Children's Problem Solving as Inter-Individual Outcome

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For my parents

Abstract

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This study explores the relationship between the "cognitive" domain and the "social." It seeks to differentiate the ideas of Piaget and Vygotsky concerning the child's developing understanding of physical realtionships (embodied in balance scale problems) and social relationships (embodied in the interactions between children who are working simultaneously). It examines cognitive theorists (R. Siegler, N. Anderson) who analyze domains of knowledge as task analyses, Piagetian research (A.N. Perret-Clermont) specifying the relations between operations and co-operations, and recent work (V.V. Rubtsov) in the Vygotskian tradition, in which the proble-solving activity dictated by the task is varied.

In the present study a comparison was made of children's performance at balance scale problems while working individually with the experimenter and while working in small groups. Three group conditions were organized to model theoretical accounts of how social interactions are related to cognitive problems. Data from the interactions and from the individualized tests were evaluated by five different theoretical models. Results of multiple partial correlation analyses showed that changes in individual children's performance on balance scale problems, following group interactions, were best predicted by a model that included the contributions of group members' skill levels and the extent to which individuals engaged in particular types of verbal exchange. Engaging in fruitful verbal exchange was shown to be dependent on task arrangement. Individual cognitive measures failed to account for changes as well as

is predicted by traditional models of development. It was concluded that, in a general way, the kinds of interaction a child engaged in are complementary to the child's cognitive level. In the case of a specific task domain, however, it is the inter-individual transactions which allow a child to engage in on-task activity and to acquire the goal of problem solving. In the concluding chapter the implications of assuming social origins to problem-solving activity for the study of cognitive development are discussed.

Chapter I

Introduction

A central issue for contemporary developmental psychology is the relation between "cognitive" and "social" development, or, the relation between the domain of problem-solving and the domain of personal interactions. The present work contrasts two views of the relation, and several derivations of these views, each of which has general theoretical and pedagogical significance. On the theoretical side, the work seeks to differentiate between the ideas of Piaget and of Vygotsky concerning the relationship between the child's developing understanding of physical relationships (embodied here in balance scale problems) and of social relationships (embodied in the interactions between children who are working simultaneously on the balance scale problems). Also examined is the empirical research of cognitive theorists who analyze domains of knowledge, and researchers in the Piagetian tradition who have sought to test some of the ideas advanced by Piaget. On the pedagogical side, the present work seeks to clarify the conditions under which the joint activities of several students may be arranged to optimize learning as an outcome. To accomplish this objective, it was essential to find measures of this joint activity which might be expected to predict individual performance.

The Piagetian and Vygotskian analyses, and those that follow from them, are distinguished, first of all, by their respective views about what constitutes the object of investigation for developmental psychology. In their volume on the development of formal operations, Inhelder and Piaget (1958) maintained that in order to understand conceptual development, both the logical combinatorial actions and the rules that are embodied in those actions must be taken into account. These actions and rules constitute a system of transformations-- identical, inverse, reciprocal, and correlative--termed the INRC group. At the same time, a problem domain is defined by its abstract propositional dimensions. For example, the concept of proportionality underlies geometric problems (as in Piaget's shadows problem), dynamic problems (the balance scale), problems in probability, and so on. In order to study the acquisition of "proportionality," Piaget presented children with balance scale problems and described the child's actions and the child's working hypotheses of proto-logical statements.

In the Piagetian series of investigations, children were shown a beam scale from which weights could be hung. The children were asked to either make an unbalanced scale balance or to predict what effect a particular combination of weights would have. Applying the "clinical method," the experimenter then elicited the children's reasoning about the scale dynamics.

The problem domain is described by Inhelder and Piaget as resting on a child's actions. Four year old subjects, for instance, tried to make a scale balance by holding the arms of the beam straight, as if the problem could be solved by dint of volition. The stages that children exhibited were: symmetrical actions, correcting imbalance by adding and subtracting weights which leads to reciprocity, inversely corresponding actions, and finally, trial and error moves to transitivity. The number of weights and the distance of the weights from the fulcrum were acted upon at separate times by the children, until the two dimensions finally became coordinated. When, in the highest stage, the child discussed the Law of Proportionality, Piaget assumed that the child had progressed through the set of transformations that comprise the INRC group.

Another way of characterizing the rules children acquire to solve balance scale problems involves a decision-tree model (Klahr & Siegler, 1978). This approach begins with the features of the task that children are most likely to notice. For example, computation and comparison of torque values (multiplying the weight and distance values on one side of the scale and comparing that with the product from the other side) describes the rule used by all who successfully solve business scale problems. While young children do not tend to consider the distance dimensions in their comparisons, older children may not correctly compute the torque values. A description of the sequence in which the problem elements come to be integrated by a majority of children in a sample, gives Klahr and Siegler a model of the balance scale task. Rules for combining problem dimensions can also be described by an algebraic equation (Wilkening & Anderson, 1982). At issue for this cognitive algebra is the relative dominance of weight and distance in determining judgments of balance.

Yet another approach to children's developing knowledge, and one that is developed in this dissertation, is to consider the conditions under which suggestions to notice the distance dimension and to multiply weight by distance are effective. This investigative strategy has significance because it is not so clear that the child will "discover" the relations of the world unassisted, especially if the child is bound to a narrow realm of concrete instances. However, if we assume that it is by arrangement of concrete instances that task aspects come to be effective in determining the child's behavior, we need to shift away from traditional objects of analysis (the formal scale problem) and the traditional methods of obtaining evidence of learning (individual tests), to more functional ones.

If we take the latter approach to studying the circumstances of learning, two important consequences follow: First, the object of investigation changes because we may be looking for the appearance of different "understanding;" in the case of the balance scale, for instance, instead of proportionality it might be more reasonable to look for a simple multiplicative rule (i.e., weight x distance). Although many adults are not aware of this rule, telling them to multiply the weight and distance values on a scale arm and to compare it to the product for the other arm is sufficient for them to solve scale problems with 100% accuracy. Second, by assuming that experience with particular instances builds knowledge, we are obliged to consider the arrangements of those experiences as well as the laws they embody. In the end, these arrangements are largely a function of the social environment (Laboratory of Comparative Human Cognition, 1982).

The contribution of the social environment to the development of expertise in a task domain is a central issue if we take the latter approach. And it is an issue currently being debated by developmental psychologists. Piaget (1965) maintained that operations and cooperations develop simultaneously; that is, he posited no unidirectional causal relation between cognitive and social domains. For Piaget, the contribution of others, peers specifically, to the development of a child's logical schemata resides in the mechanism of "group conservation." That is, the information of others is available simultaneously with the child's own information and the child groups all available information to the extent that the child groups all available information to the extent that the child can utilize it lawfully and logically. Piaget did not otherwise specify the relationship between the individual and the group except to maintain that such correspondences concern only the problem domain.

Contrary to a strict Piagetian view, recent investigations of certain conservation problems by Perret-Clermont (1980) and others have found that there may be a directional relation between the group's activities and an individual's cognitive activity. Group problem solving experience seems to benefit children, at least those who are at the point where they show awareness of a problem domain but do not yet show fully logical situations. This is so, researchers conclude, because of a special form of conflict which can occur in groups. The exchange of perspectives concerning a logical concept (i.e., "cognitive conflict"), promotes new understandings or cognitive restructuring. In contrast, conflict concerning the cooperative exchange itself (i.e., "social conflict") is not presumed to result in cognitive restructuring. More recently, these researchers have found evidence that cognitive conflict depends on the goal of a task and that not all task situations promote the proper conflict (Perret-Clermont & Schubauer-Leoni, 1981). Their work, which has always been predicated on a formal analysis of the task, has led them to vary the test materials and the relative socioeconomic status of the experimenter and subjects.

In contrast to the Piagetian assumptions, Vygotsky (1978) argued that intellectual activity occurs as relations between people before it becomes internalized as part of an individual's repertoire. It is others, furthermore, who meditate a child's relations with the objects of the natural world. Consequently, concept development may depend on task organization that is not analyzable by formal task analysis alone, but is analyzable if one considers the history of the child's socially organized activities with the task. Finally, if intellectual activity begins as an inter-individual activity, the extent to which a child understands the goal of the activity in the same way as the other participants may be a more significant issue than the child's understanding of the formal structure of the task.

With only one exception (Rubtsov, 1981), those studying the contribution of the child's group to the child's concept attainment have not varied the task apparatus or the problem-solving goal. Although Piaget himself varied the apparatus embodying proportionality (Inhelder & Piaget, 1958), he did not vary the goal of the problem-solving activity. Rubtsov's work, based on a classification task, provides a model for pinpointing the domain of study for developmental psychology as it addresses the relation between activities called "cognitive" and activities called "social." By systematically rearranging children's roles in relation to the objects embodying a problem, Rubstov has been able to show that differential gains made by children correlate with different cooperative structures.

This study examines the intersection between a problem domain, the task structure, and the contribution of others to the change in a child's cognitive judgments. The relative importance and the interrelationship of these factors will be tested by means of an analysis that combines individual, group, and structural measures of problem-solving situations. If Vygotsky's theory is supported, then we would expect that measures of inter-individual problem-solving transactions would predict a significant portion of children's learning on the task. The effects of task organization on children's gains are also considered. Effects of organization should not be critical if the structural task analysis approach is the best way to assess potential information available in problem-solving situations.

In the present approach to the issues I compared the performances of second and third grade students at balance scale problems while working individually with the experimenter and while working in small groups. Interactions among the children while working in groups were organized to model theoretically competing accounts of how social interactions can be meshed with nominal cognitive problems (the balance scale). Data from the interactions and from individualized tests were evaluated by five theoretical models which attempt to account for the learning that occurred.

The five models are grouped into those that consider individual measures of performance and those that consider interactive measures. The former, arising from task structure analysis, include a Simple Skill model, a Group Skills model and a Rule Use model. Models based on interactive measures include one deriving from work done in the later Piagetian tradition (the Post-Piagetian model) and one derived form the Vygotskian school.

Piaget's theory pervades the research in both groups. It will be discussed in two contexts: his operational development theory in the context of structural task analyses, and his theory of cooperation in the context of the analysis of social aspects of problem-solving.

Chapter II reviews the assumptions of structural theoretical approaches to a balance scale task which concentrates on the individual and do not include the study of social elements. Chapter III reviews recent research being done in Europe which addresses the social origins of knowledge. This work is contrasted to work being done by Soviet psychologists in the Vygotskian tradition. A detailed explanation of the design rationale for the balance scale task is found in Chapter IV, followed by a presentation of the methods and of the measures used in the data analysis (Chapter V). The results of the analyses are reported in Chapter VI. In Chapter VII the results are discussed and the relevance of the work for future theory and application are argued.

Chapter II

The Formal Context of the Problem-Solving Task

In this chapter, some of the assumptions and predictions of a formal structure approach to problem-solving are presented in order to begin a systematic examination of aspects of problem contexts not generally considered by the task analytic method. Piaget's analysis, based on his notion of operational development, is discussed, as are its explanatory limitations. Recent work by cognitive theorists (R. Siegler, F. Wilkening & N. Anderson), which share aspects of the structural approach taken by Piaget, are also examined for the purpose of clarifying the differences between these structural approaches and more functional ones, which will be discussed in Chapter III.

Structural cognitive approaches to the delineation of problem-solving begin with the derivation of problem components. It is assumed that a model of the task enables an evaluation of the subject (Klahr & Siegler, 1978). For example, most cognitive theorists view instruction as the process of producing new knowledge. The success of instruction, in turn, depends on the child's conceptual representation system. As a consequence, efforts are made to derive precise task analyses that isolate problem features and specify the sequence in which they are acquired by the learner.

I will argue that while analysis of the formal problem-solving task by itself is useful in that it derives the functional units of learning a particular task, it systematically excludes from consideration those features of the problem-solving situation which tell us how change in children's thinking may come about, which is of particular interest for those who seek to arrange instructional interactions. That is, if instruction is viewed as an emergent consequence of the interaction of teacher and student, we might be forced to consider aspects of the problem-solving context beyond its formal features.

Piaget's Proportionality Schema

The originator of the Balance Scale task, Jean Piaget, sought to discover how the "proportionality schema" arises intuitively. {iagetr's choice of apparatus and questioning procedure were designed to elicit logical reasoning with little experimenter intervention.

Piaget sees early logic of all kinds as beginning in the "centrated" experiencen of the child's own sensory-motor activity; in the early stages of reasoning, children fail to distinguish their own actions from external processes. Children who seem to reason that their action of placing weights on the scale will make it do what they wish are said to be Stage I children. Later, children are seen to respond to weight and distance dimensions independently, even to distance alone, and, because the two dimensions are said to be not coordinated, children's answers may vary depending on how near the fulcrum the weights are placed.

Piaget's observations of children performing the scale task reveal some subtle interactions between internal and external events, or, in his terms, "logical" and "empirical" events. Several of these observations are of interest here. For instance, children may be able to do a correct proportionality manipulation on the scale but may be unable to reverse the weights for a corresponding solution. Children's "discoveries" may vary depending on whether the experimenter placesthe weights simultaneously or successively. Finally, children may respond to the distance dimension on two planes, horizontal and vertical, as the scale arm swings, and these may not be coordinated.

According to Piaget's analysis of logical operations, the logical proposition the child eventually can utilize corresponds to the earlier intuitions of proportionality achieved through "trial and error" (Paiget, 1958, p. 169). Balance on the scale is arrived at two different stages, simple symmetry and, later, inversion and reciprocity. The similar outcomes of the intuitive and logical operations may allow the child to coordinate the two processes; additionally, in Piaget's method, the children are prompted by the experimenter to make logical responses to the observations which are taken as reflective of their level of schema development.

Piaget's observations are invaluable because he considers a wide range of illogical variables that may be affecting children's guesses. Nonetheless, the experimenter's role as part of the task is not analyzed except when it is notes that children's reactions are "not completely spontaneous" (i.e., in need of prompting) at the higher stages on this task.

Although Piaget does not say so in so many words, his methodology locates thee learning in the apparatus. That is, the experimenter can get children to produce more advanced reasoning with fewer prompts by changing the scale used in the situation. In fact, the next task in Piaget's series is constructed specifically to cause children to discover the proportionality laws without being prompted, the apparatus being "designed to bring out the work relationships" (1958, p. 182).

The first question that Piaget asks, generally, concerning a child's response to the task is: how is the proportionality schema organized and how does it relate to the INRC group? While phrased as a question about internal logic, the manner in which the experimenter gets the children to produce behavior for analysis suggests that this question is might be considered as a social organizational one, not a formal structural one. We would want to know, for instance, if it would be possible to arrange a training task, i.e., a within-subject treatment, in which the experimenter's participation is systematically varied.

The second question Piaget asks is whether the proportionality schemas are constructed from the world empirically, or conceptually, but the INRC group. He answers his question by showing that they are constructed from both sources in equal measure, from empirical data acted upon conceptually. The additional question we need to address concerns the social empirical environment available: surely if the empirical sets the occasion for the logical, it is the social that has set the occasion for the empirical initially. We would claim that the idea of instructional responses, or learning, implies that, at the least, there is a specific instantiation or arrangements of materials that usually yields the so-called "spontaneous" logic Piaget detects.

Rule Assessment Method

Recently, Robert Siegler and his colleagues have described a four-stage system of rules children acquire to reason about certain problems. These rules are derived from the patterns of subjects' responses to structural components of several Piagetian tasks.[1]

In contract to Piaget's analysis of the formal logical principles which assess proportionality in the scale to be a dynamic concept—force—Siegler looks for evidence of a states concenpt—torque computation—in children's problem solving. Klahr and Siegler (1978) analyze the standard tasks in terms of a skills sequence built upon the children's assumptions and perpectives; they describe a formal decision tree model that can account for the problem-solving choices children are seen to exhibit at different ages. Instructional systems, according to Klahr and Sielger, should be designed to push a representation at stage N to state N+1, along the sequential path.

This means of deriving a model of the states of children's logical thinking leads Siegler and his coworkers to ask practical questions concerning the critical features of instruction. One question involved the optimal level of difficulty or discrepancy of information with which to confront a child, relative to the current representational state. Siegler (1980) finds, in a series of training studies on conservation tasks, that presenting children with information several steps beyond their current stage according to the task analysis, is not useful for producing a change in representation; presenting "nearer" information in the sequence is found to be useful. Thus, one contribution of the Siegler model is to describe which sequences of discriminations usually must follow each other in concept learning. Like Piaget's task analysis, Siegler's analysis describes similar relational features obtaining within different concepts; unlike Piaget's system, Siegler's does not require generality of stage across concepts. In fact, since his approach takes what children do as evidence, Siegler expands his task analytic model by comparing the logic children apply to the different problems (e.g., the shadows problem, probability, etc.). From the varying results, Siegler then constructs an expanded model of children's conceptual representations across problem domains.

Another question Siegler raises in his work concerns differences in children's learning from he same instructional sequence. In order to account for individual differences, according to Siegler, one must first closely specify the child's representational state, and second, study the acquisition process itself (Siegler, 1981, p.63), an enterprise as yet only suggested for future work.

From observations of children's responses to training they have conducted, Klahr and Siegler hypothesize that "differential encoding" is the cause of individual differences in the training sessions. Although later, Siegler (1981) is careful to note the arbitrary nature of any performance criterion, his work rests on the assumption that there is a necessary sequence of "encodings" that need to be provided.

The approach to learning as a representational raises useful questions concerning instructions; it also leads to two problems which may weaken its claims. First, while a match between formal problems and the "internal representation" model is useful for describing probable responses, it cannot be relied on as an indicator of all the variables affecting children's performance, as will be demonstrated. Since the model is derived from children's answers as they are seen to relate to the formal problem, one may be restricting what is counted as a task response. It is claimed here that in the study of the acquisition of logical responses by children, such restriction of consideration is invalid.

The problem of restricting the notion of what constitutes a task may originate in Siegler's idea of a "functional" task analysis. Because the "functional" part of the analysis lies in the detection of a necessary sequence of representations A, B, and C, for example, within a formal domain, rule assessment serves to fix A as coming before B; but because this is derived from the patterns of children's judgment, this is circular, not functional. As Strauss and Levin remark in an afterward to Siegler's monograph, "Siegler argues that the rules are a reality which organize children's thinking and guide their behavior and that evidence of this reality is the remarkable consistency in the use of these rules, which in turn give rise to patterns of judgments" (1981, p.76). But, they argue, "the interplay between this cognitive apparatus and the structure of the tasks presented to the child produces patterns of responses that can be summarized as rules" (1981, p. 77). It is argued that the probability of rules emerging from such an interaction is also a function of what the analyst is looking for and what the problem-solving setting permits; that is, not all children and materials would do the same thing in every setting. Flavell argues, too, (cited in Siegler, 1981) that A coming before B (or N coming before N+1) may be a function of the measuring instrument.

When Siegler reflects on what criteria we use for saying a child "understands" a concept, he looks first at the representational criteria and then at the formal task analysis. He says, however, that "within the present analysis, there is no compelling basis on which to choose any particular level of knowledge—initial, intermediate, or advanced—as the true index of understanding" (1981, p.57). Because Siegler seeks a formal descriptive system of knowledge production states he remains atheoretical about the acquisition process itself, and is left in a position of relativism about the circumstances under which a child's knowledge is definitively measurable. Because the mastery process itself appears so relative to Siegler, he finally suggests that it might best be studied in "multiple task circumstances" where understanding may be displayed. It could be argues that such an investigation of the organization of experience would yield functional acquisition and transfer rules instead of structural representation rules. A truly functional analysis, in fact, says a child has "learned" a concept when s/he displays it in many different settings.

If learning is viewed as a change in response on the part of the child to a range of cures differentially available in the instructional settings, the measuring instrument would need to include those variables outside the scale, or apparatus, that we suspect influence children's problem-solving. Instructional responding differs from production of knowledge in that it implicates the occasion of the response and refers to more than the child.

Siegler's summary assertion that "at the mastery level, reasoning must conform to the structure of the concept, while at lower levels people are more free to display their own approaches" (1981, p. 66) can take on a different meaning than intended. The observations that led to this assertion actually reflect differential task occasions, for younger and older subjects. The variables that shape young learners into rule users partly lie outside the formal logic of the problem. What is still to be determined is how these non-formal task variables operate in the socialization of problem-solving.

Siegler recognizes that the problem of relative measures depends in part upon having different theories of the task. What is at issue however, is not how to decide on one formal description of conceptual developmental sequences, but instead, how to employ a theory and find empirical evidence that takes into account a genuine functional relationship between context and task.

The second problem in Siegler's work, discussed by Wilkening and Anderson (1982), is the extent to which decision tree methodology can get at the "knowledge structures" that give rise to choices under specific conditions. We are not concerned here with that particular problem but with the assumption of formal rule assessment that what is inside the head undergoes transition without context. The point in the current study is not to derive a common formalism to account for all possible transformations of production, or output, but to suggest that the inputting process is what more fully counts for the individual differences in problem-solving.

Siegler's rule assessment, is adequate to use in beginning this enterprise for a number of reasons. One is that it does describe a certain reliable pattern among subjects. Wilkening's and Anderson's criticism that the method imposes itself on the data (Wilkening and Anderson, 1982, p. 232; see below) is true if we take the findings as representation rules. As a method of describing answers, however, it does detect commonalities in the situation. Secondly, Siegler's method can yield unspecifically named patterns of "misencoding," that is, seemingly non-systematic approaches to the balance scale problems. Instead of throwing this data out, we can examine them as windows to what may influencing categorizable children in non- obvious ways. Looking at protocols accompanying the Siegler task (Klahr and Siegler, 1978), much as is done in standard Piagetian method, also may suggest routes to follow towards picking out the other-than-task variables affecting children's judgments.

In utilizing Siegler's rule assessment method, several caveats must be kept in mind. As Wilkening and Anderson note, and Siegler admits, the method only permits consideration of a limited set of task embedded questions. So, for example, children's responses to feedback of any kind are not measurable. The significance of feedback is understood by Klahr and Siegler, in the training studies, to lie in the fact that "recognition" of error leads a child to choose a different response; in fact, it is when a child changes a response pattern that we say "recognition" has occurred and this may arise because of feedback that is not counted by a formal task analysis.

Klahr and Siegler say “older children are more adept than younger ones at mastering many novel problems on which task-specific knowledge is equally lacking” (1978, p. 74). It is argued here that the equality of task-specific ignorance is only measurable in terms of a formal task analysis. In no other context could one possible compare problem- solving capabilities, and no such pure context can ever exist.

The present analysis attributes the productivity of problem-solving strategies to the variety of effective responses vis a vis the task, defined in a broad sense. While this includes the use of feedback, familiarity with and attractiveness of materials, it primarily imputes the social context that mediates all of the more abstract behavior generally associated with successful problem solving.

Functional Measurement

The method of Norman Anderson and his co-workers, called functional measurement, or information integration theory, represents another formal task analysis seeking to characterize children’s knowledge structures. The challenges that information integration offers to rule assessment will be mentioned briefly and then the limits of this approach in the study of problem-solving will be discussed.

Wilkening and Anderson’s criticism of Siegler’s method (1982) is basically two-fold: first, the authors say, binary decision trees do not and cannot represent children’s judgments, especially integrative ones. Therefore, Siegler’s system may misrepresent children’s knowledge.

