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ABSTRACT

While many contemporary developmental theorists have avoided taking a stand on the controversial relationship between learning and development, this paper is based on the belief that the notion of "bandwidth of competence," or L. S. Vygotsky's "zone of proximal development," provides a useful framework for considering this relationship. As Vygotsky argued, learning in context, including the social context, creates development which in turn determines the level of learning and teaching for which the child is ripe. Any estimate of developmental status depends on the environment in which it is revealed. Contexts can be overtly social, as in the case of adult or peer assistance, or covertly social, as in the case of responding to an imagined or internalized audience. Children create their own zones of competence by working recursively on their own theories of cognition. In the future, developmental psychologists should learn to understand (1) sensitive methods of assessing readiness for change, (2) self-directed learning, (3) the dynamics of social situations that are successful in inducing change, and (4) supportive experimental contexts. Nineteen pages of references and several tables and figures conclude the paper. (HOD)

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Technical Report No. 336

BANDWIDTHS OF COMPETENCE: THE ROLE OF SUPPORTIVE CONTEXTS IN LEARNING AND DEVELOPMENT

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Abstract

In this paper we examine the relationship between learning and development from a Vygotskian perspective. While many contemporary developmental theorists have avoided taking a stand on this controversial relationship, we believe that the notion of "bandwidth of competence," or Vygotsky's "zone of proximal development," provides a useful framework for considering the relationship between learning and development. A basic theme of this paper concerns the concept of bandwidth of competence created by contexts which vary in degree of support for cognitive activity. We suggest that these contexts can be overtly social, as in the case of adult or peer assistance, or covertly social in the case of responding to an imagined or internalized audience. We also contend that children create their own zones of competence by working recursively on their own theories of cognition. Finally, we stress the importance of studying processes of change in children's thinking by observing cognition over time.

Bandwidths of Competence: The Role of Supportive Contexts in Learning and Development

Learning and Development

How do children learn? How are new modes of thought developed? Most would agree that these are the guiding questions of a developmental cognitive psychology. The relation between learning and development has always been controversial, however, and many contemporary developmental theorists avoid taking a clear stance on this issue, a fact that reflects the current state of flux of developmental theory. But all the traditional positions can be recognized today in somewhat disguised form, i.e., (a) that learning and development are unrelated; (b) that learning and development are identical; (c) that learning precedes development; and (d) that development precedes learning.

Some have interpreted the orthodox Piagetian position as adhering to the first position, that learning and development are unrelated. Vygotsky (1978) certainly classified Piaget's early writings as examples of an independence position and the tenor of the introductions to the Genevan work on Learning and Cognitive Development (Inhelder, Sinclair, & Bovet, 1974), by both Piaget and the authors, suggests that they were aware of the claim of a separate and "secondary" status for the concept of learning. The opening line is, "It may seem surprising that Genevan developmental psychologists have seen fit to write a book on learning." The turn learning, however, was interpreted very much in terms of a reinforcement theory, Piaget's "learning in the strict sense (sensu stricto), rather than learning in the broader sense (sensu lato) which embraces cognitive development as a whole" (Piaget, 1959). On the basis of this definition, Piaget could equally well be classed as regarding learning and development as inseparable (sensu lato). When making claims about any theoretical position on the centrality of learning to development, it is essential that one clarifies the concept of learning being espoused. Guthrie, Hull, Spence, and Tolman all had theories of learning: sorting out the differences between them, however, occupied the talents of whole generations of experimental psychologists.

The most explicit version of the learning equals development position is the Skinnerian stance, eloquently expressed by Baer (1970), who claimed that the concept of development was redundant; improvement with age is merely the sum of past learning. Perhaps not so readily recognized as a member of this camp are extreme versions of universal novice theories of immaturity, and simple forms of novice to expert shift explanations of development (for criticisms, see Brown, 1982; Brown & DeLoache, 1978; Carey, in press). A position that holds that development is the result of the acquisition of expertise, without recourse to developmental constraints, would be a clear example of learning being equal to development.

Another recognizable position is that learning is prerequisite to developmental. Skills hierarchy approaches that postulate the acquisition and automization of subskills leading to, or even affording, a restructuring at higher levels are examples of this theoretical ideal type (Gagne, 1962).

And finally, probably the most commonly expressed position (at the level of text books) is that development is prerequisite for learning. Examples of this include maturational theories, certain simplified stage theories, and notions of readiness in general.

