in his school career, became determined to work on memorizing the facts. We do not want to deny that having automatized knowledge of multiplication facts helps children in learning the algorithm. We want to point out, however, that it also works the other way. Confronting the algorithm also organizes and motivates the math facts. The facts and their organization are given, perhaps for the first time, a clear function. We can thus suggest that the algorithm could be used as a way to drill and practice the math facts provided that in the initial phases of working with the algorithm, written tables were made available to the children. The standard sequence of math facts, then long division is a necessary sequence only where the tasks are conceived of as a series of individual accomplishments. Under conditions of an expert providing support for the "lower" level components, the child may profit by a reversal in the sequence. At least, it should not automatically be assumed that failure to learn a complex algorithm indicates the need to do more rote work on the basic skills. A reordering such that the higher level actions give functional significance to the lower level operations may be far more valuable.

Designing Instruction

We began this report with a discussion of its relevance to Cognitive Science. While the mentalistic assumptions that predominate in much of that discipline are contradictory to our own position, we nevertheless consider our work to be part of that effort and these chapters to be a contribution to it. Where we do resonate strongly with current formulations of Cognitive Science is in the notion of "artificial" systems (Simon, 1981). Research on education is also a science of the artificial in that the study of how educational interactions work can never be far removed from the task of engineering them to work better. Thus we will end this report with a set of practical recommendations for education that follow very directly from our observations and analyses.

The underlying theme of all our recommendations is that designing more effective instruction involves designing systems of social interaction and social organization. Better textbooks or better microcomputer "courseware" will be only as good as the multiple settings in which teachers get them to function. For example, the new domain of "intelligent computer aided instruction" (ICAI), a notion that is very popular among cognitive scientists, is usually thought of in terms of constructing a stand alone machine that will replace the teacher for instruction in its specific domain. We have tried, in this report to emphasize the complexity of the teacher-child negotiation in the process of appropriation. Efforts at designing ICAI will benefit from careful analyses of how concepts emerge in the teacher-child interaction. But current computer systems are actually quite far from being able to perform the feats of sensitive interpretation performed routinely by human teachers. A recommendation that follows from our research is that the design of ICAI should not attempt to replace the teacher but rather it should set the machine up as a tool that mediates between the teacher and the child. In that way, the human teacher can still act as the interpretive expert appropriating the child's responses into the terms of the machine and helping the child to appropriate the machine as a new tool for learning. Our recommendation, however, requires that the designer of the machine be sensitive to the socially organized settings in which the machine might function in the classroom. It would not stand alone. It would be integrated into a setting in which it had a functional role.

Conclusions Regarding the Broader Issues

In the previous section we summarize our conclusions in the terms that occupy us as scholars and theoreticians. In this section we repeat those points in the terms that we think of them as citizens who are also scholars. We want to return to the broad questions that got us to come to NIE several years ago to ask for support and summarize what we think we have learned that may be relevant to the staff of the institute and other policy makers who look to research for guidance. These remarks are extrapolations, in some cases, from the facts at hand. But in each case we asked ourselves, "What general conclusions about kids and schools have we arrived at? What experiences led to those conclusions? What data do we have to support those conclusions that we can show to others as warrants for our conclusions?" In each of the points that follows, we will briefly point back to the source of our claims.

1. Coding schemes as process measures of education. It makes good sense for educational planners to seek objective data about classroom events to help

in teacher evaluation, curriculum evaluation, and a number of issues that revolve around the core of the educational experience. But there are theoretical limits to what can be expected from on-line "process" measures of education. Over and over again we have seen that such schemes do not err in a random way; they do not permit the inference that a child or teacher who is apparently doing "poorly" is in fact doing well with respect to another task. This is a theoretical limitation because we have shown that structured ambiguity is central to the educational process. Teachers give children the "benefit of the doubt" not out of softheartedness, but because this "as if" assumption is absolutely essential to the communicative process.

2. Do kids behave differently on the same task in different contexts? This intuition has a firm grounding in experience and our evidence, but it is incompletely formulated. Our tracer procedures show that what sort of task one is in can be discussed systematically, but it is a mistake to take certain logical or action schemas that are coded in our language as procedures (for doing intersection, dividing, etc.) as the process of learning/teaching. The explicit procedures are an important part, but only a part, of the actual constraints constructing the event.

In real life, the teacher credits children for their contributions to doing the whole task that include many elements missing from the diagnostic experiment. She/he is able to observe a child who does poorly when someone else initiates "take charge" and discovers for herself what cannot be told, or organizes someone else to do a next step. This is evidence of ability to deal with intellectual tasks, but if it is taken care of ahead of time by the adult or the procedure, the child cannot display it.

Thus, although it is inconvenient, we find intuition correct and science wrong because science is operating at the wrong level of description. To teachers and children, "whole tasks include figuring out that the problem is there, figuring out what to do about it, and doing it within the constraints at hand." Standard testing practices truncate this process in ways we have repeatedly demonstrated; the result is more standardized codings of behavior at the cost of a process that values shaping over development.

3. What about equity issues? A major motivation for this work was a series of equity issues that arise around the diagnosis/instruction nexus. One major line of effort over many years is to come up with ways in which those segments of the society who achieve poorly in school can be helped to raise their educationally-related skills significantly. Several conclusions concerning equity are warranted by our work.

1. It is a mirage to think that it is possible to redress early educational deficiencies without adding extra educational activity for poorly achieving students. (We do not here address the problem of teacher/student ratios, just the issue of time.) The evidence from our work shows clearly how weaknesses in early parts of the curriculum sequence become weaknesses and perhaps even terminal difficulties by the later grades.

2. Uniform conditions of instruction imply that some students will have to do more work than other to complete the same task. Yet heterogeneity that only makes some tasks "less" of another is not the answer; just as children's conceptions differ from each other in more ways than we can know, so there are many qualitatively distinct ways to accomplish a given criterion of performance.

3. A solution to educational deficiencies that emphasizes more time on task without taking into consideration variable organization of activity is not sufficient; it can dig a child deeper into a rut instead of giving him a head start.

4. Our research leads us to emphasize the importance of continuity in the experience of both teacher and student in the educational process as an

> important assist to equity in conditions like the ones we analyzed in which teachers believe in the children and are working as hard as they can to help them understand. If the cast of characters keeps changing, none of the parties have badly needed information to overcome tough spots. But continuity without variability isn't likely to help.

There has been a great deal of debate for a long time about the problems surrounding diversity in school achievement and the means that can best be used to improve performance in all sectors of our school system. The current pressures and dissatisfactions are generating a lot of finger pointing and exhortations to hold people accountable. The centralized, bureaucratically driven need for objective data is perfectly understandable in a giant system of the sort that our educational establishment has become. Our work is but one of many indicators in recent years that the process of educating a large and very heterogeneous population on a universal scale has been handed to the schools as an institution without sufficient attention to all of the functions which schools cannot fulfill. When students fail, the social response is one of impatience, and eventually anger and disgust. Looking at the process of learning/ teaching in a normally heterogeneous California school with skilled and dedicated teachers has served amply to emphasize the great difficulty of the teacher's and the schools' task. Even very basic skills, like long division, turn out to be mine fields of uncertainty that cannot be explicitly explained but must always rely on the child to make the leap between teacher's word and child's deed.

This characterization of the educational process implies the contents and style of education should always be changing to help connect the culture's abstract formulae to an ever changing reality. To capture a modern phrase, we must not get caught in the illusion of "back" to basics. Instead we must use schools to help coordinate all the social social institutions that give continuity and variability to the child's experiences, a coordination that is organized around abstract concepts and concrete, always diverse, social experience.

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