Concerning integration versus binary choices Wilkening and Anderson (1982) are not concerned with “the empirical correctness of either kind of rule for each may be valid under different conditions, but [are concerned] with the diagnostic adequacy of the two methodologies." For example, rule assessment, according to them, cannot fully explain the varying responses to conflicting dimension problems nor can it specify the rather global transition phase from Rule III (advance concrete operational) to Rule IV (formal operational) it posits, beyond "muddling through." The criterion for the categorizing cannot be validated.

Relying on binary decision trees for evidence of logical thought may "mask true knowledge," say Wilkening and Anderson. Even Klahr and Siegler noticed more advanced reasoning in children's verbal responses compared to their non-verbal choices. According to Wilkening and Anderson, Siegler's method systematically obscures the possibility that children are using an algebraic integration rule. For example, if a child used a weighted addition rule on the balance scale task like 2w + 1d, rule assessment could evaluate the child at two different rule levels for two different sets of problems; in the case of a multiplicative integration rule, the child is always assessed to be at the higher level by Siegler's method: the decision tree Rule IV implies knowledge of a torque principle when in fact a composite adding and multiplying rule may be being used. A torque rule in Siegler, Wilkening and Anderson note, is a "default rule."

These authors' response to the balance scale task is to use an "adjustment procedure" which allows testing of transitional problem forms. These graded problem series are sensitive to the process by which young children integrate information, i.e., using subjective weightings, rather than ignoring dimensions entirely. Children in this procedure are asked to balance a scale with one weight opposing systematically varying corresponding weights places by the experimenter. This method allows the experimenter to see gradations in children's judgments, such that they can be described by an algebraic rule which integrates both weight and distance information.

Information integration methodology also raises the question of the sense in which "representations" or "rules" are independent of the task presentation. We have evidence that two different formal descriptive systems, namely decision-tree and information integration, may be derived from children's actions in two different task settings. This simply indicates that other variables than weight and distance, in the case of the scale, are part of what influences children's judgment activity.

Generally, cognitive theory seeks to standardize task settings in a way that maximizes children's performance according to what is the most advanced thinking possible as was mentioned for Inhelder and Piaget's examination of children's proportionality schemas. This is legitimate to do if knowledge is viewed as a production system, in which case, we cannot resolve Siegler's argument with Wilkening and Anderson, since evidence for both models can be found. But, as Istomina (1975) showed, when she had preschoolers perform memory tasks in playroom and laboratory settings, less static descriptions of thinking are necessary if we are to account for context discrepancies in children's performance. Istomina's work demonstrated that there is no context in which non-formal variables do not operate, especially for very young children; in assessing children's learning, one can, however, choose to ignore these variables. Accordingly, explanations of concept development based on task analyses could be extended if it could be shown what the examples of balance scale are that children generally encounter and what their experience is with the task settings, such that rule formulation is evoked. We might, alternatively, decide that our goal is to train specific correct performance with a specific scale apparatus, and then see which rule analysis facilitated the training, as Siegler does propose.

Wilkening's and Anderson's model is also constrained by task presentation conditions. We might suspect that different integration rules are acquired under varying task conditions, although at this point all we know is that different procedures measure the effects of different variables not inherent in the problem.

The questions raised in this work concern getting beyond relativism in task analysis. We have seen two approaches that led us to this point: controlling some of the variance in subjects' responses, as Siegler does, for the sake of developing generally effective training procedures, and, controlling another part of the method variance, like Wilkening and Anderson, to derive individual integration rules but which cannot explain how they came to be acquired.

Also of concern is how children move from a level of understanding N to level N+1. Siegler demonstrates an optimal range of new information to encourage learning, but he does not analyze the process of task control, i.e., how children cease irrelevant responding. In some cases children regress in their thinking (Perret-Clermont, 1980); formal task analysis cannot account for this phenomenon. According to the present framework, a problem exists concerning where information about variables affecting performance could be sought. Wilkening and Anderson, criticizing a Piagetian stance that young children cannot coordinate information from two dimensions (1982, p. 219), quite rightly do not take children's verbal reports as evidence for the learning process. However, there is another sense in which protocols of communicatory activity accompanying problem-solving may be useful; as Piaget himself does in part, one may use this source of data to generate clues to the non-formal processes at work.

Summary

Each of the approaches to cognitive development discussed above relies on a structural task analysis in describing and delimiting children's unfolding learning an understanding.

The Piagetian model of the task is driven by a more general model of developmental stages and, in particular, development as a process of decentering away from egocentric cues in problem-solving to logical abstract ones. Although the factors considered by Piaget in his description of concept development comprise both a formal dynamic principle of problem solution (force) and the use of feedback by the subject in schema formation (assimilation), the final mapping of what it is children "known" excludes the experimental factors entirely; the INRC group is pure, formal logic.

Siegler uses a static notion of the balance scale problem, where operating rules are arithmetic; Wilkening's and Anderson's analysis allows a more individually dynamic system to emerge by formulating an algebraic integration rule system; Piaget's, the most dynamic task analysis looks for the development of reason in the interaction of formal schemas and external events. These approaches lead their proponents to evaluate problem presentation conditions only insofar as they influence the experimenter getting at the "true" concepts. An investigation of influences of context on the learning process are not motivated by these approaches.

Siegler acknowledges the limits of his measuring devices and the arbitrary performance criteria selected. He argues that these factors are reasonable approximations of standards by which most people would agree children "understood" a concept. The rule assessment model can account for the majority of subjects' response patterns on the task; in training sessions, Siegler shows rule assessment to a be a useful guide for the teacher, in choosing concepts to emphasize.

Wilkening's and Anderson's main objection to using rule assessment is that it may not accurately represent the actual computing process children employ in multidimensional tasks. They suggest a critical predictive and descriptive problem if a method fails to capture individual differences in information integration. Wilkening and Anderson claim greater predictive power of children's patterns, utilizing information integration procedures.

Each of these analyses begs the question of how concepts get to be used by the child, because they do not directly address the issue of whether the variables measured by the model correspond to those which influence how children learn in the first place. A look at problem-solving, the active sense of concept formation, in a more everyday context, using the social variables previously omitted from the analysis, may permit better specification of the relationship between the task structure, the task presentation conditions, and the probability of learning occurring for the child.

Chapter III

The Social Context of Problem Solving

In Chapter II, Piaget's theory of the development of the proportionality schema was said to share a structural task-analytic feature component with models developed by contemporary cognitive psychologists. In two respects, however, Piaget's theory cannot be entirely grouped with these structural approaches. First, his task description is based on the structure of formal logic, while the others' are based in Newtonian physics; second, Piaget's theory includes the axiom that knowledge derives from action, not from objects per se. This axiom leads Piaget to consider, in theory at least, features of the learning process besides the match of the task to the child's representational system.

In this chapter, a larger context of learning is considered; more specifically, the arrangements by which activity that leads to learning is promoted by others.

In some of his work, Piaget studies the child encountering information which causes a change of viewpoint (Piaget, 1965; 1958). His views on the matter changed, as will be discussed. The position he ultimately took concerning the contribution of others is now being tested by researchers in the Swiss tradition, with the results that the later theory is being challenged. In fact, as will also be discussed, the challenges to Piaget offered by the Swiss in their most recent work, are based on relationships in the data predicted by Vygotsky, to whom the Swiss do not refer. In the present study, we seek to compare the theories directly.

While Piaget says that knowledge derives from action, the exact connection between the two has not been delineated for specific domains of knowledge. Studying the “ideal equilibrium that is described axiomatically is realized by practice” (Piaget, 1976, p. 166). In the present example, since a scale does not exist in purely axiomatic form, neither one must argue, does a child’s “deficit” or illogic exist apart from the very specific history of activity that produced it.

Rather than being seen as a function of practice problem-solving is most commonly judged to be a function of task difficulty and individual capability. This capability is said to be comprised of a knowledge base and strategies for accessing knowledge (Keil, 1981; Klahr & Siegler, 1978). Studies in this tradition concerned with the development of problem-solving skills do not take into consideration the circumstances under which the “skills” are to be applied, though it has long been known that factors such as familiarity of setting affect performance (Cole & Scribner, 1974). Even Piaget’s approach to children’s developing cognitive sophistication attributes change in the child’s reasoning to a “decentering” process of the schemata, necessary to and arising from the recognition of alternative viewpoints, a result of “social” encounters. However, the impact of the “social” setting on the development of thought is unexamined in his work (Hatano, 1982).

The view of the development of problem- solving which is assumed by Soviet psychologists working in the tradition of L.S. Vygotsky, conceives of skills acquisition in quite a different way. The universe of experience is seen to be carved up into functional domains by members of a culture. Different configurations of material, inter-individual interactions serve to delineate domains of activity so that the social setting affords differing opportunities and circumstances for such nominal acts as "problem-solving." Supporting this view, recent studies have begun to measure the ways in which interactions work to select cognitive behaviors from a child's repertoire in particular contexts (Wertsch, 1980; Ratner & Bruner, 1978; Stern, 1974; Inagaki & Hatano, in press).

It is argued here that the development of problem-solving is best studied under conditions in which general factors of setting and task are considered. We may take a problem domain for which the data from task analysis offers a good description, and look at how social and material conditions promote and select the sequence of discriminations needed for solution.

In the first section of this chapter, Piaget's account of the larger social setting will be briefly reviewed. Following that, work being carried out in Switzerland that explores social and cognitive interfaces will be described. The latter has shown a change over time, as Piaget's own work does. The conclusions of the first major study, discussed here in detail, have in part been amended by more recent investigations, which are also mentioned here. This work will be compared with recent studies arising in the Soviet tradition of educational psychology, according to the theory of L.S. Vygotsky.

Cooperations and Operations

Piaget's theory of Co-operations, or group cognitive activity, may be treated virtually independently of his theory of the proportionality schema, discussed in Chapter II, since his work on cooperation was not applied to this task content. While Piaget does not claim that physical reality is independently knowable outside social reality, he does overlook the contribution of social experience to the child's patterns of access to the physical (Newman, Riel & Martin, 1982). His later “dialectic” approach addresses one traditionally defined duality, that between internal and external experiences for an individual (1948); it does not address the mutually transforming quality of inter- and intra-individual activity, which have been studied, for example, in work on mother-child interaction (Stern, 1974; Tronick, Als &Brazelton, 1979). That is, while his theory considers the effects of the social environment on the individual, and the individual’s level of participation in the social world, he does not discuss the individual’s impact on the world from moment to moment, which changes the system of operations.

Conflict of viewpoint is said to be the way by which social interaction serves to motivate cognitive change (Piaget, 1948, 1976; Kuhn, 1972; Perret-Clermont, 1980). For Piaget, egocentrism, wherein thought is assumed to occur as a result of subjective activity, commonly characterizes all early thought, and has three consequences. According to Light (1979), the consequences may be grouped as follows: a) the confusion of subjective justification with verification, motives with causes, and psychological activity with physical mechanisms, b) difficulty in exchanging information, and c) plays as a frequent activity, reflecting egocentrism in its purest form.

Piaget’s position on the role of social experience has changed over time. His early statements claim that social input is necessary to jog the child from an egocentric stance so that the self and the percept (on contiguous percepts) are caused to decenter, by refocusing attention (Piaget, 1932). More recently, Piaget denied a cause-effect relation in stating that the inter-individual level of development reflects the individual, that they are “two aspects of the same reality” (Piaget, 1965, p. 158). His argument is one of complementarity; that is, logical groupings are said to result at the same time from the input of others with varying viewpoints, and from the individual's assimilation of the regularities of experience into his/her unique history. "It is meaningless," says Piaget, "to wonder whether it is the cognitive cooperation (or cooperations) which engender the individual operations or the other way around" (1969, p. 118). They are manifestations of the same organizational level from the point of view of the action of the individual child. He demonstrates his point by arguing that a single person could not possibly construct all the possible viewpoints of a concept, nor could the person then recall them all simultaneously to group them, causing the social environment to be viewed as a necessary mnemonic, or input device. Obversely, he writes, in order to participate in such "collective conservation" (1976, p. 165) the individual must already be capable of intra-individual reciprocity that characterizes general forms of equilibrium. Piaget writes, "Grouping is a co-ordination of operations, i.e., of actions accessible to the individual. Co-operation is a co-ordination of viewpoints or of actions emanating from different individuals" (1976, p. 163).

For Piaget, the schemata of social cooperation are not the same as the schemata of operational concepts; however, the two types of schemata have corresponding relational structures. In that sense, they are two sides of the same developmental coin.

Piaget defines cooperation as the joint activity of people who have achieved operational thinking since operations are governed by reciprocity. Piaget poses a question which he later dismisses, in order to explicate the simultaneous nature of cooperations and operations: why does cooperation not precede operation? For Piaget, cooperation of any kind (moral, cognitive, etc.) is not possible before at least concrete operational stages exactly because of the reciprocal and generally equilibrated nature of exchange and viewpoint. Earlier social exchanges are egocentric: they are social only from the viewpoint of the child; the informative actions of others are assimilated to the child's actions. Later, social input is assimilated to coordination of a child's actions, i.e., to the logical operations (1969, p. 118) and this are cooperative.

The non-specificity of Piaget's claims led researchers in the Piagetian school (Perret-Clermont, 1980) to seek the exact level of operational development at which cooperation would be possible. But the question for the Swiss researchers, who were motivated by practical issues of classroom curriculum design, became: In what way did the cooperative schemata aid or organize activity independently of the cognitive schemata? These investigators wondered if attention to the social aspects of the classroom setting would reflect in children's learning responses. Asking such a question begins to tease apart the operation/cooperation duality.

Cooperations and Conflict

Piaget's dualistic definition of operations and cooperations cannot explain the findings of children doing better in interaction than when alone (Koltsova, 1978), or doing worse (Beaudichon, 1977; Martin, 1979), since there is no basis on which to hypothesize decalage of this sort. In a research program that began in the mid-70's a group of Swiss investigators have been looking at children's cognitive "restructuring" in relation to group coordination. The problems Piaget's theory poses in view of empirical findings is grappled with by Perret-Clermont in series of studies.

Perret-Clermont's particular investigation (1980) looked at some aspects of the conditions in which the coordinated actions of individuals facilitate the emergence of operations. The enterprise is based on certain assumptions consistent with Piaget's views. The important ones to note are:

1) Cognitive activities and social activities are separate domains. Previous work leads Perret-Clermont to delineate some overlap between the two domains and to devise ways to measure performance in overlap situations. The delineation process entails discovering "what characteristics of social interactions are likely to lead to mental growth" (1980, p. 26) and how children perceive each other "apart from actual [cognitive] equality" (1980, p. 20).

2) The "necessity to resolve conflict" ultimately resides within the individual. One may have one's viewpoint challenged by encounters with others, but the drive for organization and equilibration is what motivates the knowledge groupings. Perret-Clermont addresses the question of whether a child "in the absence of social situations" (1980, p. 179) is sensitive enough to detect equilibrations. She concludes, with Piaget, that an individual cannot form groupings independently but, at the same time, individuals must do their own assimilating and structuring of the new viewpoints encountered.

3) "At certain phases of development the common action of several individuals depends on the resolution of conflict between their different centrations and this state of affairs leads to the construction of new coordinations in the individual" (1980, p. 26). Hence, as a measure of learning, one would take pre- and posttest individual performance and not a group performance measure, in keeping with standard individual measurement of performance. This also means that only particular types of argumentation will be admitted as "conflictual;" namely, ones that relate to the problem

(logical operation) being tested. Perret-Clermont distinguishes the object of analysis from Inhelder's notion of a conflict between hypotheses and observation, and from Lefebvre-Pinard's notion of conflict between different schemas. Further, she posits a "third type of cognitive conflict, socially experienced" (1980, p. 31).

4) The clinical method of verbal probing allows the experimenter to verify inferences about the meaning of subject's acts (see also Wilkening & Anderson's criticism of Siegler, 1981).

Perret-Clermont has several objects of experimental investigation. She looks at the effects of group coordination on conserving behavior, on individual cognitive restructuring, at initial cognitive level as a factor in cognitive change, and at the effects of working with a less advanced partner. The experimental goals include: 1) to show that certain interactions can produce an effect at the level of individual cognitive structure, 2) to examine the nature and role of interactions and structural transformations in subjects in detail, 3) to show transfer across conservation tasks, 4) to investigate "prerequisities" for social interaction and the level of cognitive comprehension which subjects must possess before a given interaction causes cognitive development, and 5) to specify changes in subjects who are already at ceiling by looking at the "role of the type of conflict brought about by different centrations" (1980, p. 148).

Some methodological problems mar the empirical studies in this Post-Piagetian research. For example, individual control subjects have less contact with the test materials than the children in the experimental groups. Also, the elimination of task irrelevant talk from the protocols limits the experimenter's ability to test the overlap of the social and cognitive domains. Still, for the present purposes, we shall review the work, since it is the most extensive one reported addressing the issues of concern.

The basic conservation task Perret-Clermont uses began with protesting 100 5-7 year olds on a task which consisted of sharing juice equally in two different glasses. Children were then scored according to their level of performance as being Non-conservers (NC), Intermediate Conservers (I) or Conservers (C). Two weeks later trios of children consisting of two C's with either an NC or an I were given to the same juice task. The NC child did the pouring and children were not permitted to drink until everyone agreed that they had the same amount to drink. One week and one month later each child was tested individually again, and a new glass was added. One to two observers noted procedures, the experimenter's interventions and relevant (i.e., conserving) actions and words of the subjects.

Generally, results are reported showing advancement in the experimental treatment groups that is maintained through the second posttest. Perret-Clermont concludes that "this new ability cannot derive from the assimilation of others' behavior . . . but must derive from nothing less than the <u>creation</u> of new operational structures" (1980, p. 64; see also Kuhn, 1972).

Perret-Clermont's research turned up several interesting points. For one thing, the children are seen to convey coherent messages about physical laws. This is not always seen in studies of children working together. It has been noted elsewhere that children's performance may suffer because they mix each other up, with messages becoming unparsimonious and disruptive (Beaudichon, 1977). Secondly, all subjects finished the tasks despite the presence of "emotional" conflicts Third, there is evidence that transfer occurred to a new glass, a new social context, and to other conservation domains, in another experiment, though the relation between the mode of acquisition and the task demands is not discussed.

If we start with a different set of assumptions for Piaget, these results raise further questions. To begin with, there is a problem of circular definition. The children who do well on the pretest are said to be operational. Their reasoning is said to exemplify good argumentation because the children have the ability to conserve. Yet, "ability" is the name we give to people who do well on the test. Children who performed at higher levels may be more aware of what the experimenter is getting at, not because they are operational, but because they realize that someone taking them to a special room to share juice may have something else in mind: this juice game isn't what it seems. Children who don't see a conservation problem may not detect a "test" and in both cases this might vary as a function of other children being present or not. Evidence for this effect can be found in Martin & Koltsova (in preparation; see also Mugny, Doise & Perret-Clermont, 1981). Perret-Clermont, however, asks "but would a knowledge of the subjects' true interpretations of the instructions add to our understanding of their behavior? While this question is an interesting one, it is not fundamental" (1980, p. 29). A large body of cross cultural literature demonstrating performance differences due to instructions shows that this question is fundamental; it has become one of the most important methodological issues in the field (se Cole & Means, 1980).

In Experiment 2 of her series, Perret-Clermont noticed "constellations" of partners, classified according to conserving or non-conserving responses made during the collective sessions. Because of her notion that posttest performance constitutes the dependent measure, the constellations are not seen as valid indicators of "knowledge;" conservers who make non-conserving judgments during the group sessions are said to "behave like" non-conservers (1980, p. 113). On other hand, assuming that the same nominal task occurs in the two social settings, individual and collective, is not warranted (Cole & Means, 1980); while avoiding this assumption would allow an explanation for anomalous performances, it would also vitiate the value of the individual-group-individual design of the experiment in relation to the measures.

Looking at consistency of argument during group sessions she notes:

> If this efficacy of inter-individual consistency needs to be explained in the absence of an effect of intra-individual consistency, then it seems more appropriate to explain it, not as a process of social influence, but in terms of the fact that inter-individual consistency gives a different point of view greater salience in the eyes of the subject.
>
> None of the results we have indicate that such influence processes are the cause of the cognitive development in our subjects. (1980, p. 111)

That is, if the children don't display the same cognitive ability during group interactions, the factors responsible for the behavior in the collective setting are independent of those that cause a child to make cognitive gains.

Another argument Perret-Clermont gives against using group measures is that conserving or non-conserving agreement did not predict subsequent gains. "Our interpretation is that the development in non-conserving subjects is not stimulated by influence, persuasion or dominance on the part of the conservers, but rather by being confronted with a different viewpoint" (1980, p. 114). In other words, "social" organization or skills are unpredictive of performance since the effects of the influence of others, measured by consistency of argument and agreement, is not found; rather, the informational content of a communication is predictive. This series, however, seems to yield no way of testing whether social skills promote or repress the likelihood of information being heard.

When Perret-Clermont mentions that the experimenter has to step in to either keep the conversation going or to direct arguments away from getting too "emotional," she omits analyzing a critical portion of the "clinical" situation. Adult prompts, far from being negligible, may strongly cue children to attend in a variety of situations (Greenfield, 1966; Wertsch, 1980; Mehan, 1978). Learning resulting from prompts concern the task frame itself; therefore, analysis of the experimenter's input could yield important information about setting and age differences.

Similarly, what children do besides learn about the task is relevant. Such analyses, however, require a framework that views the interviewer and the children as creating and maintaining (or, co-constructing; Light, in press) a social situation in both individual pre- and posttests and in the group treatment condition.

To summarize Perrer-Clermont's 1980 conclusions, she claims that individual restructuring occurs because of cognitive conflict experienced in interaction.

Furthermore, "the child who is already relatively advanced can progress just as much as the less advanced child, in a situation in which two children are finding ways of coordinating their activities" (1980, p. 27). She describes children as first recognizing conflict without assimilating alternative viewpoints, and then coordinating their viewpoints into a joint system by imitating and elaborating others'. A "social learning" explanation for the effects of interaction with others is rejected, as is that of the limited "equilibration model," which says a superior model provides stimulation rather than a form to model. Both these positions assume a more advanced model being present in the interaction, whereas Perret-Clermont finds that only a different, not more advanced, viewpoint must be expressed. Perret-Clermont says benefit accrues if "the difference in centrations and the nature of the collective task call for reorganization of coordination between the partners" (1980, p.172). It is important to keep in mind that the task referred to here is a single arrangement of a conservation task embedded in juice-sharing.

Although she simplifies "social learning" theory, Perret-Clermont claimed that its proponents could not explain why a less advanced model is not likely to be imitated, nor why imitation studies don't show as big gains as the "restructuring" studies. According to her, equilibration theory says a superior model provides stimulation, not a form of thought to imitate, and it also predicts an optimal "gap" between the model and the subject (1980, p. 171). Perret-Clermont criticizes the social modeling theorists (Rosenthal & Zimmerman, 1972, for example):

> While imitation, as a process of assimilation, may eventually explain certain instances of development, it is important to emphasize that social interaction does not merely offer a kind of 'intellectual

> nourishment' to assimilate, but rather stimulated an activity of <u>accommodation</u>, and it is this which creates new development. If children were fashioned in the image of the behaviors which occur in their social environment, the presentation of less developed models, or interaction with them, should bring about regression; on the contrary, however, we have shown experimentally that in certain cases children are impermeable to such influence. (1980, p. 174)

This is a very simplistic notion of modeling as necessitating a one-to-one correspondence between the world and the information learned. In addition, Perret- Clermont's alternative explanation as "accommodation" has the same problem of circular definition referred to above.