The above examples are meant to illustrate that it is perfectly reasonable to hold any permutation of the learning/development issue and, at least implicitly, developmental psychologists do. Many also believe that a combination of the above approaches characterizes human development (Case, in press; Fischer, 1980), and this was certainly the position taken by Vygotsky (1978). In this paper we will concentrate on central aspects of Vygotsky's theory of learning and development, most notably the concept of a zone of proximal development.

The Zone of Proximal Development

Vygotsky's central interest was in the evolution of cognitive processes, in growth and change rather than "fossilized," or automated processes of static state cognition. Even if one's goal is to understand adult cognition, this does not imply studying cognition in stasis. On the contrary, it is necessary to "alter the automatic, mechanized, fossilized character of the higher forms of behavior and turn it back to its source through experiment [to permit] dynamic analyses" (Vygotsky, 1978, p. 64). Vygotsky's "experimental-developmental" method was designed so that "one can, under laboratory conditions, provoke development" or "create a process of psychological development" experimentally (Vygotsky, 1978, p. 61). Given this emphasis on developing processes of thought, it is not surprising that Vygotsky had a special interest in children's learning, where one can observe cognitive processes "undergoing change right before one's eyes." For Vygotsky, developmental analysis was central to psychological investigation, not a peripheral offshoot having to do with the specialized study of children.

Vygotsky intended the notion of a zone of proximal development to capture the widely recognized fact, then and now, that "learning should be matched in some manner with the child's developmental level" (Vygotsky, 1978, p. 85). But he went farther, by arguing that one cannot understand the child's developmental level unless one considers two aspects of that level: the <u>actual developmental level</u> and the <u>potential developmental level</u>. "The zone of proximal development is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance, or in collaboration with more capable peers" (Vygotsky, 1978, p. 86). The actual developmental level is the result of "already completed developmental cycles." When a child's ability, or competence, is assessed on some static, independent test, this measure reflects his actual level of development; and this is true whether the measure is a standardized test or the laboratory experiment familiar to developmental psychologists.

An example of a static test of actual developmental level would be the estimate of an average five-year-old's performance on a particular task purportedly measuring a particular cognitive process. Many researchers stop here; this is certainly the primary method of testing children if articles in the major developmental journals are representative of the field. But what if one does not stop here, and like Piaget in his clinical interviews, one "offers leading questions" or, like Vygotsky, one demonstrates "how the problem is solved" or "initiates the solution and the child completes it"--in short what if the child "barely misses an independent solution of the problem" (Vygotsky, 1978, p. 85) and is helped by a supportive environment to achieve a greater level of competence? As Vygotsky posed the problem:

> Suppose I investigate two children upon entrance into school, both of whom are ten years old chronologically and eight years old in terms of mental development. Can I say that they are the same age mentally? Of course. What does

this mean? It means that they can independently deal with tasks up to the degree of difficulty that has been standardized for the eight-year-old level. If I stop at this point, people would imagine that the subsequent course of mental development and of school learning for these children will be the same, because it depends on their intellect. Of course, there may be other factors, for example, if one child was sick for half a year while the other was never absent from school: but generally speaking, the fate of these children should be the same. Now imagine that I do not terminate my study at this point, but only begin it. These children seem to be capable of handling problems up to an eight-year-old's level, but not beyond that. Suppose that I show them different ways of dealing with the problem. Different experimenters might employ different modes of demonstration in different cases: some might run through an entire demonstration and ask the children to repeat it, others might initiate the solution and ask the child to finish it, or offer leading questions. In short, in some way or another I propose that the children solve the problem with my assistance. Under these circumstances it turns out that the first child can deal with problems up to a twelve-year-old's level, the second up to a nine-year-old's. Now, are these children mentally the same. (Vygotsky, 1978, pp. 85-86, emphasis added)

Vygotsky argues that what children can do with the assistance of others is "even more indicative of their mental development than what they can do alone" (Vygotsky, 1978, p. 85), a point to which we will return.

The zone of proximal development marks boundaries of competence within which a child can navigate with and without aid. At the lower boundaries are those "fruits" of "developmental cycles already completed," a conservative estimate of the child's status. At the upper bound are the estimates of just emerging competences that are actually created by the interactions of a supportive context. By considering both levels of the spectrum, one has a better estimate of a child's potential and, in addition, by observing the process of change as it occurs microgenetically one learns a great deal about development (Brown, 1982).