> For a certain type of social interaction to occur, the subject must have minimum cognitive competencies in order to be able to participate in the interaction, and, if this condition is met, structuring in the subject. (1980, p. 145)

That children engage in the type of conflict they are ready for is close to a tautology and is not useful for an analyst.

Perret-Clermont discounts peer pressure as the cause of development (though it is observed among her subjects), and discounts as well the effect of the correctness or consistency of argumentation, although conservers tend to dominate interactions and to present more "salient" arguments. It is meeting a different viewpoint that counts. When conservers became aggressive, however, it is not considered to be "cognitive conflict," rather, "true conflict" is said to have been "masked." Evidently, only one type of outcome from interaction is counted, and everything that doesn't co-occur is labeled and pointed to as non-contributing. What we really have is a description that, at the least, demands cross-validation and further examination of the situational variables actually operating.

The assumptions of Perret-Clermont concerning the spheres of "social" and "cognitive" are limited by the Piagetian framework from which they arise, preventing a test of any variables outside the explanatory framework. For one thing, there is a confusion between arguments of social content (e.g., domination) and arguments of social form (cooperation). An inter-individual discussion about a logical issue is considered cooperation but one concerning other content is not, by Perret-Clermont's operational definition. However, socioloinguistic work has shown the necessity of this "social" content in maintaining "cooperative" interactions (Wertsch, 1980).

Just as recent developmental work finds children capable of perspective-taking at earlier stages than Piaget posited (Light, 1979), so previous work has revealed that the interface of "social" and "cognitive" is more complex than formal analytic categories allow. "in working out experimental methods for studying this problem [cooperation] Piaget…remained at the level of finding empirical confirmation of his logical schemata" (Rubstov, 1981, p. 46).

Cooperation and Communication

It has been argued that in considering an individual's experience with particular problems, or classes of problems, the contribution of the social setting in which problem-solving occurs may enter into the development of intellectual functions more centrally than heretofore suggested.

The series of studies published by Perret-Clermont in 1980 addressed important practical questions and represented a very well reasoned examination of group interaction, within the constraints of the Piagetian theory. The limitations are seen in the fact that, much as Siegler and Anderson assume the scale task only concerns pieces of the apparatus, Perret-Clermont assumes that the socially experienced cognitive conflict includes only others' principled statements. The Piagetian system yields another formal view of the development of understanding. There is no real way one may ultimately derive an explanation of change-of—viewpoint without an analysis of the way in which the viewpoints got internalized; without this, their operation can't be explained. Recall that Siegler arrived at this conclusion as well (1981).

Why does a child, at certain times, act as if s/he "knew" something (showed "understanding")? In order to understand why two children who scored the same on a pretest learn differently from the same teaching procedure (Klahr and Siegler, 1978), especially if the children were being presented with alternative viewpoints to consider by the teacher, one would have to vary the conditions of acquisition as well.

Interestingly, when confronted with differences between immigrant and native Swiss children on the standard tasks, Piagetian researches began to seek the social experimental origins of the differences, and to train the immigrant children up to the standard. In doing so, these researchers unwittingly reconstruct Vygotsky's theory, as we shall show in another section.

Children's interactive, i.e., communicative, abilities concerning problem-solving are well known to depend on such factors as social relationships in the test setting (Labov, 1972); "intersubjectivity," or the sharing of semantic common ground (Rommetveit, 1979) and setting (Istomina, 1975; Cole, Dore, Hall & Dowley, 1978); familiarity with test materials (Brown & DeLoache, 1978; Chi, 1978); and the form of the materials (Gregg, 1978).

A study looking at communicative efficiency in 6-10 year olds under problem-solving conditions (Beaudichon, 1977) found that "across the entire age range, the children showed little ability to say only the necessary information" (1977, p. 336). Additionally, different children did not use the same communicative means for the same content. Beaudichon concluded that "communication efficiency improved with age, for reasons owing to cognitive and linguistic development rather than relational capacities (attending to the other person, the desire to successful communicate, etc.) or the qualitative broadening of the means employed" (1977, p. 372).

This conclusion however, could be seen, not as a causal, but rather as a descriptive statement concerning the socialization process into problem-solving. That is, development may be looked at as the suppression of irrelevant responses, or, the strengthening of the task control, in particular settings (Luria, 1932). The efficiency of children's messages measures the extent to which they are "social" beings in a culture. Beaudichon feels, too, that egocentrism fades because of a communicatory activity, not that any lack of perspective inhibits perspective-taking. If we think of the child, not as egocentric, but as responding as a result of internalized social events, and as in the process of being socialized, the control exerted by the task organization itself must enter into the analytic picture.

Like Piaget, I claim a complementary relation between the individual and interpersonal factors. Interaction is the condition under which encodings may be improved and decodings refined, depending on the extent to which the "referent" affords communication by the individual. Beaudichon's work is useful in supporting the idea that communicative behavior depends in part upon what could be called task control, i.e., the subjective task vis a vis the nominal task. For the Piagetians, the cognitive task, even as it is embedded in the juice-sharing task, is assumed to remain invariant.

It appears that a theory which explains the process of inter- to intra-psychological development is needed for clarifying the process of developmental change. The Post-Piagetians can demonstrate movement of between-subject thinking to within-subject thinking by varying the social acquisition conditions, (for example, by asking subjects to enter into conflict with an experimenter, a peer, or with a doll). Their studies suggest that the notion of the task, the participants' "understandings" and the status of the partners as models all affect the likelihood of cognitive change (Mugny et al., 1981). The formal task is not seen to change. In contrast, Soviet psychologists seek to delineate the material task conditions that may give rise to particular kinds of social exchanged that may or may not lead to what psychologists count as problem-solving.

Cooperation Types and Organization

In turning to Vygotsky's theory and to empirical work in that tradition a principled basis for including inter-individual variables in the analysis of problem-solving becomes available.

Vygotsky's view is that what become individualized responses are first experienced socially, in contrast to a Piagetian view, which sees the child as internalizing patterns of action. Vygotsky expands on the concept of action, which ineluctably implies subject, object, social setting, and the uncertainty generated in living human activity. "In distinction from Piaget we propose that development does not proceed toward socialization but toward the conversion of social relations into mental functions" (quoted in Wertsch, 1981, p. 34).

Not only does Vygotsky see relations with objects and others as socially defined but he also suggests that the same activity can be carried out between people or individually, as a cognitive process. (This is not to say that action and thought are isomorphic; for Vygotsky, these are at different levels of functioning). This view gives rise to the concept of the Zone of Proximal Development. The idea of the Zone stands in contrast to the performance sampling procedures we generally use in any problem-solving situation: The child is changed in the course of the experience. The metaphor of a "zone" also includes the notion that the "expert" and the "novice" distribute the problem-solving task between themselves. Because all the information that is needed for a problem solution is available in the interaction, the "expert" can allow the child to take on a greater part of the solving operation as the child shows mastery of the simpler task. If we look at a test as a measure of the instructional distance between a child's current understanding and the culture's (teacher's) state of understanding, it would permit a more accurate assessment of the relation between the child's "knowledge" and the tools needed for changing the knowledge. It can be seen that the Zone notion is a process version of Siegler's description of the difference between state N and state N+1, describing the movement between the two states. It is not a child's ability to solve a problem that is sampled but the discrepancy between the child's performance and the level to which the child may be trained. Siegler accomplished this in a similar sense with his training procedures, although he did not recognize its significance. Vygotsky says, "Studying the child apart from the influence of instruction, as Piaget did, excludes a very important source of change and bars the researcher from posing the question of the interaction of development and instruction particular to each age level. Our own approach focuses on this interaction" (1962, p. 117).

Most significantly for Vygotsky, it is the instructional process that mediates between a child and direct experience. The teaching/learning process serves to locate concepts in relation to each other, i.e., to stimulate the logical, abstract groupings concentrated on by Piaget. This effect is heightened for children attending school. Vygotsky's theory never minimizes the extent to which the hand of the adult (or expert peer) is present in arranging these locating and relating experiences.

School particularly confronts the children with orderly, culturally delineated "scientific" concepts that bring to conscious thought or to practice the interrelations between the events the child may have experienced separately in the less structures preschool existence. The specific properties abstracted from scientific objects are also functionally part of the socialization processes, because these objects are both the route to practical activity and the transformers of that activity.

This approach to development means that with children of early school age, it may be critical to observe and characterize the kinds of inter-coordinations that may be generated under specific interactive-task organizations. In doing so, the variables influencing children in different states of “scientific” development of the kind exemplified by the balance scale problem may be better illuminated; we may then better address the directionality issue of cooperation and operations such that we can increase the chance that information will be utilized for learning.

In an attempt to establish a correlation typed of coordinated actions and content of knowledge structures, V. V. Rubstov of the Soviet Union designed an interesting procedure: using a Piagetian classification problem of overlapping objects sets as the nominal task, children of different ages were requiring to arrange particular sets jointly (1981). The tokens to be arranged varied on two dimensions; wood/metal and circle/rectangle. Children were presented with a series of set-construction problems that, according to Piaget’s task analysis, should progressively require the concept of reversibility for accomplishment; that is, the harder problems require that the child keep the equations describing the relation of a whole to its parts in mind at once (A plus A’ =B; A-B minus A’). By matching the elements of the conceptual problem directly onto the individual’s roles in the group, Rubstov hoped to detect how a child’s operative or cooperative activity may be advanced.

The procedure resembles a kind of role-playing, with children unwittingly taking on the role of abstract properties of the object to which they are assigned. As the experimenter sets the ground rules for the game, or activity, the children guide their actions accordingly, through the medium of their “role.” Since they all, presumably, would like to accomplish the game’s objective, they take their task seriously and cooperate to accomplish it. In doing so, they necessarily run into the constraints of others, or rather, of the other roles. In that way, dialogue is generated that involves the conceptual problem. The cooperative goal is super ordinate, and serves to keep the children's actions tied to the conceptual task. The experimenter, of course, can vary the super ordinate goal in a way that facilitates different patterns of cooperation, and, perhaps, different conceptual discriminations as a result. In Rubstov's groups, the adult continually reframed the goal so that the necessary coordinating became based upon more and more problem elements at once.

In Rubstov's method, there is an isomorphism between physical rule and group scheme that affords control and measurement of the interaction in a way that directly addresses the theory of operation and cooperation. Rubstov writes, "We assumed that the organization of a jointly accomplished activity of a group of children involving the inclusion of a particular set of objects in a general class would establish the appropriate relational structures within the relationships among the participants themselves" (1981, p. 47).

Thus, though the data collected were correlational, it was assumed that if the experimenter varied the inclusion task, the subjects would be forced to cooperate in different was. The individuals, in the context of a particular problem, would revise the "schemata of joint activity" (1981, p. 47).

After giving the subjects, children between 5 and 15 years, problems involving non-overlapping sets, the problems changed so that

> The use of these objects was a material 'prohibition' on the previously used forms of distribution, and forced the children to look for new forms of joint work, to redistribute and exchange their object procedures; and this led to the development of new mutual relations.

> By observing the activity of the children in this context of this redistribution, the experimenter was able to study the composition of the mutual relations, their distinctive features, and their uniqueness. (1981, p. 13)

Children were seen to advance in thinking during problem-solving, by Piagetian standards. This result is attributed to the fact that a new and specific action of transformation leads to new discriminations and new assimilations and also, most importantly, at a refocusing of task goal to a more general or abstract level. By participating in an activity whose goal is shared, the child discovers that the operation of object transformation is common to all the participants.

Analysis of children's activity yielded three distinct types of cooperative activity, and these were compared to Piaget's stages of logical thought. The three types of cooperation discerned may be briefly characterized as follows: Type 1 – the absence of interrelations among the group members. The type of conflict generated here is described as "due to indifference to others" (Rubstov, 1981, p. 56). Type 2- children were likely to substitute their own procedures for that of another child, in a temporary exchange of viewpoint. Mutual exchanges, though present, were never combined into a unified solution. Type 3 – children exchanged procedures but opposing procedures were treated simultaneously for an overall viewpoint of joint activity, accomplishing a single solution.

Three points should be noted about these observations. The first is that in Type 2 exchanges, temporary decentrations were observed. Such behavior is explained by Piagetians by saying the child doesn't have complete grouping ability and therefore can't hold differing viewpoints at the same time. The schema-assimilation model, however, does not specify the manner in which the new discrimination, articulated and then dropped, comes to be reliably produced. By Rubstov's analysis this type of temporary centration may be a function of the task goal organization, which needs to be varied before assumptions about the child's learning capability are made.

Second, because of its assumption that the individual proceeds from the "social" (which is mixed with the "material"), Rubstov's theory can point to new, individual knowledge as the result of a process of internalizing a "condensed form of mutual relationships" (1981, p. 24).

Although Rubstov does not report on subject selection and group assignment, and although it does not appear that subjects were matched according to classification stage, the groups studies could be described categorically by cooperative activity type.

Rubstov concluded from his work that substituting a classificatory procedure is impelled when, in a group context, participants "encounter a contradiction" (1981, p. 25) between the method they use and the outcome with respect to the group task requirements. A general correlation is thus described between the content of thought and what happens in a group. The unanswered question is to what extent the material forms embodying the problem determine what type of cooperative strategy is generated.

Summary

The distinctions between the Post-Piagetian position and the Vygotskian position are fine ones, but real all the same. Both describe the interwoven relation between the cognitive and the social. Piaget's theory specifies more closely the formal logical similarities of the two domains, while Vygotsky concerns himself with "cultural development," or, the correspondence between interpersonal and "scientific" development.

Pedagogical questions led the Piagetians to work on ways of successfully matching peers in problem-solving groups. From there, they began to ask questions about the possible causal relations between the domains of operations and cooperations. Since the time that this study began, the Swiss researches have found effects of task context on performance which are not compatible with their original viewpoint. They have not, though, abandoned the logical task as the thing to be learned. Other work, here and in England (Mehan, 1979; see Bryant, 1982) concludes that learning how to act like a learner in the task setting is, perhaps, the primary lesson.

Soviet theory has always assumed that psychological functioning occurs first on the "interactional plane" (Vygotsky, 1978). The researchers were interested to examine the origins of the kinds of concept development which, by most analyses, appear to be spontaneous. They found, like Siegler, that within certain limits, the concepts could certainly be trained. In order to understand performance at all, they argue, one must look at the interactional acquisition history.

The theoretical distinctions between the two positions, which both seek to describe the relation between social and cognitive functioning, has led to differing methodological positions. Perret-Clermont's study, discussed here, suggests that interaction can affect individual children's new reasoning about formal problems through "conflict;" however, the contribution of other factors present in the problem-solving situation are not tested. Logical statements, correct answers, and principled statements by individuals are considered as measures of group activity. In contrast, Rubstov examined how particular social grouping may cause new discriminations to be formed, not through an analysis of the information provided by others to the schemata, but by examining the organization of this occurrence: the goal of problem-solving is analyzed in the joint problem-solving situation, and can be varied to produce different interactional patterns. The Soviet work, however, appears to be limited to describing the "group types" that fall out of these goal configurations; when pre and posttest individual measures are taken, they too are correlated to these observed "group types" (also see Koltsova, 1978).

It seems as though, on one hand, we have an assumption that individual performance is countable the same way in the group and out (Perret-Clermont) and as well as assumption that the measure of group activity necessarily can be related to individual measures (Rubstov). These may arise because of previous characterization of the variables actually affecting problem-solving activity. In the present study, an attempt is made to specify and compare both individual and group performance measures. An attempt is also made to test whether an individual's initial skill level determines the nature of the interactions s/he enters into, or whether these kids can be altered by deliberate manipulations of the goal of group activity. It may be, after all, that the variables determining change of viewpoint, or learning, are best defined by an analysis of the task. This possibility is also tested with the same data, thus providing a direct basis of comparison for the theories discussed.

Chapter IV

Design Rationale

A good portion of problem-solving activities occur in interactional contexts. The work just reviewed is itself motivated by the goal of trying to understand the specific effect of schooling on different groups of children. In addition to these studies, several others have noted what at first glance may appear to be considered a paradox: groups of children of differing individual approaches (“abilities,” “levels,” etc.), working together, can be characterized systematically as a group (Martin, 1979; MacCombie, 1978; Rubstov, 1981). That is, the whole is different from the sum of its parts because individuals of presumably differing experiences are seen to act in concert. This observation, though implicit in studies of cooperation, is an important key to the analysis of the interface with which we are concerned.

Generally, studies of group problem-solving have compared the efficiency of solving problems as a group relative to individual problem-solving (see Anderson, 1961). The problem of relating group to individual performances in terms of “internal restructuring” has not been widely approached, but certain experimental findings suggest that group and individual measures may not be readily comparable. For instance, Nosulenko (1979) showed that the psychophysical scale used to estimate sound intensity changed and shifted for individuals when they worked in joint detection conditions.

Laughlin and Sweeney (1968) compared adults’ group and individual problem-solving in a series of three concept-attainment problems. Among the results, was the finding that pairs of subjects were consistently better than individuals in efficiency and focusing strategy (as judged by specific deduction patterns) and, that the focusing strategy was related to the eight different classes of concepts tested. All subjects made gains on these measures between the first and second problems but not between the second and third; group advantage also declined across problem order. In addition, it was found that interproblem consistency for efficiency and focusing was low for individuals in pairs and groups, indicating that the superiority of the group was not due to the presence of any consistently "better" individuals; some additional facilitation had occurred in the group setting.

In their discussion, Laughlin and Sweeney suggest that "concept attainment involves a complementary task," following Lorge and Solomon's (1955 Model B task. Model B describes a group task wherein each individual has "unshared" resources that become pooled in the group setting, much like Perret-Clermont's effect of conflict of limited viewpoint. [Model A, by this analysis, a "disjunctive task" (Steiner, 1966), represents the situation where the group is able to solve a problem because one member can do it.]

In a later study examining performance transfer using similar tasks, Laughlin and Sweeney found that "…there was neither individual-to-group transfer nor group-to-individual transfer, but . . . groups performed better regardless of the temporal order of the individual and group problem-solving experience" (1977, p. 250). Laughlin and Sweeney also measured the solution strategy typed of their subjects and found

> "neither individuals nor groups followed any of the pure formal strategies, such as conservative focusing, proposed in the literature. Rather, both individuals and groups used mixed strategies. Moreover, individuals and groups did not follow

> demonstrably different strategies, but groups used the same information more effectively." (1977, p. 254)

Thus, in a study which used identical criteria to judge the efficacy of group versus individual strategy, group performance was found to be superior in concept learning.

Lomov (1978) studied pairs of adults doing a series of verbal and spatial recall and perception tasks, and found that group strategies did differ from those used by the pair members individually. Specifically, he found that "focusing" could characterize the group performance and "scanning" characterized the individuals' approaches. Lomov, however, only reported what occurred at particularly "knotty" moments in the recall and detection process, so we do not know if, the whole, subjects' strategies in the two social conditions varied.

Mugny, Perret-Clermont and Doise (1981) have summarized the results one could expect from putting children together to solve a task. Below, their points are italicized, and commentary added.

1. *Cooperative performance cannot be represented by the sum of the performances of individuals in the situation*. They refer to a Model B description; additionally, the work of Anderson (1961) and Laughlin and Sweeney (1977) support this observation.
2. *Participation in joint problem-solving can lead to individual progress; group performance may not predict individual performance later, however*. Their studies show that it may be that only at certain points during the acquisition of a problem-solving repertoire that social interaction leads to increments.

3. *Cognitive gains are the result of conflictual interaction.* That is, agreement, correct or incorrect, is less likely to produce decentration. Furthermore, there seems to be an optimal range of disagreement, beyond which the arguments cease to address each other. This phenomenon is consistent with a Zone of Proximal Development notion (Vygotsky, 1978; LCHC, 1982) and with Siegler's N+1 teaching strategy. Children working alone are seen by these researchers to produce their own different arguments, but they are seen to produce them serially (Rubstov, 1981; Piaget, 1965) and thus do not benefit from their own irresolve. A group of Soviet researchers, studying the acquisition of physics concepts in school children, found that when the children worked on different aspects of the problem serially with a partner, they did not learn as much as when they worked on opposing problem aspects simultaneously with a partner (Rubstov, 1981).
4. *A distinction may be made between imitation and modeling in effectiveness: imitation produces less learning, whereas in modeling the child seems to be acting in response to a challenge experienced by the model's moves.* It may be, however, that what we call imitation is the case where we see no "learning" and that what we call modeling is the other case. Mugny et al. feel that "conflict" may be underlying the effectiveness of modeling as an instructive tool but this "conflict" is an inadequate psychological explanation, though it may be valid descritively. The effectiveness of "modeling" seems to be independent of task difficulty, as has been thus far studied, again,

suggesting an optimal and very specific "zone" of conflict for each problem activity.

5. *A partner's status has been seen to influence performance, not only because the partner may be too advanced or equally ignorant, but also because the rank of peer, teacher, playmate, stranger, etc. differentially weights the information available in the interaction.*

These points support the analysis of contexts of information exchange in the consideration of early problem-solving, since contexts may cause a shift in the variables influencing performance. They also support analysis of the organization of the problem-solving team. A review of some of the measures of interactive exchanges will follow, and their implications for studying the external-internal shift will be discussed.

Some of the variables tested and found it to be related to joint problem-solving performance include: amount of talk (Beaudichon, 1977), the frequency of giving and receiving information (Webb, 1980), and the time permitted for a task (Anderson, 1961). Even three year olds are seen to be quite capable of maintaining and controlling interchanges with peers; over time, children's initiating repertoire increases and the range of useful feedback increases (Holmberg, 1981). Presentation of correct information early in an interaction is not necessarily critical to arriving at an ultimate solution (Glachman & Light, 1979; Perret-Clermont, 1980). In children's group problem-solving, knowledge gains have been shown to be both more stable and transferable (Inagaki, 1981) and variably so (Perret-Clermont, 1980).

In the case of concept development, the two criteria used to measure performance in children of different ages are motor (e.g., a correct gesture, paper-and-pencil answers etc.) and verbal (articulation of a correct justification). But children alone and children in groups are still learning about the task contexts (Istomina, 1975) and it is exactly these two criteria of judgment that the interactive dynamics will affect. While the distribution of gesture and verbalization will also change when adults work together on a problem in comparison to solo activity, the extent to which this enters into the solution will change the probability of particular responses. If these are exactly the routes by which children learn, then the problem of comparing groups and individual children is a much more difficult one; not only can we expect a lot more "noise" to analyze, but to the extent that children are under task control, the noise will affect them differentially.

The problem with drawing on such a diverse set of measures and results is how to empirically describe the common effects of what has been called "cognitive motivation" (Inagaki, 1981) since this factor is the overriding one implicated in the literature and the least frequently dealt with. This motivation factor is, more specifically, the "frame" effect: how a context comes to occasion performance.

Interaction

The mutual constituting of social setting by participants becomes significant here in several respects. First, it has been shown that learning the "frame," learning school, is an activity constantly engaged in by teachers with their students (Mehan, 1979). Part of the lesson is shown to be communicative style (question answering, turn taking, and phrasing, for example), independent of ostensible lesson content. Second, it has been shown in schools and in home observations of very young children (Greenfield, 1980; Wertsch, 1979) that there frequently are large gaps in participants' knowledge levels but that, nonetheless, children and adults employ many devices to maintain interactions. Although it is usually the most "competent" member of a pair who is credited with the adjustment responsibility, there is evidence that young children initiate adjustment of communicative patterns as well (Tronick, Als & Brazleton, 1979). In the case of problem-solving, it is reasonable to suppose that the constituted setting as well as the individual's previous contact with the information are important to consider since the group goal depends on the extent to which partners are led to respond to each other. A problem-solving setting contrasts with a situation in which the consequences of failing to arrive at a joint outcome are negligible.

Two different types of synchronized interactive patterns have been distinguished by MacCombie (1978(: reciprocity, where two people's actions become similar, and complementarity, where actions are "different but logically related" (1978, p. 7). One could suppose that complimentarity can be nested within a reciprocal exchange, as in the case where two children are offering each other different solutions to the same problem.

MacCombie examined reciprocal behavior between pairs of 2-9 year olds in a school and a lab playroom setting. One aim of the work was to identify the mechanisms that contributed to interchange regulation and thereby to reciprocity.

All ages of children, observed in natural and lab settings, were seen to engage in a high proportion of reciprocal patters with mutual regulation. Younger children did this to a lesser extent than the older children and with less well-correlated actions between dyad members.

In the experimental part of the study, it was hypothesized that if children's reciprocity was the outcome of mutual adjusting, then having one child's activities constrained (by instruction) would lead to less reciprocity but that uninstructed partners would produce patters synchronous to "confederates."

Five-year-olds were trained by videotape and face-to-face instruction either to draw a picture with crayons or to play in specific ways with other materials available in the playroom. Experimental children, paired with these confederates, were seen to spend the major portion of their time on the same task as the confederate. While overall time spent on the same activity together among pairs was comparable to that among non-experimental pairs, separate analysis of the behavior of children who had not previously participated in the playroom, showed that they were significantly less likely to engage in reciprocal behavior. This effect was not due to the lack of invitations to participate on the part of the experienced confederates; rather, it was attributable to the inexperienced subjects' countersuggestions to do something else. That is, these subjects were simply not attracted to the experimental "tasks." Also noted by MacCombie is that reciprocal actions between two experienced children and in control pairs diminished over the observation sessions, whereas, pairs with inexperienced members started at low rates and then increased.

This study is of interest for several reasons: 1) through instructions, the experimenter “easily” influenced the activity patters of the children, 2) confederates’ understanding of the task affected their partners’ responses, 3) children experienced in the setting influenced the patterns of interaction, and 4) children’s propensities to interact with different materials affected the language patterns of agreement and reciprocity.

The Design According to Vygotskian Conceptualization

The present study addresses theoretical and methodological issues concerning aspects of performance which need to be included in an analysis of group problem-solving, taking into account the variables shown to be of significance to the issue. Two separate threads emerge from the literature, beyond those dealing with the testing context itself. The first is that the units of performance may shift depending on whether the subject is tested alone or in a group. Deciding what constitutes response equivalence, even between moments in the test session, is perhaps an arbitrary decision (Seigler, 1981). The experimenter (tester, teacher, etc.) then decides when a “concept” is used flexibly enough to be called “knowledge.” In some cases a pencil-and-paper response is called for, and in others articulation of a “reason” or a particular gesture indicate to the arbitrator that learning has occurred. But, it remains a possibility that each mode response is controlled by different variables.

Secondly, in order to measure between-subject units and trace their relationships to subsequent measures of individual performance, it may be that some of the more obvious units (e.g., the statement of correct answer) are not necessarily dependable. For instance, we don not know the extent to which a verbal confirmation or disconfirmation by partner influences the information value of a prediction.

What is entailed I an exploration of approaches to this task: Can we find predictor variables? Can we arrange them? If we characterize the process of problem-solving as that by which the child learns to respond to "tasks," independently of the factors that gave the child the initial notion that a problem existed (i.e., aspects of the social context) then the task for the researcher becomes one of measuring the probability of cognitive change as a function of the changing social order of things.

Social/Cognitive Task Analysis

If individual conceptualization is made more or less probable by the nature of the collective tasks at hand, we should find variations in learning by arranging different conditions requiring children to solve balance scale problems. Because the conflictual situation can be varied in many ways, an attempt was made to select arrangements which model theoretically competing accounts of how social interaction can be meshed with the nominal cognitive problem (i.e., the balance scale).[2]

Configuration Type 1 (Modeled). In Configuration 1, children were asked to predict the outcome of a preselected set of balance scale problems. Children were asked to agree upon one member's prediction or to compete for credits but, either way, the problem established for the children was a social one, involving the (dis)agreement between individuals.

The task arrangement approximates a standard testing format, with the status of the other person changed from expert to peer. This format was designed to create a competitive motivation for drawing participants' attention to the outcome of predictions. Input fro the experimenter was minimized. The problems were presented on a worksheet and the procedure (which was a familiar interaction type for these school children) was modeled in the Pretest condition. No generalized higher plane of coordination between the children was required.

Configuration Type 2 (Scale Conflict). By this arrangement, children was assigned responsibility for one arm of the scale, and they were asked to balance the weights placed by the other group who followed a prearranged plan. The group assigned the challenge of balancing were further restrained in that they could achieve a balance on some problems, they were not allowed to place weights symmetrically. This requirement was designed to induce the children to arrive at notion of compensation. However, the assignment to be responsible for one side of the scale arm may make the competition greater and the accuracy of the problem-solving lower. In this arrangement, subjects' competitive conflicts were linked to the apparatus in a way that would distract from the concepts necessary to solve the problem. That is, who works on which scale arm is irrelevant to proportionality.

This kind of person/task interface is not an uncommon one. In this pilot work, many subjects assumed this kind of relationship, saying "My side will go down." The juice-sharing conservation task, where each member of a group is assigned a different glass, also exemplifies this conflict type.

Configuration Type 3 (Experimenter Conflict). The third configuration involved assigning children responsibility for either weight or distance but not both. In solving a problem together, the coordination demanded was assumed to cause the children to notice and to coordinate these properties of the task. Accuracy is not necessarily the issue but attention and coordination are. The general coordination ism, nonetheless, based on a division of activity.

This arrangement, comparable to the classification coordination is Rubtsov's study, was assumed to reduce extraneous social interaction between participants, because the social conflict is tied to the content of the intellectual conflict. Another way of looking at it is that social interaction statements should be functionally different in this condition.

The Design According to Rule Use Conceptualization

There is another way of diagramming the interactions, according to Siegler's N+1 notion. In this notation, the teacher defines the new response to be learned as N+1, relative to the child's state, N. The concept as a whole (e.g., a Rule IV state) can be seen as a problem space, towards which the student will be moved, and of which the student has partial overlap that allows the move to N+1. Figure 1a diagrams a model of the overlapping sets of the child's response domain and the objective domain.

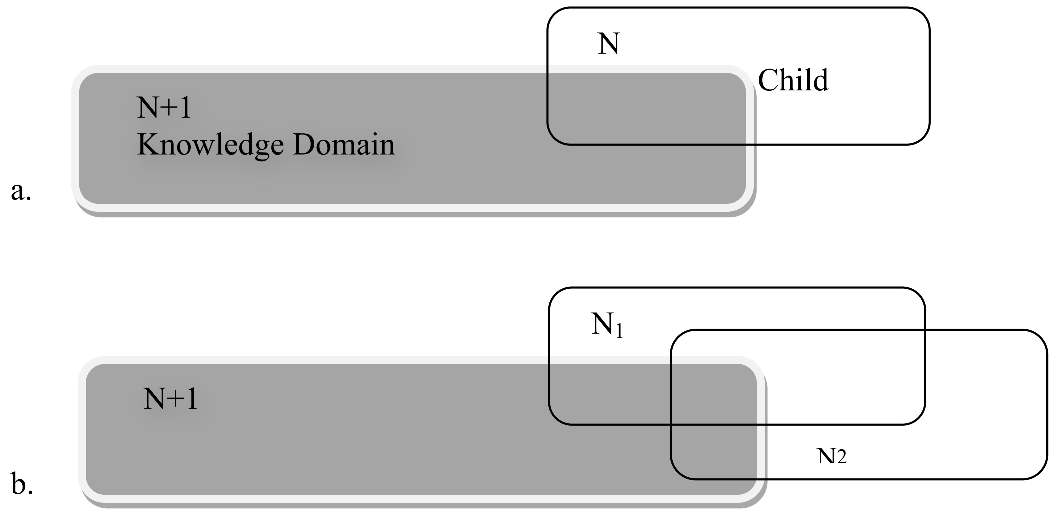


Figure 1: *Schematic drawing of knowledge representation overlap for one and two children*

Pilot work and work using the Seigler balance scale task (Martin & Koltsova, in preparation) shows more variance among children's answers than Siegler found and several additional rule-types (Martin, 1983). These findings indicate that Rule I is not a subset of Rule II nor Rule II of Rule III etc., but rather, that partial knowledge is comprised of associated concepts or responses to the task which eventually drop out. In particular, the evidence of the children for whom the so-called subordinate dimension is dominant points to this. In other words, the intermediate N states include residual information.

A situation of completely embedded states of N in N+1 would be the case if a stage-theory of concept acquisition held. Testing procedures which generate a stage-like sequence, however, are sampling performance from only part of the set which comprises a particular concept in formation because problem presentation is not varied. The issue, of course, is that when we make a claim about how "knowledge" is constructed using such a testing procedure, when can never fully account for the behavior conceptually related to N+1 for the <u>child</u> but not for us. This area arises, among other ways, from a set of experiences we do not control. The fat that significant numbers of children share similar area means that their experiences in relation to N+1 have been similar. Varying the social acquisition conditions will cause shifts in the overlap both within and between subjects. Figure 1b depicts the overlap of two subjects in relation to the final concept.

In what way does peer interaction contribute to the move towards N+1? Recall that although neither of two children know N+1, their discussion can result in new understandings. First, the closer fit of the peers' N states in certain cases may allow more effective discriminations to occur; this is the sense of optimal "gaps" between N and N+1. Then, if we can reduce the residual areas of the sets by tying the children's talk to the elements of N, the interaction can be said to be guided by the nominal problem; the resulting on-task behavior is more likely to put the children in contact with the elements constituting N+1. The social constraints placed by an adult can more or less force the interaction to conform to the area defined by the problem task. In contrast, a procedure such as Piaget Siegler or Anderson uses, only arranging a single condition of interaction, cannot detect development of a concept, nor make claims about optimal learning conditions since a measure of the residual but associated activity is not taken.

We do not know how different social task configurations optimize or, perhaps, inhibit children if the children's understandings overlap differentially with N+1 to such an extent, that they are said to be using different rules. Perret-Clermont and her colleagues are n the process of examining such issues. We do know that the child's level of understanding influences communication on a task, the partners' skill level has an effect, and we have some evidence that particular experience levels systematically relate to the form interaction will take.

On the other side, we have developed an analysis that allows us to characterize the social/task demands arranged, usually unanalyzed, in the various experimental and test conditions from which we draw our evidence and conclusions about cognitive development. Figure 2 shows the interrelatedness of subject, experimenter and task arising from the three theoretical positions discussed above.

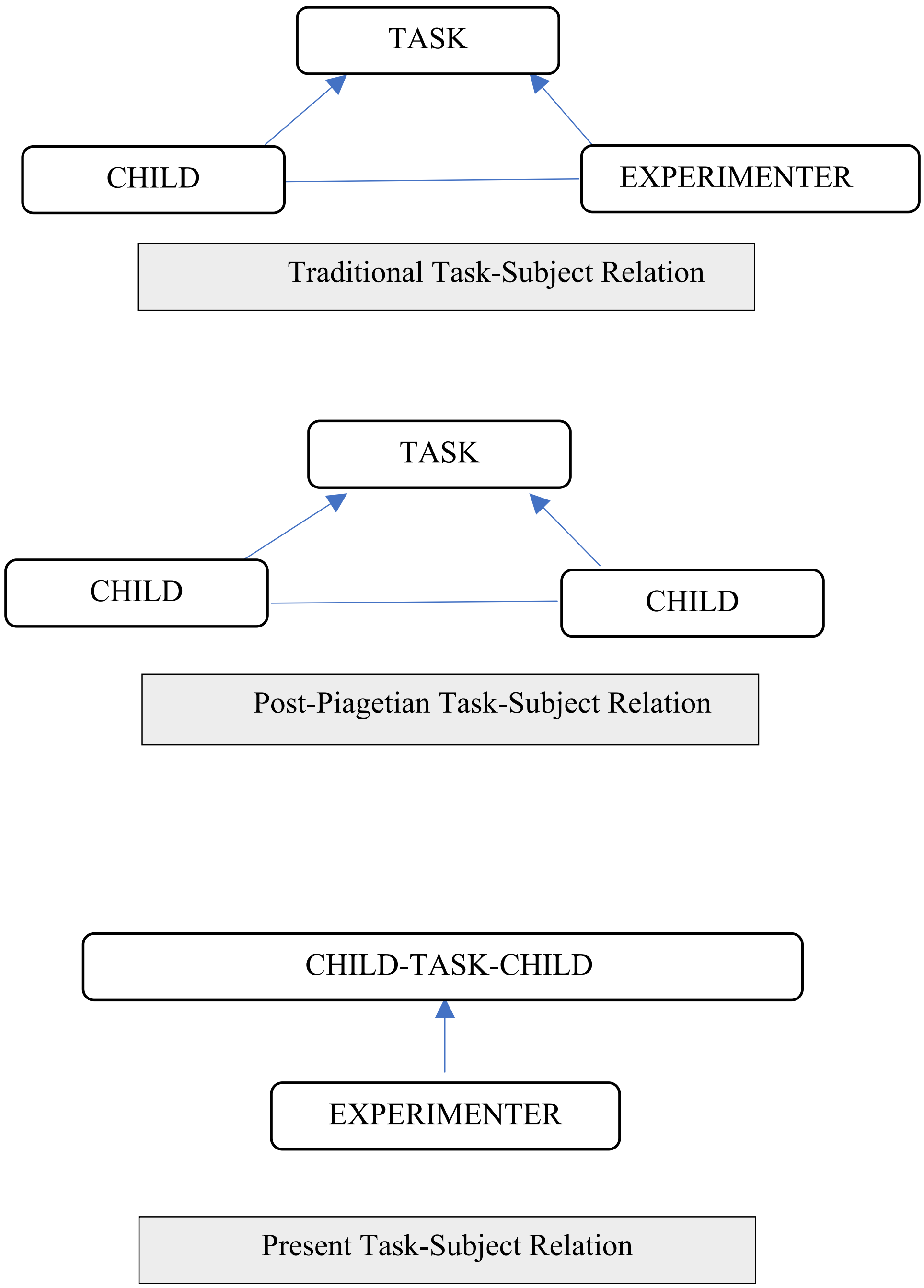


Figure 2: *Schematic drawing of task-subject relations derived from 3 developmental models*

Chapter V

Method

Subjects

Subjects were eighty-six second and third graders between the ages of 7 and 9 (M = 7.76) who were attending a local elementary school that served a lower middle class population. There were 38 girls and 48 boys in the sample. All children were in mixed grade classrooms, one of which was a bilingual Spanish-English class. However, all the children were fluent in English. Children in the second-third grade classes served a subject it eh pretest condition. Those children with, a) parental permission, and b) categorizable responses on the pretest, were selected to participate in the group problem-solving conditions. Of these 36 children, four failed to complete the final posttest: two relocated, one was on vacation ad one was recuperating from an accident. An additional 12 children were tested in group conditions as pilot subjects. Forty-eighty control subjects were chosen by the same pretesting method among children of the same age group at another local school.

It was determined fro pilot work that pairs and trios of children were not likely to generate as much talk and independent activity as were groups of four children. Consequently, groups of four children were matched for participation in the group sessions on the basis of pretest categorization, classroom membership, and, as far as possible, on pretest presentation condition and sex. Each quartet was divided into teams of two (for the purpose of challenging each other during group conditions).

The groups included in the final analysis consisted of the following:

There were three “Level I” groups. Each of these groups consisted of four children all of whom had been addressed by Siegler’s method as Rule I users. That is, these children did not show an awareness of the distance dimension. In fact, however, one child had given one “distance” response on the Pretest.

There were three “Level II” groups. In these groups, all members showed some awareness of the distance dimension. However, one entire group and one member in a second group had answered only half the distance questions on the Pretest on the basis of distance; they were judged to be mid-way between Rule I and Rule II. The remaining children were characterizable as Rule II users by Siegler’s criterion.

Finally, there were three “Mixed I-II” groups. The mixed groups included two Rule I children and two Rule II children. Two of these groups included one Rule II member who actually scored midway between Rules I and II.

One group of Mixed I-IIs was composed of two boys and two girls; all other groups were either all girls or all boys.

All testing was carried out in a semi-isolated area of a large resource room where the children were accustomed to going for special activities and for individual work with aides. During the testing sessions, other students in the school were usually working at nearby tables. Testing was done between 10:20 and 11:30 a.m. and between 12:20 and 1:15 p.m.

Apparatus

The scale used for pretesting was a wooden beam-type scale especially constructed for this study (see Figure 3a). On either side of the center point, the beam had four upright pegs that were placed at equidistant intervals. The beam measured 68 cm x 8 cm; the distance between each peg was 7 cm. Weights consisted of 12 wooden squares of equal weight which measured 5 cm x 5 cm. These weights were drilled on one face and pegged on the opposite face enabling them to be stacked.

The scale used for the group problem-solving sessions was a round metal pan, 10" in diameter, that supported on a pivot. Radii, marked at four equidistant intervals from the center point, were enameled onto the pan's surface. The weights used with this scale were 10 round, flat magnets, 2 cm in diameter. Figure 3b depicts this scale.

A VHS color video camera and deck were used to record the group sessions and a directional microphone was used to supplement the one built into the camera.

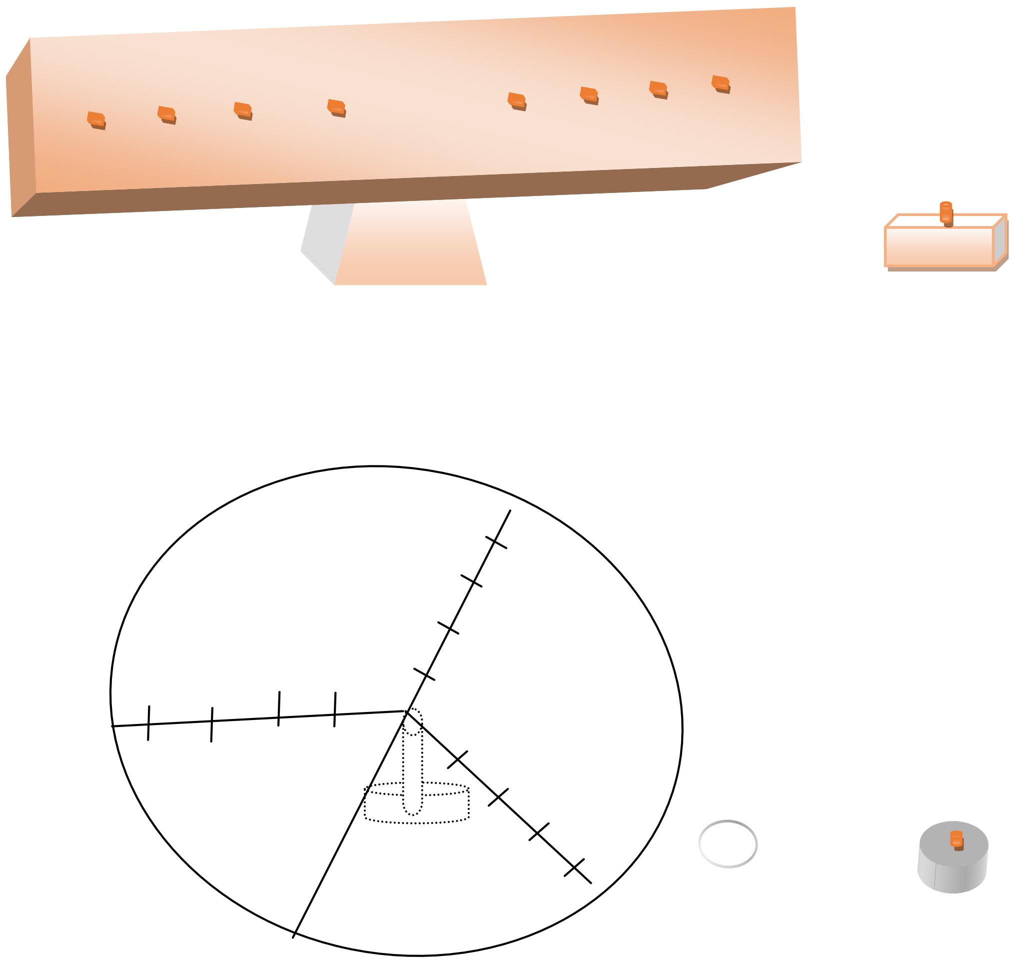


Figure 3*: Scales*

Procedure

Figure 4 schematically depicts the order of events in the study. Children were first pretested individually and assigned to groups according to their Pretest performances. Approximately ten days after the pretest session, the groups of children met together for the group problem-solving session. Together, they worked on solving balance scale problems under three different conditions of task organization. Following each of these Conditions, children were given an Intermediate Test to assess their understanding of the scale. The Intermediate Tests were administered to the children as a group, but each child answered on his/her own answer sheet. One month after the group sessions ended, individual children were given a final Posttest.

Conditions 1, 2, and 3 always followed the same sequence for the experimental groups. For the purposes of analyzing particular effects, twelve control groups were given the Pretest followed by either Condition 2 and one Intermediate Test or by Condition 3 only and one Intermediate Test.