The zone of proximal development permits us to estimate the child's "immediate future and his dynamic developmental state" (Vygotsky, 1978, p. 90). It is important to note, however, that what the child can do now in social interaction becomes, in time, part of his independent repertoire. Social interaction creates zones of proximal development that operate initially only in collaborative interactions. But, gradually, the newly awakened processes "are internalized, they become part of the child's independent developmental achievement" (Vygotsky, 1978, p. 90). What is the upper bound of competence today becomes the springboard of tomorrow's achievements.

Because Vygotsky concentrated primarily on social contexts for creating competence, he placed a heavy emphasis on imitation as the well-spring of learning, arguing that a "full understanding of the concept of the zone of proximal development must result in reevaluation of the role of imitation in learning" (p. 82). To this end, Vygotsky pointed out that a person can imitate only that which is within her developmental level; the point is made clearly in the following obvious example:

> For example, if a child is having difficulty with a problem in arithmetic and the teacher solves it on the blackboard, the child may grasp the solution in an instant. But if the teacher were to solve a problem in higher mathematics, the child would not be able to understand the solution no matter how many times she imitated it. (Vygotsky, 1978, p. 88)

In common with current language development theorists, Vygotsky believed that knowing what a child is ready to imitate is knowing a great deal about her underlying competence.

But imitation is not the only driving force of progress. Vygotsky also emphasized such socially directed activities of a more knowledgeable other as providing prompts to a more mature solution, directing leading questions, forcing the child to defend or change his theory, etc. In this respect, Vygotsky had much in common with early (contemporary to him) Piagetian theory (The Language and Thought of the Child, 1926, and Judgment and

Reasoning in the Child, 1928) where it was also argued that the development of logical thought is enhanced by the need to defend one's ideas to actual or imagined audiences. The notion of supportive contexts creating new levels of competence can include contexts other than the overtly social.

Outline of Paper

A basic theme of this paper will be the concept of bandwidths of competence, or zones of proximal development created in contexts that vary in degree of support. These contexts can be overtly social as in the case of adult or peer assistance (Section II) or only covertly so in the case of modifications in thinking in response to an imagined or internalized audience. We will also argue that children create their own zones of competence by working recursively on their own theories (Section III). In Section IV, we will discuss how developmental psychologists, sometimes unwittingly, create supportive contexts to reveal and perhaps even accelerate development. Two themes that run throughout the paper are: (a) the importance of studying processes in change, of observing cognition over time, or microgenetic analyses espoused by both Vygotsky and Genevan psychologists, and (b) the overriding concept of supportive environments for learning. Finally we will argue that a consideration of zones of proximal development at the very least permits us to consider the central issue of learning and development in a somewhat different light.

Social Interactions as Contexts for Learning

The Genesis of Individual Thinking in Social Settings

The claim that individual thought processes might have their genesis in social interactions is not unique to Vygotsky; in his early work, Piaget also considered the role of social experience in development. In particular, Piaget regarded peer interaction as an ideal forum for helping children "decenter" their thinking from one particular egocentric perspective and consider multiple perspectives; such social settings also provide incentives to coordinate opposing egocentric views, and hence arrive at a more mature sociocentric consensus. Faced with a group of peers who not only fail to accept one's own views but hold opposing opinions of their own, the child must compromise. In the process of compromising the group produces a solution that is more mature than each individual effort. The conflict arising from group disagreement creates disequilibrium and the resulting adjustment to this state is a primary cause of cognitive development.

In his early work, Piaget stressed that a great deal of development was mediated by just such social interactions (see Doise, Perret-Clermont, and Mungy for recent Genevan work on social interaction, and Forman, 1982, for a discussion). In addition, Piaget claimed that we internalize such interactions to form the basis of individual cognition, especially in the case of logical thinking:

The adult, even in his most personal and private occupation,

> even when he is engaged on an inquiry which is incomprehensible to his fellow-beings, thinks socially, has continually in his mind's eye his collaborators or opponents, actual or eventual, at any rate members of his own profession to whom sooner or later he will announce the result of his labours. This mental picture pursues him throughout his task. The task itself is henceforth socialized at almost every stage of development . . . the need for checking and demonstrating calls into being an inner speech addressed throughout to a hypothetical opponent whom the imagination often pictures as one of flesh and blood. When, therefore, the adult is brought face to face with his fellow beings, what he announces to them is something already socially elaborated and therefore roughly adapted to his audience. (Piaget, 1926, p. 59)

In the middle part of this century, American social psychologists interested in group dynamics also became concerned with the group as a learning context for individual cognition. For example, Bales (1950) argued that individual problem solving and group problem solving are necessarily similar, as the one (individual) is born of the other (social).