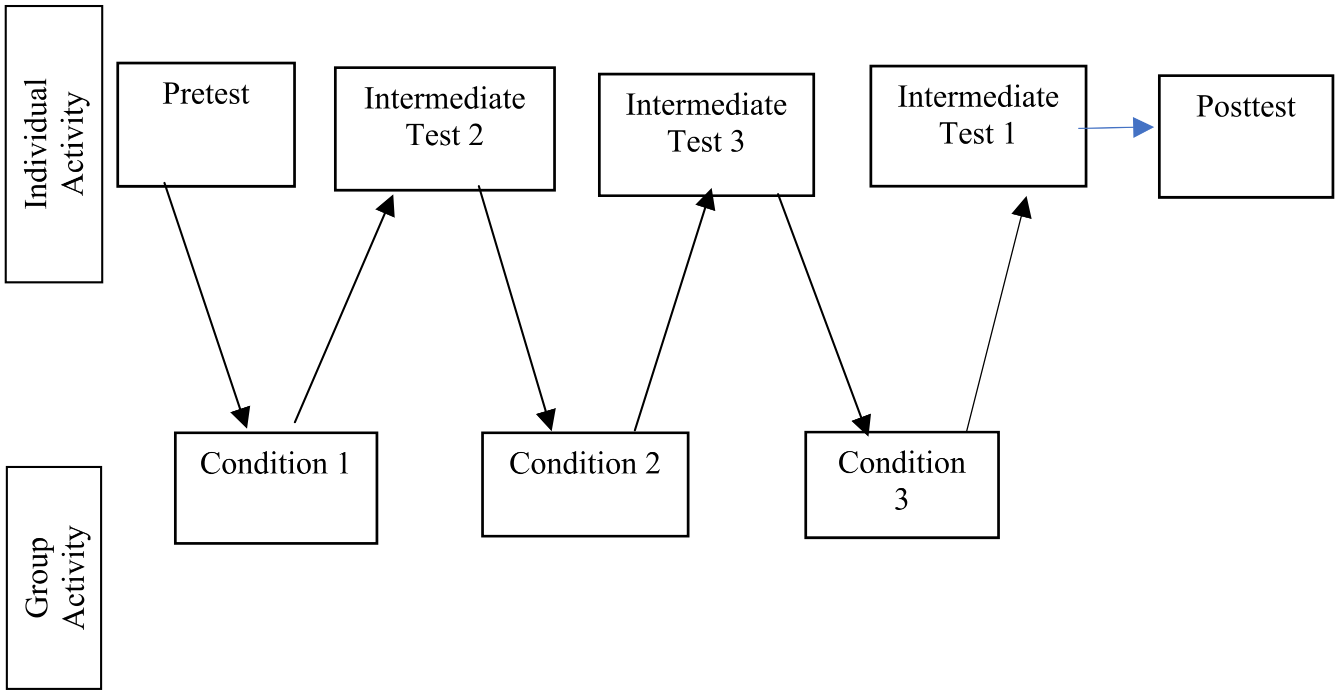


Figure 4: *Sequence of events in the study*

Pretest and Posttest

For the Pretest and Posttest sessions, children were sent one at a time by their teacher or they were brought by the experimenter to the Resource Room from their classrooms. Children sat at a standard school table opposite the experimenter, and in the pretest condition, were asked if they could identify the apparatus. If a child could not, s/he was told that it was a scale. In order to demonstrate that the scale could move, subjects were shown what would happen if the experimenter placed a block on the right arm, on the left arm and on both arms simultaneously. Children were then told that they would be guessing what would happen to the scale in a series of problems. For both Pretest and Posttest problems, the experimenter held the blocks over the specified pegs, but did not rest them on the scale, thereby preventing feedback. It was ascertained that children understood that their guesses concerned what would happen if the blocks were really put down on the beam. During the testing, neutral exclamations such as “okay” and “all right” were uttered by the experimenter; children were told when they had completed half the problems and asked if they wished to continue (all children did). Following the series of 24 problems, each child was praised and offered raisins. The Pretest and Posttest procedures lasted approximately five minutes.

Pretest and Posttest Problem Format

Each 24-problem sequence in both the pretest and posttest included four problems of each of the 6 types delineated by Siegler. Three of the six types of problems are defined by equal values on either the dominant dimension (weight) or the subordinate dimension (distance), or both (“Weight,” “Distance,” and “Balance” questions, respectively) and three are defined by unequal values on these dimensions (“Conflict Weight,” “Conflict Distance” and “Conflict Balance” questions, respectively).

The sets of 24 problems were composed of two randomized blocks and two clocks which ordered the six problems by increasing complexity according to Siegler’s formal task analysis. This format was used instead of Siegler’s randomized block design so that it would be possible to test whether the difficulty or clarity of problems affects subsequent judgments on the task. The results of this test are analyzed elsewhere (Martin, 1983). The problems themselves were drawn from a pool of all possible weight combinations.

Children’s verbalization to each question were transcribed at the time of testing on a coded sheet and were later scored according to the principle that was judged to underlie the response. For example, a child who guessed “balance” on a problem with two weights on the third peg of the right scale arm and two weights on the first peg of the left scale arm was credited as using a “weight” principle for prediction.

Using Siegler’s criterion of 20 out of 24 consistent response types, each child was categorized according to Rule Type both on Pretest and Posttest performance. Children for whom it was not possible to assign a category (except children whose response patterns fell midway between Rule I and Rule II) and children who were classified at a Rule III level were dropped from further participation in the study because it would not be possible to make principled statements about rule changes in these cases.

Group Conditions

Condition 1 (the Modeled Condition). In condition 1, the two teams of children were each given a preprinted work sheet on which was represented six balance scale problems, one of each problem type. The teams were instructed to use the white enameled line on the pan scale and to place the weights on the marks, according to what the worksheet dictated. Teams were told to ask each other the six problems in a manner similar to the pretesting, but that they should put the weights down on the scale and see what the correct outcome was. The team posing the questions marked down whether the predicting team had guessed correctly or not. One team asked all six questions on their worksheet before the other team had their turn to pose the problems; the experimenter chose which team would be the first to pose the problems. The teammates were left to organize the writing and the weight placement as they chose. Following the completion of the twelve problems, and, thereafter, following each of the two remaining group conditions, the four children adjourned to a separate, larger table to be administered an Intermediate Posttest.

Intermediate Posttests. Immediately after each group condition, each of the four participants were given a form, depicting 10 scale problems. The problem depiction format was the same as that used on the worksheets. These Intermediate Tests depicted one example of a simple balance and a simple weight problem, and two examples each of distance and conflicting dimension problems. Children were instructed to write their own answers on a test sheet. Children were seated to prevent them from looking at each other's papers. The experimenter sat at a table visible to each child and demonstrated each problem on the wooden balance scale without giving feedback. Children who marked their answers before the problems were demonstrated were told, "Watch the experimenter anyway, because sometimes you change your mind when you see the problems on the scale." After the First Intermediate Posttest the children returned to the table to participate in Condition 2.

Condition 2 (the Scale Conflict Condition). Condition 2 immediately followed the first Intermediate Posttest. In this second condition, children were given worksheets with space provided to construct their own scale problems. Instructions, which were given verbally and prompted during the session, were also written in the margin of the worksheet next to each problem. Here, children of the posing team were told to hold the pan and place some magnets on one side of the scale on one of the marks of their choice. They were to write down what they did. The answering team's task was to place some weights on the other side with the aim of making the scale balance. The posing team would write down the responders' choice and then see if it was correct by letting the scale pan go.

Several restrictions were placed on the responding team, however; for the first two trials, they could place as many magnets as they chose wherever they chose; that is, they could set up a symmetrical solution. For the second two trials they could not use the same number of magnets selected by the posing team, but they could put the magnets anywhere along the radius. On the final two trials the responders could use any number of magnets they liked but they could not put them on the space symmetrical to the posing team's placement. Children were not instructed to mark each other for correctness but they asked to indicate which side had fallen or if the scale had balanced, on each trial.

As in Condition 1, one of the two teams, presented all six problems to the other team, and then the teams switched roles. Upon completion of Condition 2, children moved to the large table and, working individually, they marked their second Intermediate Posttest sheets. Again, the experimenter demonstrated the Intermediate Posttest problems on the wooden scale.

Condition 3 (Experimenter Conflict Condition). Condition 3 was usually conducted on the day following Conditions 1 and 2, although in two cases, the entire group procedure was carried out inn one day. In Condition 3, the experimenter sat at the table between the two teams and placed magnets on the scale according to a predetermined schedule. The children were told that the weights would not allow the scale to balance, and their job was to fix them so that it would. The magnets were placed along the radii, in a Y-configuration. The experimenter controlled the weights on one radius and each team was responsible for the weights on one of the remaining radii. This configuration permitted the teams to work against the experimenter's side, while at the same time requiring that the two teams compensate each other's moves. Four problems were presented and the group was given two chances to make a joint correct compensation for each problem.

Certain restrictions applied in Condition 3: for each problem, one team was allowed to vary the number of magnets on their side, but they could not move them; the other team could move their magnets, but they could not change the number. After two problems, the teams switched roles. Neither team was allowed to manipulate the experimenter's weights.

Upon completing the four problems, the children were given the third Intermediate Posttest. Approximately two weeks after their group sessions, each child was administered a 24-item final Posttest. The procedure resembled the Pretest, and each child's Rule level was determined. Final Posttests all presented the children with an ordered block of problems followed by a block of problems in random order with respect to difficulty.

Variables

Assignment Variables. There were two assignment variables for each subject. First was the child's Pretest level. For the purposes of analysis, the Rule Levels were ranked on a three point scale, including those children whose Pretest level fell midway between Rule I and Rule II. Children who were characterizable on the Pretest as Rule III users according to Siegler's criterion, were eliminated from the study; no Rule IV users were found in the sample.

The second assignment variable was Group Level. Group Level was scored for each child as the sum of the Pretest rankings of the other children in his/her group, since each child was exposed to the opinions of three others, one partner and two opposing teammates. Thus, a Rule I child working with three other Rule I children had a Group Level score of 3 (1 + 1 + 1) and a Rule I child working with a partner against a team of Rule II children had a Group Level score of 7 (1 + 3 + 3).

Independent Variables. Measures of the children's in situ verbal behavior were chosen in order to test competing models of how learning results from children's group problem-solving interactions. The videotaped records of the nine groups of children were coded by two, or, for some categories, three independent raters; interraters agreement averaged 76.2% across the categories; in the case of disagreement, the opinion of the main investigator was deciding one.

For some measures, the complete videotaped sessions for a group were scored; for others a sampling procedure was used. The total time taken for the three videotaped sessions ranged from 34 minutes to 59 minutes between the groups (M=42.4 minutes). Some variables, such as Number of Arguments, are meaningfully compared in their absolute frequency; others represented responses whose relative frequency was at issue (e.g., the percent of time someone stated a justification when they were proven to have been correct). Table 1 provides definitions of all the subject variables counted for the purposes of the current analysis and shows which represent sampled behaviors and relative measures.

Probability of Prediction and Responses to Problem Outcome were each based on the child's first two codeable behaviors at two points in the problem-solving process: For each of the 32 problems a group experienced, the first two codeable responses of each child of the predicting team were noted 1) at the time each problem was posed, and 2) at the moment the solution was revealed but the posing team (or by the experimenter in Condition 3). Responses to Problem Outcome were counted as the percentage of the total number of problem outcomes that a particular response occurred. Children's On-task and Off-task responses in each interactive condition, and in reaction to having been proven correct and incorrect, were summed from a count of more specifically defined responses.

The number of arguments each child engaged in, the average length in turns taken of the argumentative exchanges by the group, the number of principled rules or reasons a child articulated and the number of times a child referred to the scale principle that the opposing team was controlling were counted for the entire corpus. It was reasoned that, although groups took varying amounts of time for completing the group problems, the absolute count of these variables represents the cognitive density of the situation, and may account for final performance differences.

Finally, independent variables also included responses on the Intermediate Tests. The appearances of types of answers not previously seen in the child's repertoire were counted and the Intermediate Test (1, 2 or 3) on which a particular new response made its appearance was coded. Level I children could display a total of three new responses (Distance, Conflict Distance and Conflict Balance); Level I-II and Level II children could show as many as two (Conflict Distance and Conflict Balance).

Dependent Variable. Children's rule use level, as assessed on the final Posttest, was the dependent measure in this study and was considered an index of the effects of group problem-solving interactions.

The results of the Posttests, the format of which permitted assessment of each child's response patterns according to Siegler's analysis, led to a six point scale. Rule I children were ranked at level 1; Rule I-II were ranked at level 2; Rule II were ranked at level 3; children who answered all conflict questions on the basis of Distance or who showed an uncharacterizable pattern that included Distance answers were ranked at level 4; Rule III children were ranked at level 5; and Rule IV users were ranked at level 6.

Table 1. *Definition of Subject Variables*

Inter-Individual Occurring in Group On-Task	
Variables	**Definition**
Number of Arguments in Conditions 1,2, and 3; Total Arguments	How many strings of conflicting statements concerning the problem a subject engaged in each interactive condition. At least a statement and retort were counted; single, unchallenged criticisms were not counted.
Number of Rules and Reasons Stated in Conditions 1, 2, and 3; Total Rules and Reasons Stated	How many utterances a child made in each interactive condition and in total, that explained why the scale behaved as it did, either in general principle or in specific (e.g., "more blocks are heavier" vs "this side has more."
Number of Cross-Observations in Conditions 1, 2, and 3	How many times a child made references to a principle of the scale applying to the opposing team's side, according to the experimenter's rules, in each condition.
Percent Predictions	When one team placed weights on the scale and posed a problem, each child may have responded immediately with a prediction of what the outcome would be. This measures what percent of the time a child took a fast guess.
Off-Task	
Mean Length of Argument in Conditions 1, 2, and 3; Grand Mean Length of Argument	The average length of the argument chains, measured by back-and-forth exchanges, for eacj group in each interactive condition.

Percent Social Responses to Problem Outcome in Conditions 1, 2, and 3	Upon learning the outcome to a problem they have tried to solve, a team's member may have responded with a social statement such as "Yay! We won!" This measures what percent of the time a child exhibited such a reaction.
Percent Social Responses to Correct and Incorrect Problem Outcome	The percent of time Social Responses occurred when a child was proved to have predicted a problem's outcome correctly; the rate of occurrence when a child was proven wrong.
Occurring Individually On-Task	
Co-occurrence of New Discriminations on Intermediate Tests	The ratio between the total number of new logical scale discriminations produced by group members on the Intermediate Tests following the interactive conditions and the number of identical new answers produced on the same Intermediate Test.
Individual Coordination of New Discriminations On Intermediate Tests	A nominal score of whether a child showed new scale discriminations on the Intermediate Tests: consistently at the same time as group members, sometimes at the same time and something independently of group members, always independently, or the child produced no new answers.
Intra-Individual Occurring in Group On-Task	
Number of Accurate Predictions, Conditions 1 and 2	How many times a child correctly predicted the problem outcome.
Number of Accurate Predictions, Condition 3	How many times a child moved the scale weights in the direction of a correct compensation in order to make the scale balance.

Number of new Illogical Responses	The number of new scale discriminations
Compensations, Condition 2 Frequently, the move was ultimately incorrect and the scale did not balance, but the3 move was, in principle, in the right direction.	produced by a child on the Intermediate Tests that were not logical, for example, saying that the weights closer to the fulcrum, on a distance problem, were heavier. Frequently, the move was ultimately incorrect and the scale did not balance, but the move was, in principle, in the right direction.
	The number of times a child mentioned
Number of Metacognitive Statements	his/her own thought process, for example, “I think it will work” or “I don’t understand what happened.”
Percent Attentional Responses to Problem Outcome, Conditions1, 2, and 3.	The percent of time a child, in each condition, responded to a problem’s outcome with one of the behaviors coded as “Attention”, for example, asking or remarking on the principle at work, correcting a prediction.
Percent Attentional Responses to Correct and Incorrect Problem Outcomes	The percent of time an attentional response occurred when a child was proven to have predicted a problem’s outcome correctly; the rate of occurrence when the child was proven wrong.
Occurring Individually On Task	
Distance Responses by Intermediate Test	The Intermediate Test on which a new distance discrimination pattern was observed for a Level 1 subject.This measure was not included in the correlation matrix.
Conflict Distance Responses by Intermediate Test	The Intermediate Test on which a new Conflict Distance pattern appeared for a child.
Conflict Balance Responses by Intermediate Test	The Intermediate Test on which a new Conflict Balance pattern appeared for a child.
Number of New Logical Responses	The total number of new logical scale discriminations a child produced on the Intermediate Tests.
Number of new Illogical Responses	The number of new scale discriminations

Chapter VI

Results and Discussion

Statement of Goals and General Findings

The object of the present study was to demonstrate that improvements in the performances of individual children on balance scale problems are related to aspects of group-mediated problem-solving activities. The results showed that improvement of individual performance is best predicted by a combination of individual cognitive measures and measures of the group on-task interaction. Individual cognitive measures failed to predict individual change in the way that would be expected by traditional models of logical development. Instead, two sets of variables combined to predict individual learning: 1) the skills of the group members, and 2) the extent to which individuals engaged in particular typed of verbal exchange. The likelihood of engaging in fruitful verbal exchange depended on the arrangement of the task.

In arriving at these conclusions, five models were tested. The first three models (Individual Skill, Group Skills and Rule Use) all rely on measures of individual test performance. The fourth and fifth models (Post-Piagetian and Vygotskian) include data derived from the group interactions.

Models Based on Individual Measures

Models using Pretest and Posttest Results. In order to test the models of learning that were derived from the differing theoretical accounts, it was necessary first to evaluate whether the children in this study made systematic gains. Table 2 shows the number of children who showed either higher level Rule use on the Posttest relative to the Pretest, less advanced reasoning than they had on the Pretest, the same reasoning, or an indeterminate change of response pattern. Most children showed some change over time; most of those who did not change showed improvement to a categorizable rule. Eleven children did not vary the rule they used on the two tests, and one subject was measured as regressing from Rule II to a rule midway between I and II. A Chi-square test for a single sample was performed, testing whether the number of children who made gains was significantly greater than those who did not. The results of the test showed that difference was not significant, $\chi 2$ (1)=.92.

Table 2b shows the number of children in each pre-to posttest category according to their initial Pretest Level. It can be seen that the majority of Rule II and Rule I-II children improved, but that approximately half of the Rule I children also used Rule I on the Posttest. A Chi-square text, collapsing indeterminate scores with gains, showed that initial Rule and gain on the Posttest were not related, $\chi 2$ (2) = 5.95, $\underline{p} < .10$.

Changes in children's rule use, according to group composition, may be seen in Table 2c Rule I children working with each other tended to continue to use Rule I whereas Rule I children working with Rule II children changed their Rules, $\chi 2$ (2) = 5.95, $\underline{p} < .05$. Rule II children were seen to improve their performance whether they worked with each other or with Rule I children; the small simple size did not permit a test for the Rule II-I group, however, it appears as though group composition and change in rule use were unrelated.

Table 2. *Numbers of children showing change in Rule Use Level on Posttest*

		Pretest to Post Test Rule Level Direction of Change			
	n[a]	Increase	No Change	Decrease	Change to Unknown Rule
All	32	16	11	1	4
Rule					
I	15	5	8	0	2
I-II	7	6	0	0	1
II	10	5	3	1	1
Rule	Group				
I	I-I	2	8	0	0
	I-II	4	0	0	2
II	II-II	7	1	1	2
	II-I	3	2	2	0

[a]Four children in the study were not available for post testing

These results replicate previous findings (Perret-Clermont, 1980) consistent with an explanation based on individual cognitive measures. More advanced rule users make gains regardless of the skill levels of the peers, while less advanced Rule users show advantages when working with more capable peers.

A count of the direction of change in children's scores, however, does not distinguish subjects who advanced one versus those who advanced more Rule levels on the Posttest. Such variation may not be immediately attributable to the individual or group level variables. Neither does Pretest or Group type explain very much about what may have been influencing learning for the children, and the small sample size is a problem for frequency counts. In order to account for children's gains on a finer-grained level, a more detailed analysis was undertaken.

The Individual Skill Model. The simplest account of changes in rule use is that learning is related solely to the child's initial performance level. That is, it would be expected that higher-level learners, the advanced non-conservers (Rule II children), should benefit more from exposure to the task than lower-level non-conservers (see Figure 5).

In order to test the contribution of Pretest scores to scores on the Posttest, the coefficient of determination was calculated and tested. The correlation coefficient for the relationship between Pretest and Posttest scores was .45, which was significant at the .01

Level, F (1, 30) = 7. 65. A good deal of variation in Posttest scores remains unaccounted for after the common variation of Pretest scores is partialed out. Other measures of performance and interaction may also contribute to the prediction of Posttest gains.

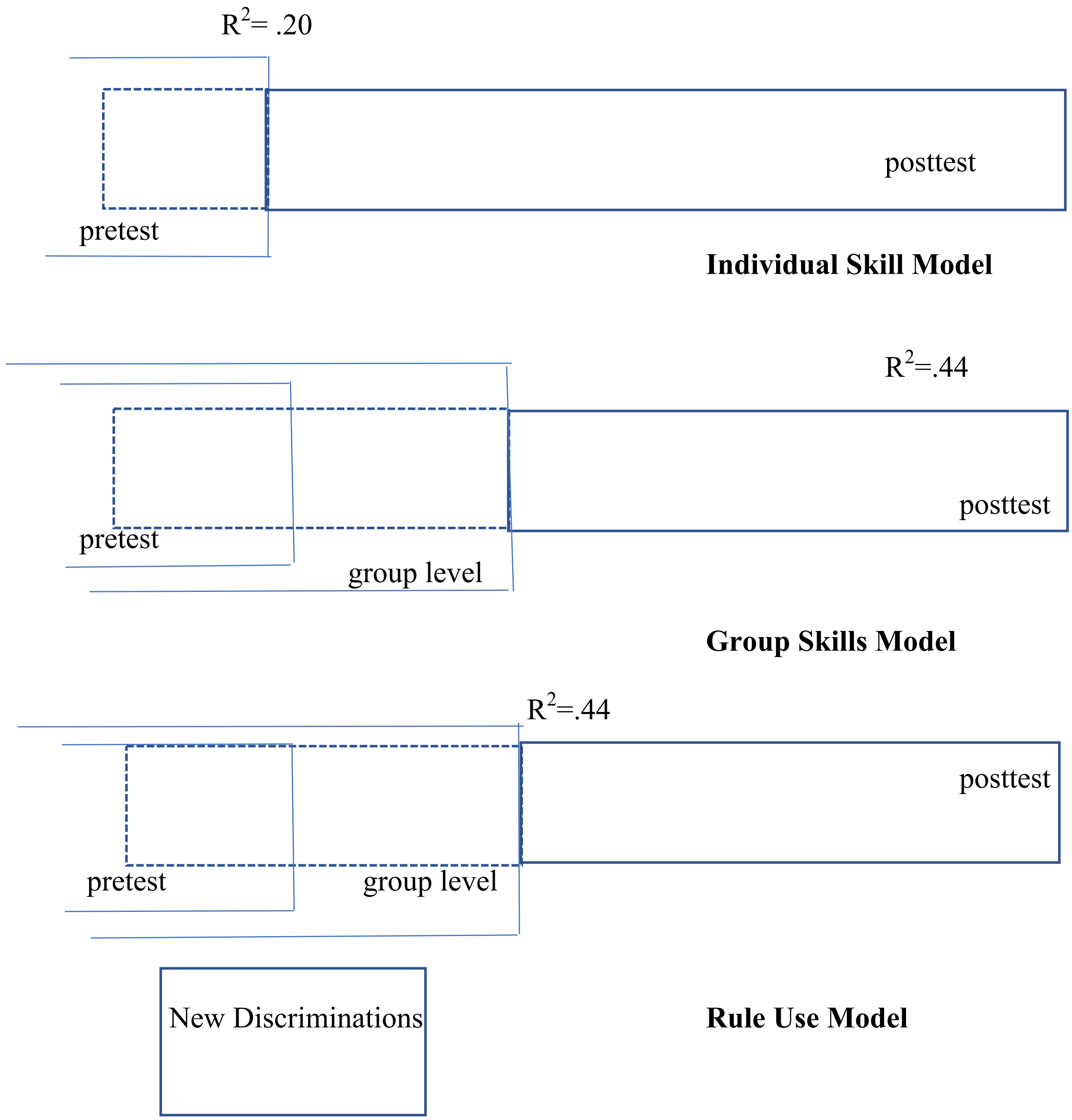


Figure 5: *Models predicting Posttest Score variance based on individual measures*

The Group Skills Model. More recent explications of the simple Piagetian model of cooperative problem-solving held that learning is related to task-specific, decentering experiences that the learner has with others (see Figure 5b). The model does not require any of the problem-solvers to articulate the logical rule or even to behave entirely consistent with the rule in order for gains in logic to be made; however, partial knowledge is seen to be necessary. Children who do not yet show the instability of intermediate stages of operational thinking, and who are said to think with the same incomplete logic, would be unable to challenge another non-conserving partner's viewpoint. This would mean that, in a group learning situation, lower level learners (e. g., non-conservers) would be more likely to improve if they made contact with higher-level learners who articulated points of view different from their own, even though such views may only be partially accurate.

To test this model, a partial correlation analysis was performed in which the effect of Group Level on Posttest scores partialed for Pretest scores was evaluated. A test of the partial correlation coefficient showed that the contribution of Group Level to the prediction of Posttest scores, beyond that variation predicted by Pretest scores, was significant (partial $\underline{r}$ =.55; $\underline{F}$ (2, 29) = 12.46, $\underline{p}$<.01). The multiple correlation coefficient for this model is .67.

The effect of Group Level provides support for the Group Skills model, and confirms that knowing the level of a child's group can be additionally informative to knowing the child's own level when it comes to predicting the gains that are made.

A Model using Pretest, Posttest and Intermediate Test Results: The Rule Use Model. In addition to Pre- and Posttests, Individual measures of performance were taken from the Intermediate Tests, which had been administered after each interactive problem-solving condition. It might be assumed by sequential Rule-use analysis that the experience of working with the scale would, by itself, cause disequilibration, and that this would be reflected in the appearance of new patterns of answers on the Individual Intermediate Tests. Because these Intermediate Tests consisted of only 10 problems each, full rule assessment according to Siegler's criteria was not possible. Nonetheless, the Intermediate Tests should reflect a child's realizations about proportionality principles if they occurred during the group session preceding the test. Furthermore, the appearance of intermediate stages of rule development should be correlated with Posttest gains. But, the number of new discriminations exhibited by each child on the Intermediate Tests was unrelated to Pretest levels, as determined by a significance test of the correlation coefficient. Multiple partial correlation analysis, furthermore, showed that the number of New Discriminations demonstrated on the Intermediate Tests did not contribute significantly to the prediction of Posttest levels, partialing Pretest and Group Levels. Thus, it would appear that the individual pencil and paper probe format, despite its resemblance to the Pretest and Posttest format, set the occasion for task performance, as measured by the New Discriminations, that was not generalizable.

Given the design of the study, in which all children were administered the Intermediate Tests, it is not possible to rule out the contribution of the Intermediate tests to children's ultimate performance. The fast that the results from the Tests did not additionally explain Posttest score variation means that the scores themselves may not be independent indicators of intermediate Rule use stage.

Models Based on Interactive Measures

The previous models, which were based on the Individual test measures, predict a portion of the variation in children's actual Posttest scores. Rather than approach residual variance as experimental error, measures of the interactions between the children were included in the next steps of the analysis in an attempt to further explain the Posttest scores.

The information available from the individual measures leads to two alternative hypotheses: either the only variance in learning possible to account for is due to individual "knowledge," and the model is complete or, the measures of individually testes performance are only partly sensitive to the elements in the learning process contributing to Pre- to Posttest score change.

In order to know which is the case, certain questions need to be addressed. First, what is it about the behavior of those who made gains in interactive situations that causes improvements to be more likely? Second, what went on during the interactive conditions preceding the Intermediate Tests: did group members learn the same things at the same time? Third, can a model of a problem-solving process be applied to the data such that the relation between social and cognitive cooperation is specified? These questions necessitate an examination of what transpired between learners during the problem-solving conditions themselves. Subsequent analyses are predicated on an examination of these interactional processes.

To begin, it was noticed that members of a group occasionally manifested new discriminations on the same Intermediate Test. A ratio was calculated consisting of the number of co-occurring new responses produced in a group divided by the total number of new responses for the group. This ratio yielded a group score for Co-occurrence of New Discriminations. If the simultaneity of particular test responses was important, it would suggest that something had occurred in the preceding interactions of the group as a group, rather than to the individuals independently, or the same events affected each group member in the same way.

An individual measure of the tendency for coordinated responding was also constructed, which rated whether a child had demonstrated new task discriminations consistently in a co-occurring fashion, inconsistently (that is, sometimes at the same time as group members and sometimes not), only at times different from group members, or not at all (i.e., showed no new responses on the Intermediate tests). Group Co-occurrence and Individual Coordination were included as variables in subsequent analyses.

First, Posttest scores were examined in relation to the Individual Coordination measure and to the Group Co-occurrence measure. Individual Coordination was significantly correlated with Posttest Level partialed for Pretest ($r = .47$, $p < .005$) but Group Co-occurrence was not. These findings imply that, for an individual, forming new discriminations at the same time as other group members establishes a durability of these discriminations which emerges on posttest performance. The group score, Co-Occurrence, loses individual information and may, for this reason, not predict individual Posttests. Or it may be that a global characterization of the group as a <u>type</u> (see Rubstov, 1981) in terms of the coordination of its total productions does not add predictive power to a model. Individual variation in tendencies to coordinate cognitive activity seems to be a more sensitive measure of this effect.

Descriptive and Validation of Interactive Measures

Description of the Category System. Measures of verbal interaction and measures of individual test performance were categorized according to an analysis that distinguishes between several sets of controlling features in the problem-solving situation (see Table 3). Behaviors were classified according to whether they pertained to the balance-scale task, and according to whether they occurred when the child was with his/her group or was working alone.

Table 3. *Category system for Subject Variables*

	Inter-Individual		Intra-Individual	
	On Task	Off Task	On Task	Off Task
Group				
Occurring Individually				

Behaviors which seemed to depend on the presence of others were called *Inter-Individual* events, whereas, behaviors which seemed to occur independently of others were called *Intra-Individual* events. Behaviors related to the logical features of the scale problems were termed *On-Task* and those related to other features of the situation were termed *Off-Task*. In addition to responses unrelated to the formal problem, other off-task behaviors pertained to the balance scale task itself. For example, writing on the worksheet was coded as Off-Task behavior, because, as a procedural response, it does not have to do with the logical problem. It was also coded Intra-Individual, because engaging in procedural responses does not require the presence of the participants.

In addition, measures taken from the individual test sessions were categorized as *Occurring Individually*; whereas measures taken from the group sessions were categorized as *Group* measures. Note that Inter-Individual measures O90ccurring Individually are comprised of scores taken from the Individual Intermediate tests but were measured in relation to the group's scores. Figure 6 shows the design schematic and the activities from which the various measures were obtained.

Factor Analysis. Measures of verbal behavior were chosen in order to test competing models of how learning results from children's group problem-solving interactions. Table 4 groups the variables according to the category scheme.

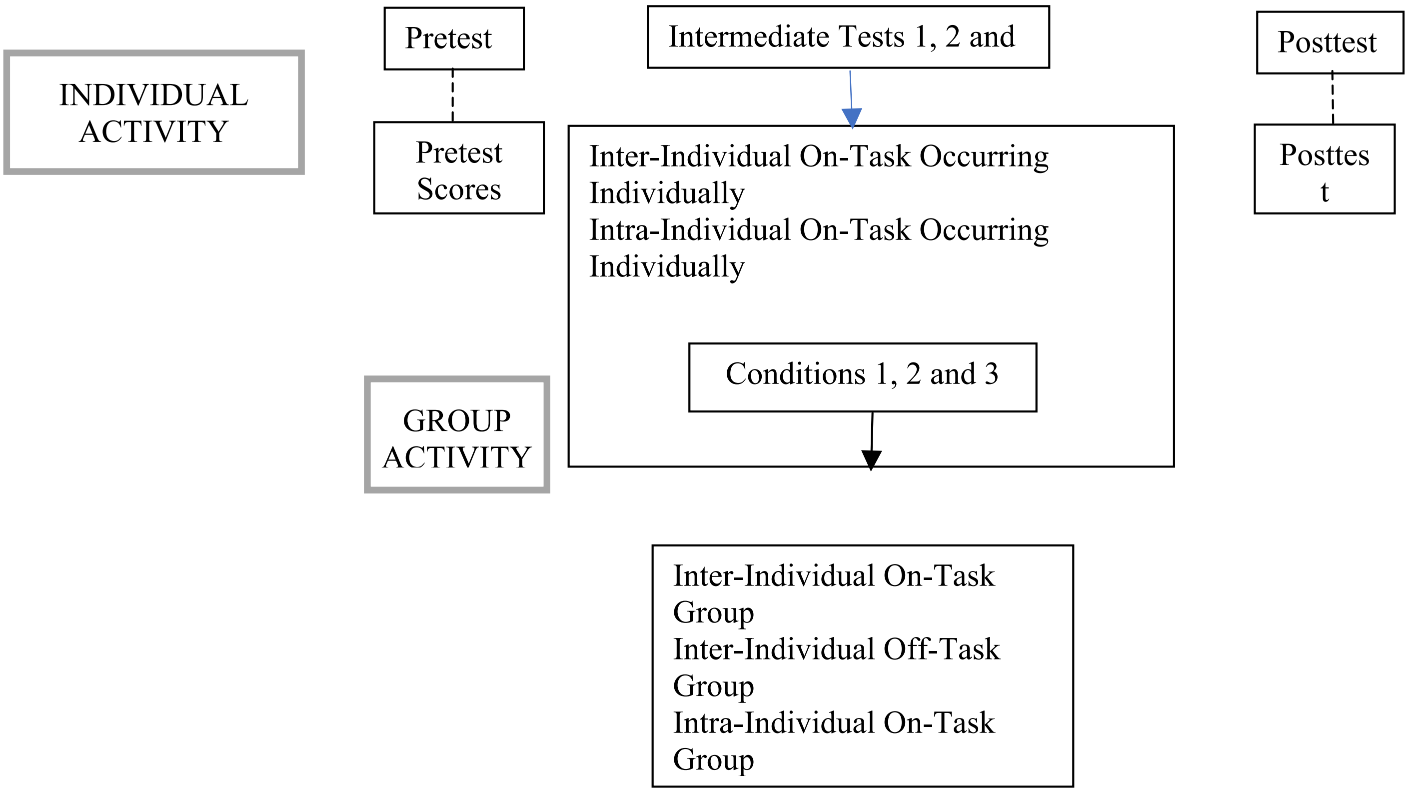


Figure 6: *Categories of measures taken during each phase of the study*

Table 4. *Variables comprising each category*

OCCURRING IN GROUP			
INTER-INDIVIDUAL		INTRA-INDIVIDUAL	
ON-TASK	OFF-TASK	ON-TASK	OFF-TASK
Number of Arguments, Conditions 1,2,3; Total.	Mean length of Argument, Conditions 1,2,3; Grand MLA.	Number of Accurate Predictions, Conditions 1,2,3.	Percent Procedural Responses to Correct and Incorrect Problem Outcome.
Number of Rules Stated, Conditions 1,2,43; Total.	Percent Social Responses to Problem Outcome, Conditions 1,2,3.	Number of Accurate Compensations, Condition 2.	
Number of Cross-Observations, Conditions 1,2,3.	Percent Social Responses to Correct and Incorrect Outcome.	Percent Attentional Responses to Problem Outcomes, Conditions 1,2,3.	
OCCURRING INDIVIDUALLY			
Co-occurrence of New Discriminations		Distance by Intermediate Test	
		Conflict Distance by Intermediate Test	
Inidividual Coordination		Conflict Balance by Intermediate Test	
		Number of New Logical and Illogical Responses	

In order to determine the empirical validity of the category system, a factor analysis with Varimax rotation was performed on the entire set of 41 variables. The analysis yielded a total of 10 factors, each with an Eigenvalue above 1.0. Variables tended to load only on one of the 10 factors; only 3 of the 41 variables loaded significantly ($p < .01$) on two factors and 3 others loaded significantly ($p < .01$) on three factors. Table 5 lists the variables which loaded significantly onto each factor.

Factor 1, accounting for 29.3 percent of the variance seems best characterized as Conflict in that the variables showing the highest loading on this factor were the Number of Arguments for each condition. Contrary to the category scheme, Mean Length of Argument was related to the Number of Arguments. Metacognitive statements and Cross-Observations in Condition 3 also loaded onto Factor 1.

The variables loading most heavily on Factor 2 were the two measures of co-occurring new discriminations. Consequently, Factor 2, which accounted for 16.5 percent of the variance among the variables, will be referred to as the Co-ordination factor.

The variables that loaded strongest on Factor 3, including Percent of Attentional Responses to Correct and Incorrect Outcomes, Percent Attentional Responses in each Condition, and Cross-Observations in Condition 3, are nearly all related to Attention to the task. Factor 3 predicted 12.4 percent of the variance.

Factor 4, accounting for 9.3 percent of the variance, was loaded onto most heavily by three measures of performance in Condition 2. Consequently, Factor 4 seems to characterize the interaction which was provided as part of Condition 2, instead of reflecting response patterns which cut across conditions. A general characterization of this cluster is not apparent.

Factor 5, called Logic, and accounting for 7.6 percent of the variance, was loaded onto most heavily by the likelihood of stating Rules and Reasons in Conditions 1 and 3. Metacognitive statements also loaded onto this factor, as did Cross-Observations in Conditions 1 and 2.

Factor Six, accounting for 7.0 percent of the variance, is characterized as Accurate Predictions, in that the variables loading most heavily were Total Accurate

Predictions and the Number of Accurate Predictions in Conditions 1 and 3. Attentional Responses to Problem Outcome in Condition 3 related as well.

Factor 7, accounting for 5.6 percent of the variance, was loaded onto predominantly by Condition 1 variables. Like Factor 4, Factor 7 appeared to reflect variation attributable to the Condition 1 procedure rather than to behavioral patterns which cut across procedures.

Factor 8, accounting for 5.0 percent of the variance, represents Intermediate Test performance as measured by the number of New Discriminations and the test on which they appeared (first, second or third).

Factor 9 was readily characterizable, and Factor 10, which accounted for 3.6 percent of the variance, was loaded onto most heavily by the set of Procedural Responses to Correct and Incorrect problem outcome.

Table 5. *Variables loading significantly onto the factors and strength of relations*

FACTOR 1	**VARIABLES LOADING ON FACTOR**	**CORRELATION TO FACTOR**
	No. of Arguments, Condition 1	.47
	No. of Arguments, Condition 2	.70
	No. of Arguments, Condition 3	.90
	Total Arguments	.80
	Mean Length of Argument, Condition 1	.85
	Mean Length of Argument, Condition 2	.94
	Mean Length of Argument, Condition 3	.90
	Grand Mean Length of Argument	.98
	Cross-Observations, Condition 3	.46
	No. of Metacognitive Statements	.54
		(29.3)[1]
FACTOR 2	Co-occurrence of New Discriminations	.86
	Inidividually Measured Co-occurrance	.78
	Percent Social Responses, Condition 3	.53
		(16.5)
FACTOR 3	Percent Attentional Responses to Correct Outcomes	.78
	Percent Attentional Responses to Incorrect Outcomes	.53
	Percent Attentional Responses, Condition 1	.71
	Percent Attentional Responses, Condition 2	.63
	Percent Attentional Responses, Condition 3	.53
	Cross-Observations, Condition 3	.52
		(12.4)
FACTOR 4	No. Accurate Predictions, Condition 2	.79
	No. Rules and Reasons Stated, Condition 1	-4.7
	Percent Social Responses, Condition 2	.48
	Cross-Observations, Condition 3	-.45
	No. Correct Compensations, Condition 2	.69
		(09.3)
FACTOR 5	No. of Rules and Reasons Stated, Condition 1	.44
	No. of Rules and Reasons Stated, Condition 3	.58
	Total Rules and Reasons	.90
	Cross-Observations, Condition 1	.60
	No. Metacognitive Statements	.42

		(.07.6)
FACTOR 6	No. Accurate Predictions, Condition 1	.49
	No. Accurate Predictions, Condition 3	.82
	Total Accurate Predictions	.90
	Percent Attentional Responses, Condition 3	.53
		(07.0)
FACTOR 7	No. Accurate Predictions, Condition 1	.57
	No. Arguments, Condition 1	.52
	Total Arguments	.44
	Percent Social Responses to Correct Outcomes	.69
	Percent Social Responses, Condition 1	.49
		(05.6)
FACTOR 8	Intermediate Test First Showing Conflict Distance Response Pattern	.80
	Intermediate Test First Showing Conflict Balance Response Pattern	.66
	No. of New Discriminations	.73
		(05.0)
FACTOR 9	No. Rules and Reasons Stated, Condition 1	.51
	Percent Social Responses to Incorrect Outcomes	.78
	Percent Social Responses, Condition 2	.44
		(03.7)
FACTOR 10	Percent Procedural Responses to Correct Outcomes	.50
	Percent Procedural Responses to Incorrect Outcomes	.54
		(03.6)

[1]Numbers in parentheses indicate the total percent of variance accounted for by the factor.

In general, the results of the factor analysis provided substantial evidence for both convergent and discriminant validation of the conceptual system. Table 6 lists the interpretable Factors as they may be categorized within the foregoing scheme. A summary of the results of the factor analysis follows, which relates the factors to the category system.

Inter-Individual/Group/On-Task: Ten of the measures theorized to comprise an Inter-Individual/Group/On-Task category loaded onto either Factor 1 or onto Factor 5. For Factor 1, these included all measures of the number of arguments and cross-observations in Condition 3. For Factor 5, all measures of rules and reasons, except those in Condition 2, and cross-observations in Condition 1 were included. Number of metacognitive statements loaded onto both factors. Notice that all four measures of length of argument loaded onto Factor 1, contrary to theoretical supposition. In summary, the Inter-Individual/Group/On-Task category was validated by the appearance of factors measuring Conflict (Factor 1) and Logic (Factor 5).

Inter-Individual/Group/Off-Task: No convergent validity was obtained for this category. Length of Argument measures loaded on Factor 1, the Conflict factor. In addition, the Social Response measures appeared to depend on the Conditions: three of the five Social variables loaded onto factors grouping Condition 1 variables (Factor 7) and Conditions 2 variables, suggesting that off-task responses may depend on how the task is arranged, rather than a child's general level of competence.

Intra-Individual/Group/On-Task: Eight of the 10 measures assumed to comprise this category loaded onto Factor 3 or onto Factor 6. All six measures of accurate predictions loaded onto Factor 3, Attention, and three of the four measures of accurate predictions loaded onto Factor 6, Accurate Predictions. Consequently, the Intra-Individual/Group/On-Task category appears to consist of two component variables, Attention (to task) and Accurate Predictions.

Intra-Individual/Group/Off-Task: This category was validated by the emergence of Factor 10, onto which loaded the percentage of procedural responses both to correct and incorrect outcomes.

Inter-Individual/Occurring Individually/On-Task: This category was validated by the emergence of Factor 2, the Coordination factor. Both measures of the co-occurrence of new discriminations on the Intermediate Tests loaded onto this factor.

Intra-Individual/Occurring Individually/On Task: This category was validated by the emergence of Factor 8, the number and timing of new discriminations on the Intermediate Tests.

In summary, the factor analysis validated five of the six categories generated by the present theoretical analysis. In doing so, a rationale is given for utilizing the factors in subsequent analysis of Posttest scores.

***Table 6**. Factors in each Category*

	Inter-Individual		Intra-Individual	
	On-Task	Off-Task	On-Task	Off-Task
Occurring in Group	Factor 1 Factor 5	[Factors 4,7, & 9]	Factor 3 Factor 6	Factor 10
Occurring Individually	Factor 2		Factor 8	

Interactive Measures: Predicting Change

The Post-Piagetian Model. Recent investigations in the Piagetian tradition, of children's group problem-solving, have evaluated decentering activity as well as cognitive performance (Perret-Clermont, 1980; Emler & Valiant, 1982; Light, in press). Based on the findings of this research, the articulation of predictions (Total Accurate Predictions) and the articulation of reasons (Total Rules and Reasons Stated), engaging in argumentation (Total Arguments) should all add to the prediction of final scores beyond the contribution of the initial skill levels of the group members and the individual's own operational stage. This analysis predicts that the total amount of these respective activities should relate to the amount of new information which is internalized though interaction.

A series of multiple partial correlation analyses tested the individual contributions of Total Arguments, Total Rules and Reasons Stated, Total Accurate Predictions and New Discriminations to the prediction of Posttest scores, partialing Pretest and Group

Levels. These analyses yielded the following results: partialing the common contribution of Pretest and Group Level from the dependent and independent variables, Total Rules and Reasons Stated ad Total Accurate Predictions did not contribute to the predictions of Posttest scores; New Discriminations had previously been shown to be unrelated to Posttest scores, in the test of the Rule Use model. The multiple partial correlation between Total Arguments and Posttest, partialing Pretest and Group Levels, did show a significant relation between the two, $F\ (3,28)=3.09, p<.05$; Multiple $R=.71$.

The amount of arguing a child engaged in could be intercorrelated with the other variables of importance in the Post-Piagetian Model. An assessment of the unique contribution of each of these variables, beyond Argument was conducted. Total Rules and Reasons Stated, Total Accurate Predictions and New Discriminations were each tested in a multiple partial correlation analysis predicting the Posttest scores, partialing Pretest and Group Levels, and Total Arguments. Results showed no unique contribution to Posttest score prediction of any of these variables after the common variation of Pretest scores, Group Level, and Total Arguments was considered.

The Post-Piagetian model assumes that higher level learners are correct more often, their accuracy is independent of others, and they should show evidence of benefiting from group interaction on the Intermediate tests. Although Pretest is significantly correlated with Total Accurate Predictions, $r=.46$; $F\ (1,30)=8.25, p<.01$, it is not related to New Discriminations, $r=.08$. Neither are New Discriminations related to Accurate Predictions, $r=.15$. This set of relationships suggests that responding to what is nominally the same problem is a function of different variables depending on whether it is verbal or written, given in interactive or in individual conditions, and so on. Higher level learners produced more Accurate Predictions in the group setting but this did not relate to their written test performance in this case, or to eventual gains. The presence of such a transfer problem will be taken up in the General Discussion.

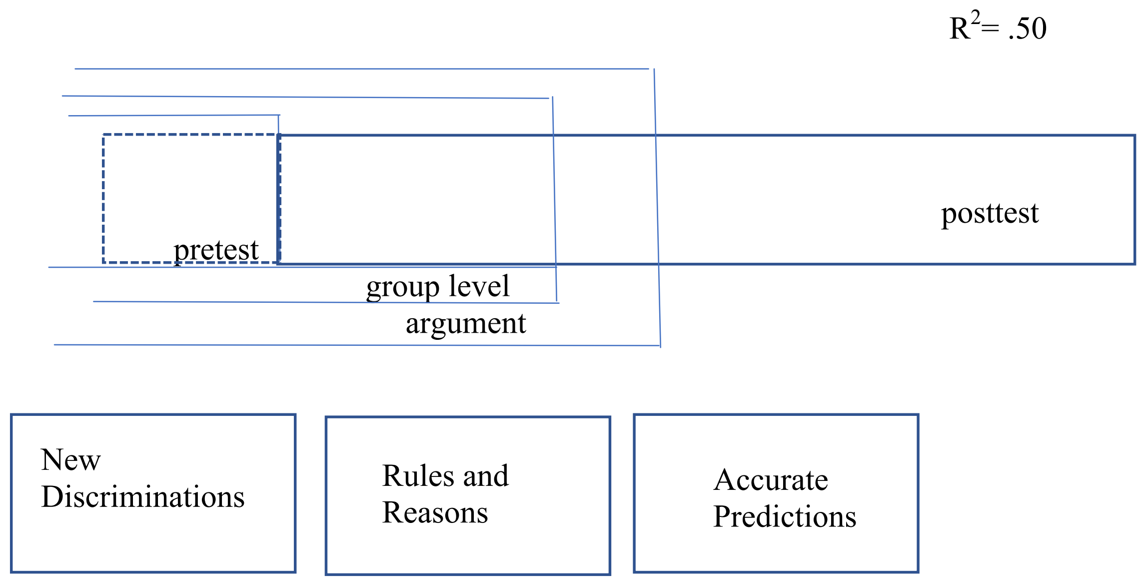
This model, based on one interactive measure (Total Arguments) and three measures of individual logical activity predicts Pretest to Posttest change with a slightly stronger relation than models based solely on individual measures of performance. However, the particular individual cognitive variables expected to predict gains by the Post-Piagetian analysis, were not seen to add much predictive weight. Children's initial Rule use describes most of the variation in Posttest scores at this point.

The Vygotskian Model. Several relations that emerged among the variables are difficult to explain on the basis of a Piagetian-based model, even an expanded version. The fact that Total Rules did not enter into the Post-Piagetian model, and that Total Accurate Predictions did not predict gains, is especially problematic. Similarly, despite the predictive strength of Total Arguments for partialed Posttest scores, it is underspecified both for describing the problem-solving interactions and for helping to account for those individual aspects of performance that are anomalous, by a Piagetian account. If engaging in Argument, irrespective of the reasoning involved, serves to challenge children's viewpoints, this suggests that Argument is better characterized as an interactive measure than as a strictly cognitive one.

Vygotskian theory, which posits an internalization process to account for individual performance, does not claim that indices such as stating rules, or events such as seeing a scale work, will necessarily predict learning. Rather, these events must be embedded in interaction with others before they come to be used in problem-solving by children.

Because it is also through interaction that tasks come to be understood as learning tasks, the so-called operational actions observed among the children are themselves products of previous interactions. For this reason, the organization of the task and the participants' roles, given the control that the task exerts initially on the child, is important to examine. Indicators of learning should show the influence of task arrangement; by the logic of this approach, summing performance across different interactive conditions is likely to obscure the differential contributions of the task organization in each interaction condition. A measure such as Total Arguments may not predict as well as the Conflict factor which includes Argument in each Condition as separate variables. According to the theory, measures taken during individual testing and during group conditions should not necessarily reflect one another because performance in the two contexts is a product of different experiences.

A model is proposed, based on the theoretical categories as they were validated by the factor analysis (see Figure 7). A general Vygotskian model predicts that cognitive gain made by the child would be a measure, first, of the child's previous contacts with similar problems and, second, of the kinds of interactions the child engaged in during the situation being studied. If individual cognitive activity begins as activity occurring between people, Inter-Individual On-Task measures (Factors 1 and 5) should best describe changes in children's performance, beyond the variation due to Pretest and combined pre-tests of the group.



Post-Piagetian Model

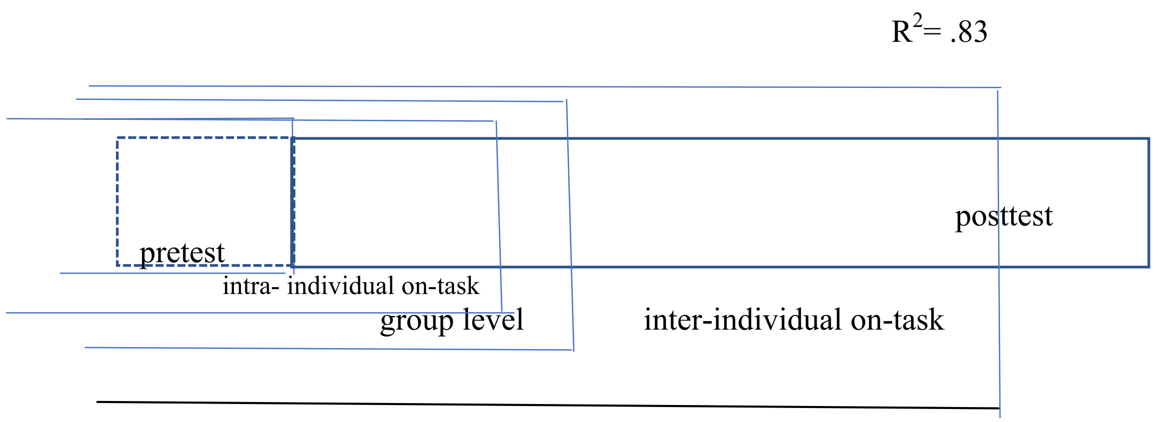


***Figure** 7*: *Models predicting posttest score variation which include group measures*

A question raised by the Post-Piagetian work concerns the contribution, distraction, or irrelevance of off-task behaviors. Inter-individual Off-Task measures (Factors 4, 7, and 9) are related to Condition factors, and may show some relation to Posttest scores because they may serve as organizers for the children's activity. The number of New Discriminations as an individual performance measure had been ruled out as a measure predictive of Posttest gains; however, according to the Vygotskian approach, New Discriminations in the context of Group Cohesion should carry some predictive value (Factor 2). The Intra-Individual factors (3 and 6, 8 and 10) were also included in a test of the model: once the variation explained by the Inter-Individual measures is partialed, the individual measures of performance may add to prediction of gains.

The two or three principally loading variables from each factor were tested by category in a series of multiple partial correlation analyses. In no case did the two variables measure the same events (e.g., Total Arguments and Arguments in Condition 1); one variable (Attention in Condition 3), which loaded onto two factors, was assigned to the factor cluster consistent with the category theory. The significance of each category was tested by an Analysis of Variance for the Multiple Partial Correlation coefficient according to Blalock (1979).

First, the partial correlation of each category, represented by the factor variables selected, was computed with Posttest scores, partialing Pretest and Group Level. Results showed that only the Inter-Individual On-Task Group category showed significant commonality with the Posttest scores (partial $r=.84$; $F(7,22)=7.19$, $p<.01$). The multiple correlation coefficient between the Posttest scores and the independent variables was .91.

It ma be that once the variation of Inter-Individual On-task Group measures is itself partialed, the other categories of variables could predict further variation. Multiple partial correlations, partialing Posttest scores for Pretest, Group Level, and the Inter-Individual On-task Group category, showed no additional contribution by any other category.

The lack of contribution by the other categories of variables, which was contrary to expectations, is difficult to interpret. First, intercorrelations between the Inter-Individual On-task Group category and no others could account for the results. However, the multiple partial correlation procedure did not permit a test of this. The other categories do add to the strength of the overall equation, as evidenced by increments in the multiple coefficient, but their separate contributions were not detectable according to the fairly stringent multiple partial F-test. In some cases, variables within the categories were significant in the multiple partial equation. The subset of variables chosen to represent the categories may not have been the most representative ones. Adding more variables to the equation, or different ones, might have changed the results.

Partialling Pretest and Group Level from an individual's change score may have removed from consideration variation that is in common with some of the other measures. Multiple correlation, testing the relation between unpartialed Posttest scores and each of the other categories, was performed. The results showed that both Individual On-Task categories—Inter-Individual ($r = .35$; $F\ (3,28) = 5.49$, $p < .01$) and Intra-Individual ($r = .35$; $F\ (3.28) = 5.12$, $p < .01$)—were significantly related to Posttest scores. Neither the Off-task categories nor the Intra-Individual On-task Group category were related to unpartialed Posttest scores although several individual variables were. These tests suggest that Pretest and Group Level share common variance with the individual measures of the category system, and subsume their independent contributions. If Rule level is related to the Individual On-task category, this says that a child's initial skill level is related to the child's tendency to coordinate and time new discriminations on individual tests, if not to the number of new discriminations themselves.

The results of the multiple partial correlation analysis allows us to conclude that the tendency to engage in particular kinds of on-task interactions is a good predicator of subsequent gains beyond initial skill level. They suggest that inter-individual exchange concerning a task may be more important to look at in a group setting than individual cognitive indicators such as correct answers, when assessing children's problem-solving. That off-task measures did not contribute to the model was contrary to expectation. However, the Inter-Individual Off-task category was not fully validated as such; rather the variables predicted by the category system to cluster by type of behavior, seemed instead to cluster according to Condition. Multiple partial correlation analysis pointed to the possibility that Pretest and Group Level share common variance with the Individually Occurring categories, which may mean they affect individual test performance.

The variables included in the multiple partial correlation analyses were not the summary scores (e.g. Total Arguments) of the Piagetian model, but reflected the contribution of behaviors in the different Conditions. Greater prediction of Posttest gain was possible using this Vygotskian model of categories. However, the results so far only support the idea that operations and cooperations are complementary and do not clarify the nature of the complementarity.

The previous analysis showed that certain categories of interchange did not seem to contribute to children's learning to solve balance scale problems; an analysis of how the coded behaviors functioned in the different Conditions may suggest whether task organization was influencing the results. If task organization affects the variables of interest, it may be possible to distinguish the data as supporting a Vygotskian position or a Piagetian one. For this reason, it will be important to describe the extent to which Inter-Individual On-Task variables are affected by task arrangements, and whether variables of other categories affect performance in any of the Conditions.

Condition Differences

Factor analysis. Differences in individual and group measures that may have occurred in the three interactive conditions are important to consider because of the significance attached to effects of task organization. Changes that occurred for single behaviors (e.g., Argument) over the three conditions were not possible to interpret because the order of condition presentation was not balanced. However, the relative influence of variables within each condition can be compared.

The analyses of Post-Piagetian and Vygotskian models each involved factor analyses which emphasized individual differences on the measures. Eight of the 10 factors reflected variables in which individual differences did not depend on Condition. Two factors (Factors 4 and 7) did seem to reflect Condition effects on individual differences for a few of the measures.

The fact that the Cross-Observation and Social Response variables, coded by Condition, did not load onto independent factors but fell out among other factors suggests that the same codable responses functioned differently in each condition. That is, there was an interaction of Condition by Cross-Observation and by Social Responses. Similarly, Rules States in Condition 2 and Accurate Predictions in Condition 2 did not cluster with the other Rule and Prediction variables. Such clustering suggests that the occurrence of these variables is tied to interactive events arising uniquely in the respective Conditions.

Mean differences. In order to delineate the functional nature of the measure in each task condition, the mean frequency of the behaviors in each Condition were compared. Table 7 displays the means and standard deviations for Group measures that were taken in each experimental condition and the t-values indicating significant differences between the frequencies in each condition.

Table 7. *Mean Differences and t-test values for group variables coded by condition*

		Condition			t-values of Condition Differences		
MEASURE		1	2	3	C1-C2	C2-C3	C1-C3
Accurate Prediction	*M* *SD*	3.08 1.34	.97 .91	4.11 1.58	7.51**	-11.47**	-3.63**
Attention Responses	*M* *SD*	34.8 24.0	30.0 23.0	49.1 34.3	1.16	- 3.38**	-2.47**
Argument	*M* *SD*	12.94 9.63	10.25 7.08	4.89 6.19	2.00*	- 5.58**	5.09**
Cross-Observations	*M* *SD*	.61 1.48	1.08 1.54	2.94 3.03	1.30	- 3.81**	-5.12**
MLA	*M* *SD*	3.03 .78	3.01 .89	2.96 .78	.21	.60	.97
Rules & Reasons	*M* *SD*	.31 .52	.11 .40	.65 .65	1.15	-1.42	- .44
Social Responses	*M* *SD*	53.75 20.75	42.66 19.43	34.23 23.08	3.64**	2.06**	4.22**

df = 35
**p* .05
***p* .01
t-values not starred are not statistically significant

Differential responding for the problem-solving task across the three interactive Conditions (Modeling, Scale Conflict, and Experimenter Conflict) may be seen in the relative frequencies of the Group measures. That the means varied in different directions across the conditions indicate a Variable by Condition interaction and hence that differences between conditions were not due to order effects. Of the seven measures, three showed significant differences ($p < .05$) between all three conditions (Accurate Predictions, Arguments, and Social Responses), and two others showed significant differences between two of the conditions (Attentional Responses and Cross-Observations). There was too little variance in the number of Rules and Reasons States across the different conditions to yield significant differences, although the trend was for a greater number in Condition 3. Mean Length of Argument also showed no differences across Conditions.

It may be seen that while the number of Arguments decreases over the three Conditions, the length of the arguments does not vary. The length of arguments, taken by condition, correlated differently with partialed Posttest scores. Specifically, Arguments in Condition 1 and in Condition 2 were associated negatively with Posttest scores while Arguments in Condition 3, though less frequent, were associated positively with gains. MLA in Conditions 1 and 2 were negatively associated with gains. This suggests that while the length of arguments may not have changed, the length may still have had differential effects in the three conditions. It may be that the likelihood of arguing is an organizational matter but the tendency to engage in lengthy or brief arguments may not be as affected by task organization. In sum, frequency of Arguments as a factor is predictive of final gains, however, the Argument variables in each Condition could be associated negatively or positively to final scores.

At the same time, Cross-Observations were equally likely in Conditions 1 ad 2 but significantly more likely to occur in Condition 3. Cross-Observations in Conditions 1 and 3 were associated with the category predictive of gains, although Cross-Observations in Condition 1 were associated in a negative direction.

Rules and Reasons were stated with equal (and low) frequency in each Condition. Rules and Reasons Stated in Condition 1 and 3 were related to gains in Posttest scores but Rules in Condition 2 were not, indicating that their function in the different interactive contexts of the conditions varied. Although Rules, as they loaded on the Logic factor, related to Posttest scores, the absolute frequencies of Rules Stated indicate that children in these circumstances are not likely to solving interactions very frequently. If they did, it may not have been useful, as in Condition 2.

Accurate Predictions, which were based on gestural and linguistic evidence in the different conditions, showed different rates across conditions, with Condition 1 allowing more verbal correct predictions that Conditions 2 and 3; but Condition 3 permitting more correct compensatory moves than Condition 2. Accurate Predictions in Condition 1 were related to gains in a negative direction.

Attentional Responses were equally likely in Conditions 1 and 2, but significantly more likely in Condition 3, while Social Responses were greatest in Condition 1 and decreased significantly across Conditions 2 and 3. These results suggest that Experimenter-Conflict task organization served to increase children's on-task behavior and to reduce extraneous activity significantly. In the other Conditions, 1 and 2, on-task behavior is not affected by organization but off-task behavior is greater in the condition that was designed to promote the greatest direct social competition (Condition 1). A separate multiple partial correlation analysis of Factor 4, 7, and 9 with Posttest scores, partialing Pretest and Group Level, showed that Social Responses do not affect final gains.

Despite the confounding of Condition and Order the manipulations included in the design, derived from a Vygotskian analysis, had the predicted effects on problem-solving behavior. Cross-Observations and Attention were greatest in Condition 3 (Experimenter-Conflict) while Argument and Social Responding were lowest; Condition 2 produced the least number of Accurate Predictions including Correct Compensations.

Both Condition 1 and Condition 2 produced significantly fewer Cross-Observations than did Condition 3.

Characterizing the function of the measures in each condition. The design rationale (see Chapter IV) predicts the behavior of several of the factor variables. The results of the t-tests and the multiple partial correlation analyses may be considered together in order to describe the functional nature of the various categories of interaction.

Condition 1: The Modeled Condition. The design of Condition 1 was patterned on the task arrangement of the individual Pretests. It was anticipated that by presenting the teams with preselected problems to pose for each other, by asking the teams to judge the scale outcome and not to calculate it, and by asking the teams to score each other that competitive behavior would be greater relative to the on-task behavior. Furthermore, teams should be less likely to exchange information about the scale features in a cooperative manner. Number of Accurate Predictions in Condition 1, Number of Arguments in Condition 1, and Percent of Social Responses in Condition 1 all loaded significantly on Factor 7. Condition 1 which was specifically designed to foster competition between the groups accentuated individual differences in the tendency to argue and to be "social". Curiously enough, however, these measures, which are thought by Post-Piagetian researchers to influence the development of knowledge (e.g., Perret-Clermont, 1981), did not predict Posttest scores. Children in Condition 1, in total, engaged in significantly more on-task argument than they did in Condition 3 and somewhat more than in Condition 2. But, a separate analysis predicting Posttest performance partialed for Pretest and Group Level, showed that Argument and MLA in Condition 1 were <u>negatively</u> related to gains. Apparently, the competitive atmosphere of

Condition 1 induced counterproductive arguments. This is contrary to a view that does not distinguish the motivation for arguing.

The Number of Arguments measure did not distinguish arguments directed at a team partner from those directed at the opposing team. Cross-Observation is a reflection of cross-team interaction. Relative to the frequencies in the other conditions, there were significantly fewer Cross-Observations in Condition 1 than in Condition 3. Making Cross-Observations in Condition 1 was also associated negatively with higher Posttest performance.

Condition 1 also produced more Accurate Predictions than did Condition 2 as well as greater proportion of "Social" responses in comparison to "Attention" responses to scale outcome across all the groups. Although these measures did not seem to be related to children's learning, they do reflect the competitive context of Condition 1. Accurate Predictions in Condition 1 were also related negatively to Posttest scores. In sum, the On-Task Group variables in Condition 1 were not beneficial for children's problem-solving, and the tendency to engage in such behaviors was not totally accounted for by initial skill level.

Condition 2: Scale Conflict. In Condition 2 it was arranged that children attend to a feature of the scale irrelevant to the problem solution, namely, one side of the scale arm. The questions they were asked to pose each other demanded both additive and multiplicative activity, but the task organization was predicted to work against this occurring. That the Condition 2 task organization has this effect can be seen in the fact that all the groups, some to a greater extent than others, at some point changed the questions they asked each other to be: which side will go down, a simple prediction problem that is easier to get right. It was expected that such a task arrangement would lead to low Attention relative to Social responding as well as to a higher proportion of mistakes and few Cross-Observations. This is what was found.

Children working in Condition 2 showed the same numbers of Attentional Responses and Cross-Observations as they had in Condition 1 and less than they did in Condition 3. They argue somewhat less that in Condition 1 but significantly more than they did in Condition 3. The frequency of their Social Responses fell between that for Condition 1 and Condition 3. Condition 2 produced fewer Accurate Predictions than the other two conditions, even when Correct Compensations are added to correct verbal predictions. In Condition 2, Argument and MLA were negatively related to gains, while Attention was positively related. Accurate Predictions, Rules and Cross-Observations occurred very infrequently in this Condition, which may explain why these variables did not appear in the factor analysis.

The arrangement of Condition 2, which was designed so that children would identify with one arm of the scale , does not foster multiplicative interactions. The problems given the children demanded that they consider both distance and weight dimensions simultaneously; since the Condition 2 procedures tied actions to the scale itself, they were unable to go beyond that which was available in the physical array that they already were attending to, and multiply the dimensions on an abstract plane. Condition 2 was organized to emphasize activity taking place on the side of the scale arm assigned to a particular team, and was expected to produce more difficulty for problem-solving because it stressed an irrelevant feature of the situation.

Number of Accurate Predictions in Condition 2, Percent of Social Responses in Condition 2, and Number of Correct Compensations in Condition 2 all loaded onto Factor 4. The arrangement of Condition 2, in fact, seems to have heightened children's individual differences in task performance accuracy and in their tendencies to respond to the task with social markers. This effect is consistent with the assumption that Condition 2 presented increased obstacles to problem-solving, and further challenges the view that individual skill differences influence performance consistently across task arrangements.

Condition 3: Experimenter Conflict. The task arrangement of Condition 3 was designed to generate coordinated activities that would lead to multiplicative thinking about the scale dimensions. This was done by making teams responsible for one dimension each and asking them to calculate moves against the Experimenter. It was expected that on-task behaviors would increase, as would Cross-Observations. It was also expected that accuracy would be more likely than in Condition 2, because compensatory moves were counted and because children were expected to notice the scale's dimensions more than they had in the other conditions.

Examination of the various measures showed that Condition 3 served to reduce Social responding significantly and to increase Attention significantly. Accurate Predictions and Cross-Observations occurred significantly more frequently than in the other Conditions; the number of on-task conflicts between children decreased significantly. More and longer Arguments, and Cross-Observations in Condition 3 were related positively to higher Posttest scores. Accurate Predictions tended to relate in a positive direction and Attention in a negative one.

The design of Condition 3 included the participation of the adult in the problem-solving activity. This may seem to account for the reduction in both on and off task dialogue, however, the way in which the adult participated was not simply as a suppressor of talk. According to the transcripts, the experimenter talked and prompted as much if not more in the other conditions, especially during Condition 2, which was difficult for the children. The effect of the interactional task structure in Condition 3, which was to establish the goal of joint team coordination against the adult's moves, was what resulted in differences in behavior frequency and in the value of communication for problem-solving.

In sum, regardless of initial Rule, children who responded to the Condition 1 arrangement by arguing were also more likely to remark on the opposing team's operations (although the absolute frequency of Cross-Observations was low) and less likely to be those who made gains; children who responded with less arguing in Condition 1 were less likely to make Cross-Observations and more likely to be those who made gains. In Condition 3, overall amount of arguing went down significantly, but those who did argue were more likely to express Cross-Observations and make gains. Children who didn't argue in that condition also were not likely to take into consideration the other team's activity and coordinate it with their own. This leads us to conclude that the distribution of activity according to the Condition 3 arrangements better promoted problem-solving activity. The likelihood of Social Responding, though affected by task arrangement, was unrelated to gains on the Posttest.

The picture that emerges suggests that first, the occurrence of a particular kind of cognitive interaction (e.g., on-task arguing) is not necessarily an indicator of informative exchange, since it can occur in a context where the task structure (i.e., interpersonal competition) may vitiate its formal value. Second, children's responsiveness to the differences in task arrangement, as measured by the On-Task Inter-Individual measures, may be an overall predictor of how well information that is available in the interaction can be utilized. That is, the power of the context arrangement precedes learning for a particular task for children of each cognitive level of capability.

The relation of condition differences to intermediate tests. The majority of New Discriminations on Intermediate Tests were observed on the test following Condition 1 (68%). This may be why Condition effects on Posttest scores for the new discriminations was not found. The fact that there were very few new discriminations possible may account for a lack of relation between the number of new discriminations and gains, even though a ratio of those produced to those possible for each group suggests that there may be group differences (and thus differences in relation to gain). That the number of New Discriminations does not predict gains in the long run suggests that Condition 1 produced only a short term advantage. For a child, demonstrating new answers on the Intermediate Test immediately following the Modeled condition was not evidence that individual "cognitive restructuring" had occurred. When these new discriminations were taken as a measure of how inter-coordinated a group was, this too failed to correlate with Posttest gains.

Two control groups of 24 children each were given the first Intermediate Test following either Condition 2 only or Condition 3 only. The control group data permitted only a limited test of the effects of condition and of order on Intermediate Posttest performance. There were two reasons this was so. First, as it was impractical to videotape the control groups, their interactions were audiotaped and this procedure disallowed a count of most inter-individual measures that may have contributed to the written scores. Second, control groups experienced either only Condition 2 or only Condition 3. Their Intermediate Test data could only be compared to the Condition 1 data of the experimental group and not to the Condition 2 and 3 data of the experimental group, who had already experienced Condition 1.

A one-way analysis of variance was undertaken, measuring the mean number of New Discriminations shown by children on the tests following the first problem-solving condition. The number of New Discriminations produced by each child in the experimental group on the Intermediate Test following Condition 1 was compared to the numbers produced by the control groups who experienced either Condition 2 or Condition 3. Results showed a significant difference in the number of New Discriminations shown by the different groups, $F(2, 81) = 4.90; p<.01$, with the groups producing an average of .92, .58, and .42, respectively. These results suggest that the tendency for new discriminations to occur on the Intermediate Test following Condition 1 may have been due to the task organization and not to an order effect.

Summary

In a general way, the kind of interactions a child engages to are complementary to a child's cognitive level, as Piaget and Vygotsky both claim. However, it was found that an individual's initial cognitive level only partially predicts learning. Group Level, or the sum of individual cognitive levels of a group, adds to the prediction but does not account for all the variation seen. Pretest and Group Level may, however, be related to children's performance on the individual tests. Such performance was not seen to relate to group measures independently of the initial entry level skills of the group members. According to the best fitting model, the most powerful predictors of learning, after previous history is partialed out, are measures of on-task activity occurring because of the presence of others (Inter-Individual).

Functioning with Rule 1 indicates a failure to distinguish the distance dimension on a scale task and also the likelihood of making correct guesses about a problem. It does not give an indication of the tendency to engage in on-task arguments with others. The tendency to argue has been shown to be made more or less likely and more or less productive depending on the task organization. Under certain conditions, children can be organized to engage in interchange that can promote the creation of problem solutions.

To the extent that learning from a group problem-solving situation involves both noticing problem features and responding to others, both cognitive Rule and Inter-Individual variables enter into the success of the experience. With this, Piaget and Vygotsky would have concurred.

The fact that the variables comprising the categories of the current analysis did not cluster solely on the basis of structural similarity, but rather showed variability due to condition differences, means that we may distinguish Vygotskian measures from the Piagetian measures. The category system, validated by factor analysis, permitted an analysis of the function of particular behaviors under different interactive conditions. Although a temporal sequence of learning was not possible to trace in these data, the analyses reveal the interaction of task organization with inter-individual problem-solving activity and, in turn, with the probability of individual learning occurring. The present analysis permits a tentative conclusion concerning the complementary nature of the problem-solving and inter-individual domains. It suggests that, while “cognitive” and “social” development generally co-vary, responsiveness to task organization, a “social” factor, precedes learning on a particular task.

In attempting to explain the process of children’s cognitive development and the effect of social-interactional problem-solving on individual performance, a series of models was generated and applied to the present data. Factor analysis, multiple partial correlation analysis and tests for condition differences performed upon the individual and group measures utilized a category system consistent with Vygotskian theory. More traditional models, based on either individual measures alone or on a limited set of inter-individual variables, did not predict children’s individual gains as well as the model based on the category system of Inter-Individual variables. Certain of the categories, predicted to influence children’s learning in group problem-solving conditions, were not found to contribute to the model.

Chapter VII

General Discussion

Categories of the Models Tested

Individual Measures. By the means of multiple partial correlation analysis, it was shown that models accounting for change in children's understanding which were restricted to individual measures of performance did not predict individual learning as well as did models which included Inter-Individual variables. The most powerful model includes both initial Rule levels of group members (assessed by individual Pretests) and Inter-Individual On-Task variables from a Vygotskian analysis of cognitive development.

Knowing a subject's entry-level skills into a problem-solving interaction does not tell us whether or not s/he will improve. When the entry-level skills of the problem-solvers' group are known, however, we can begin to predict the probability of individual learning. Consistent with the argument of Piaget and any others, lower level learners make more gains when working with higher level learners than when working with each other; higher level learners than when working with each other; higher level learners seem to learn with whomever they are working.

Based on a Vygotskian analysis, entry-level skills were argues to be a reflection of the children's previous achievement involving the task and task setting. The contribution of Pretest levels was seen to subsume the marginal contribution of variables that measured Accurate Predicting and Attention to the task. By partialling individual and group Pretest levels in the present analysis, we controlled for information that the children of the different levels had, which may be why the Intra-Individual On-Task category was weakly related to final gains. The significant contribution of the Pretest scores to the prediction of Posttest confirms that more information about the scale as important to the problem-solving situation. Pretest levels also related to the likelihood of a group demonstrating new answers on individual tests at the same time. This occurrence, however, was not a guarantee of learning.

Off-Task Categories. The non-validation of the Inter-Individual Off-Task category by the factor analysis is interesting in two respects for the attempts to better understand interactional contributions to cognitive development. First, as such, “Social” (i.e., off-task) elements in children’s interactions do not enter as a separate factor to help or to hinder on-task gains, as they are measured here. Instead, the likelihood of Social talk is tied to the nature of the task arrangement. This finding contrasts with the post-Piagetian literature and with some other findings which claim that strictly social responses affect problem-solving adversely. The way in which social responding was indexed here, moreover, was designed to be a strong test of its effect, since the movement of seeing yourself proven right or wrong is socially a heavily weighted one for children of this age group. Secondly, the non-categorical nature of Social Responses may mean that in other research situations, a high rate of such behavior signifies, not the inhibition of cognitive activity nor a child’s tendency to be off-task, but the kind of social interaction organization an experimenter has arranged. The fact that these responses were not measures temporally may have affected their contribution to the final equation predicting gains. The “social” responses by children (e.g., “Yah! I told you!”) were certainly very salient in the videotaped record of their interactions.

The factor analysis showed the other Off-Task variable category, Procedural responses, to be independent of cognitive measures; procedure was also unpredictive of children's gains. Procedural responses included actions which show concern with rules of conduct on the part of the children.

According to Piaget's analysis, the development of operational thinking is complementary to the level of flexibility concerning social rules. The results of the present analysis suggest the presence of "decalage" between these domains, since children's concern with procedural matters did not predict or correlate with cognitive measures although there were individual differences views this kind of activity as indicative of a task goal other than problem-solving on the part of the child. From the videotapes, and perhaps in the classroom setting, it appears as though the children engaged in Procedural activity are on-task. But, for example, one child, taking an organizer's role with his peers, filled in the worksheets with concentration and care but completely failed to notice what the scale outcome had been; he entered his own predictions on the worksheet as if they had been confirmed.

On-Task Categories. According to several analyses, young children have trouble keeping in mind several aspects of an issue at once (Rubstov, 1981). Theories differ, however, in the extent to which they maintain this is a necessary ability before true, individual "problem-solving" can be said to occur (Piaget, 1948; Vygotsky, 1978; Inagaki & Hatano, in press; Rubstov, 1981.)

Piaget simply does not count thinking which is not fully reversible and transitive, conjunctive and disjunctive as fully logical activity. This position may be the reason that a resolution to the paradox of needing or not needing peers is difficult to attain. In addition, because the definition of ultimate problem-solving ability is circular, it may be that the distinction between "social" and "cognitive," as opposed to on-task and off-task, conflict has been falsely drawn. That is, the task is confused with the source of the change of viewpoint. As Light points out (in press), the social, or off-task, has been confused with the Inter-Individual.

What is the nature of the relation between the intra-individual and the inter-individual? Piaget would have it that they share formal relational features, reversibility, etc. Vygotsky's notion of the relational structure between people occurs, not as Piaget's logical relations, but as a specific mediator of activity.

We must be careful to distinguish between having attention called to a task by a partner (on-task) from the class of all inter-individual relations (on-and off-task). Inter- and intra-individual relations in a general way may develop together, as previously noted. But inter-individual control is what precedes on-task behavior in a particular setting. When children make mistakes and no one is moved to call them on it, i.e., notice the category "error," no one learns. Similarly, if one child keeps pointing out what to do and no one responds, no one learns either. These observations point to the fact that what constitutes "knowledge" is initially marked by others, and becomes important to the extent that we respond to others.

A clear illustration of how this worked can be taken from the protocols. Among the groups there were two individuals who constantly commanded the others in their respective groups, issuing directives or pronouncements, sometimes in officious tones, but receiving no measurable responses. Examining the protocols, we have no evidence that the information in such utterances challenged the notions of those listening to them. This may be what Perret-Clermont calls "domination." But the lack of response to such behavior in a peer indicates low engagement on the part of group members. These groups, which showed no evidence of utilizing the organizing efforts or information contributed by the dominant individuals, could be said to be not operating as social units but only as social aggregates. They were among the groups whose members did not show gains.

Is it being proven right by a different route than your own, or being proven wrong that leads to restructuring? There is evidence for both outcomes (Bryant, 1982; Perret-Clermont, 1980). Inhelder and Piaget suggest (1958) that the child reevaluates simple symmetrical equilibrium on a scale after the multiplicative proportionality rule is operational, and reassimilates the information about the dominant and subordinate task dimensions on a deeper level. Bryant points out, however, that Piaget shifted his position on exactly how this transpired and never delineated the circumstances or exact relations by which a child "produces the solution to his own dilemma" (1982, p. 244).

The present data revealed no direct effect of being right or of being wrong during group problem-solving either on the likelihood of improving or on the nature of problem-solving interactions. Because correctness here was not measured in relation to the predictions of others, we may not rule out the importance of concurrence; that is, if two or more children agreed on an outcome and agreed for different reasons, the data do not show it. Second, the data, as with Social Responding, were averaged across problem sets. Another type of analysis that takes sequential information into account, might show an effects of problem outcome: the videotapes suggests that for some children a shift in strategy may have occurred depending on how critical or differing the group was in response to a prediction being proven incorrect. A tendency to view the origin of one's guesses as a social matter altogether seemed to be reflected in the comment of one child, addressed to the Experimenter: “How come it’s always me who’s getting them wrong?”

Why then, if it did occur, would on-task conflict be successful sometimes and sometimes not, asks Light (in press). The issue seems to be whether it is “conflict of centrations” or “co-constructing of the epistemic,” or objective attitude, that may be learned in interaction. A confusion arises because of varying reports of individual gains resulting from joint problem-solving found in the literature. The current study supports the idea that on-task conflict alone is not the issue, but neither can it be said that the construction of a problem-solving attitude is at issue, nor is the matter if of individual readiness. Rather, within the constraints of a child’s previous experience, what Rubstov calls “moving to a generalized plane of coordination,” or deriving a rule from one’s actions, can be manipulated. That is, the co-constructing of knowledge is not inevitable.

Only on-task argumentation was coded in the present protocols. The analysis based on argument in the various conditions suggests that for this task, the task-as-a-topic-of-interchange and the motivation to assert a position are not congruent; since the condition designs varied the roles of others, arguing may have more to do with the others that with the formal task itself. It should be noted that individual children’s imperative and declarative statements that met with no response were not coded because, theoretically, they don’t represent “active conflict” but only challenge.2

In order to understand why Argument as well as other Conflict variables might be so critical and why they behaved in paradoxical fashion in some Conditions (that is, relating negatively to gain), we can appeal to the notion of the Zone of Proximal Development. As states earlier in Chapter III, Piaget’s theory takes the point of view of the child in looking at cooperative situations, how the child behaves in them, how the child's knowledge is shared with others. The Vygotskian notion of the Zone of Proximal Development takes into account both the child's and the world's informational potential. The child's responses to problem-solving arrangements may interfere with the accessibility of solutions in the system.

For instance, Condition 1 was designed to promote competition by setting up a team conflict. The scale was not integrally involved in the organization of the competition, because any task would do. Decentering, or considering another's viewpoint in that case, could relate to the task goals in two ways: it could be defeating, since the idea is to keep your information to yourself and win, or, it could be put into the service of preventing the other team from accessing information. Although this was not done for the present analysis, the protocols could be checked to see whether, in Condition 1, on-task arguing was obstructively initiated (For example, the challenge, "You're wrong!," uttered as the opponent makes a move.)

Related to this is the fact that depending on the scale for information is not always a good idea. First of all, the scale will confirm only absolutely correct answers; most approximations, which could help in strategy revision, are not informative. Second, for certain problems, wrong rules work. From the particular scales used in the current study, one boy derived a subtractive rule: count the number of weights, subtract the number of positions between the weights and the end of the beam, and the larger remainder tells you the heavier side. This rule worked for about 90 percent of the problems.

Transfer

Predicting individual performance using group performance and the reverse has been said to be problematic (Mugny et al. ; see Chapter III). The results of the present study show that this is true for performance variables based on traditional developmental measures, (for example, New Discriminations), as well as for more “clinical” measures taken from verbal protocols, (for example, Accurate Predictions). The lack of transfer and predictability observed among the various individual paper-and-pencil measures in particular, underscores the idea that the responding context arrangement is, indeed, quite specific for these children. It seems that the Intermediate Tests, by asking the children to interpret a line drawing in relation to a real scale and to mark their own responses, renders itself non-representative of individual knowledge as it unfolded in the course of the study.

When children’s interactions in relation to the task are taken into account, a relation does emerge between the inter-individual and intra-individual factors. Perret-Clermont and Schubauer-Leoni write: “We would suggest that unless the subject already had full mastery and practice of the specific requirements involved, he will always be elaborating his response within the testing situation in which he has to produce it: “learning” there, on the spot, to produce it (1981, p. 231).” If testing is itself a learning situation, then social variables, task arrangement and task materials will influence performance on tests.

Since the New Discriminations on the Intermediate Tests are not predictive of final gains, how do new responses vis a vis the scale dimensions come to be produced reliably? It is proposed that this is best understood as a function of what was theoretically posited to make a difference in terms of savings across situations, namely, attending to the dimensions for which the other children were responsible: Cross-Observations and Conflict. Posing the issue at one involving context effects means that the investigator looks for or engineers generalities across situations so that children will perform similarly. The investigator's job is not focused on explaining lack of similarity in children's performance, or, decalage.

The Social Origins of Problem-Solving Activity

The point of this work has been to show that without considering the activities intervening between individual Pre- and Posttests, one cannot fully understand the relation between the task, the problem-solvers, and the information that may become available when the two are brought into interaction. This is true for the study of any situation of change, or, development. In making this claim, we must examine whether group level differences arise simply because some children know less about the problem, or, because the social interactional aspects of the problem-solving situation are variable. The issue is where to place the stress; the connection between the control a task has and that exerted by the social setting could co-vary, as Piaget and Vygotsky both suggested.

In a sense, Piaget was right when he later observed that peers are necessary to a child's intellectual flexibility, that children can't use information they aren't ready to assimilate, and that individuals' operational levels are complementary to their cooperational levels. By a finer-grained analysis, it has been possible to obtain evidence suggesting that specific forms of interaction (here, the multiplicative activity) or inter-individual responsiveness, precede the participant's ability to coordinate task dimensions alone (see also Rubstov, n.d.).

The most recent experimental work being produced by the Swiss researchers implicates the structure of the task as a factor in children's performance, but does not examine it directly. The work of Mugny, Perret-Clermont and their colleagues focuses on the question of "social distance" between the child and the experimenter, or between pupil and teacher; their analysis also includes peripheral consideration of the task material. Based on the evidence from studies conducted among children of different social classes, they call for a tripartite model of analysis: child-experimenter-object. The focus on the experimenter relates to the issue of the "social distance" of teacher for children. Inter-Individual control may be another way of describing the "social distance" between a problem-solver and a partner.

The experimenter, however, is inseparable from the task organization; the adult's relation to the children is not fixed. In the present study, the experimenter prompted the children throughout , yet is was only the condition which planned for the experimenter's participation (Condition 3) that showed a task- related effect of this deliberate role: children's attentional responding increased, social responding decreased and arguing decreased, relatively. Behavior in this condition was related positively to long-term change. Whatever adult promptings had occurred in the earlier conditions were not integrated into the task and utilized in the same way; in the other conditions, the interactive plane of coordination had not been arranged. Thus we can see that the value of an adult as an informative source may be heightened or diminished by design. Adult prompts don't necessarily function to give task frame information although we usually pick the interactive situations to study which afford this to happen, e.g., puzzle completing, reading groups, etc. The effectiveness of adult prompts has been shown to vary with the status of the adult—mother or teacher (Wertsch, Minick & Arns, 1981), the social utility of the task, for instance, whether the task associated with higher school achievement (see Perret-Clermont & Schubauer-Leoni, 1981), and the status of the child—fluent or non-fluent reader (Moll & Diaz, in press).

The "learnability" afforded by a given situation for a child is largely a function of task arrangement. The task arrangement affects the child through the mediation of others. As it has been argued, to the extent that the child is responsive to others, learning may take place.

Conclusion

Mugny and his colleagues find that the group advantage wanes as children develop skill at a task.

> Using a series of operational tests and a detailed analysis of the behaviour of non-conserving subjects during the pretest, has … enabled us to show that for each notion examined it is only at a particular stage in the development of this notion (or of the cognitive operations related to it) that the individual is likely to benefit from the social interactions taking place. Social interaction appears to be an essential condition of progress at the initial stage of elaboration of a notion and, it is from this social interdependence that autonomy in development is progressively acquired. (1981, p. 320)

Note that this is precisely the Vygotskian analysis.

But that the effect described is not a function of age per se is seen in observations of adults beginning a new task and demonstrating the same effect (Laughlin & Sweeney, 1977). Although adults are more experienced at abstraction than children are, and are not said to be egocentric, on unfamiliar cognitive tasks the very same process is at work: "cognitive progress is based on initial interdependence of actions which decreases to the extent that the individual internalizes his interactively established coordinations" (Mugny et al, 1981).

As cognitive, on-task activity is to be distinguished from intra-individual activity as a whole, similarly, the exogenous "Zone of Proximal Development" which systemizes information for the learner along the dimensions outlined by Inagaki and Hatano (in press), is to be distinguished from notions such as "field dependence," which confounds "social" and "inter-individual" problem-solving activity.

Thus, the correct formulation of the issue is not" the likelihood of learning equals the child's likelihood of decentering plus the availability of information according to the formal task analysis. Since decentering is what we call learning, we formulate the following statement: the likelihood of decentering depends on the group's collective responsiveness to the task arrangement, i.e., their inter-individual on-task history.

For Vygotsky, and for the Post-Piagetians in their most recent work, for Wertsch (1980) and others (Laboratory of Comparative Human Cognition, 1982), the social world, and, to an extent, the physical world, carry the information to be included in a complete problem solution. By assuming that the information for a solution is always available somewhere in problem-solving systems under study, the focus of a Vygotskian investigation is on how the environment arranges access to (i.e., mediates) the solution, given the tools of the learner. The social and cognitive are not separated, and so there is not the theoretical dilemma of explaining how a pre-operational child comes to discover information s/he is not ready to use. The child is supported in "next higher levels" by others, in scenes analogues to those we have analyzed. In the current framework, the inter-individual control already transacted is coordinated with on-task information, and thus the activity in relation to the goal as understood by and with others enters the individual's repertoire of problem-solving.

What is that goes on in the groups that allows us to characterize the interactions as "problem solving"? In the present situation, all the children gave evidence of actively responding quite generally to many aspects of the task—to the competition, to tricking each other, to not being believed, etc.—so that in spite of the factor analysis and the variable category system it is not easy to summarize how the overall stream of such talk, sometimes technically irrelevant, interacts with "pure" information about the scale.

The categories of verbal behavior showed that cognitive, or on-task, conflict—challenging another's problem-solving strategy—was important and occurred more often successfully in a particular situation (Condition 3). Children also made the kinds of statements that were thought to be indicators of paying attention to a new scale feature, under task arrangement conditions that sometimes didn't result in that particular function for these types of utterances.

From the present analysis we may suppose that if lower level learners are generally under less inter-individual as well as task control generally, higher level children might serve as models and focussors, not primarily because of the information they possess, but first because of their inter-individual responsiveness to the task arrangements.

The current notion inter-individual is, in the end, a measure of the probability of responding to what others would name as the target task and its rules in a particular situation. The inter-individual sense of "task analysis" is necessary to include in studies of problem-solving if we are to arrive at a picture of the development of individual skills.

Footnotes

1. Children using Rule I consider only the amount of weight on each side [of the scale]: if the amounts are unequal, they predict that the side with the greater weight will go down; if the weights are equal, they predict that the balance will remain level. Children using Rule II also consistently predict that the side with the greater weight will go down if the weights are unequal, but if they are equal, these children expand their field of consideration to consider values on the distance dimension. Those using Rule III always consider both weight and distance, but if one side has more weight and the other side has its weights further from the fulcrum, the children will muddle through or guess. Finally, children using Rule IV always consider both dimensions and compute the torques on each side if such a computation is necessary (Siegler, 1981, p. 5-7).

2. The analysis and arrangement of the three interactive conditions were worked out in conjunction with V. V. Rubstov of the Institute of General and Pedagogical Psychology, Moscow, and the members of his laboratory. 3. A tally of these statements might provide one way to determine if topic or "others" are the motivation in on-task talk. If asserting a position is primarily weighted by task considerations, an individual with a high rate of assertions should maintain that rate throughout a session; if the audience response is a determining factor, getting no response should lead to a significant decline in the behavior over the course of a session.

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Appendix A

Behaviors Coded from Videotaped Record

Adj.- Adjustment of scale. Changing weights or placement of weights.

AppE- Appeal to the experimenter. This is in the case of other-than-procedural matters.

Attn- Attention. Statement commanding someone else to attend to the scale. Includes statements like "Why do you think that happened." Also includes prolonged visual regard of scale.

Bid- Bid for a turn. Child exclaims that it is his/her turn to do something.

Chal- Challenge. Based on claims such as "you cheated," mockery of various sorts. A procedural comment offered as criticism is coded as Proc. Assumes intent, fault.

Cede- Child cedes a turn. Gives up pencil, weights, stops verbalization to a partner.

ChSh- Checks Sheet. A child looks at the worksheet.

Exclm- Exclamation. "Oooo" "Wow" "Hey" "Oh man," etc.

Imit/v- Imitation of Experimenter of experimenter verbalizes problem (Condition 3). A child poses a problem in adult-like wording; a sub-code. Or, experimenter asks the question.

Mag- Playing with magnets. Child not involved in the task; distracted with the magnets. Includes grabbing for magnets when someone's turn is over.

NoRes- No response. Child ignores what's going on. Includes children who miss some information. This must be intuited by coder from subsequent activity.

PanOT- Pan is held by the other team. The team asking the questions should be holding the scale but sometimes the guessing team does.

PredA- Prediction of an abstract type. A child begins a predicition with a reflection such as "I think…" or "I know…" Those statements are, by themselves, counted as Metacognitive statements.

PredC- Prediction of a concrete type. A child says something like "this side is gonna go down."