> Individual problem solving is essentially in form and in genesis a social process: thinking is a re-enactment by the individual of the problem-solving process as he went through it with other individuals. (Bales, 1950, p. 62)

Similarly, Kelley and Thibaut (1954) put forward a theory of internalization similar to Vygotsky's when they suggested that an individual:

> . . . acquires his thought and judgmental habits largely through interaction with other persons. It is by no means entirely fanciful to suppose that he 'internalizes' certain problem-solving functions that are originally performed for him by others. For example he may internalize a 'critic' role in the sense of learning to apply to himself the same standards and rules of critical evaluation that another person has previously manifested in interaction with him. (Kelley & Thibaut, 1954, p. 738)

Vygotsky, however, went further and argued that not only do individual thought processes have their genesis in social interaction but that individual mental processes share organizational properties in common with the social situations from which they were derived. It follows that variations in the social interactions to which a child is exposed would have important consequences for the development of certain forms of thinking, hence the importance given by neo-Vygotskians to such crucial interactions as those between peers, siblings, parent and child, and teacher and child, the primary socialization agents of the young (Rogoff & Wertsch, 1984).

Internalization of Executive Control

What kinds of social interactions, likely to occur in groups, are important processes for individual thinking? Those who have been concerned primarily with adults have stressed the internalization of executive control, critical thinking, Socractic dialogue ploys, or metacognition--whatever your theoretical bias would lead you to call activities that create and revise, oversee, question, elaborate, and control premises, arguments, and problem solutions (Brown, Bransford, Ferrara, & Campione, 1983). For example, Dashiell came very close to discussing executive control when he described the six shared group activities that a participant might internalize as part of personal cognition:

> (1) motivation by some felt difficulty, (2) analysis and diagnosis, (3) suggestion of possible solution or hypothesis, (4) the critical tracing out of their implications and consequences, and perhaps (5) an experimental trying out, before (6) accepting or rejecting the suggestion. (Dashiell, 1935, p. 1131)

Shaw (1932) also noted that one major function of the group was that it acts as a form of executive to its individual members. For example, the initiator of a suggestion will reject his own plan only one-third as often as will other members of the group. The group members function together to reject inadequate plans that escape the notice of individuals working alone. And

Bales (1950) describes the central role of such executive routines as (a) asking for, giving, repeating, and clarifying information, (b) asking for and giving directions, and (c) asking for and suggesting ideas or plans for possible lines of action. Thus, a major function of the group is that it makes overt many of the executive critical functions that are usually hidden when an individual works alone. Kelley and Thibaut (1954) suggest this essential role of critic and evaluator, first learned in interpersonal settings, becomes internalized as a set of self-regulatory skills, all favorite Vygotskian concepts.

The internalization of executive control, or the transition from other-regulation to self-regulation (Brown & French, 1979; Wertsch, 1979), has also been a major focus of developmental psychologists studying mother-child dyads. One of the most commonly reported examples of this type of interaction is mother-child dyads working on the construction of wooden block puzzles (Wertsch, 1979). The following is a sample of a videotaped interaction between a mother and her 2-1/2 year old daughter:

(1) C: Oh (glances at model, then looks at pieces pile). Oh, now where's this one go? (picks up a black cargo square, looks at copy, then at pieces pile)

(2) M: Where does it go in this other one (the model)? (child puts black cargo square back down in pieces pile, looks at pieces pile)

(3) M: Look at the other truck (model) and then you can tell. (child looks at model, then glances at pieces pile)

(4) C: Well (looks at copy, then at model)

(5) C: I look at it.

(6) C: Um, this other puzzle has a black one over there. (child points to black cargo square in model)

(7) M: Um-hm.

(8) C: A black one (looks at pieces pile).

(9) M: So where do you want to put the black one on this (your) puzzle? (child picks up black cargo square from pieces pile and looks at copy)

(10) C: Well, where do you put it there? Over there? (inserts black cargo square correctly in copy)

(11) M: That looks good.

Wertsch argued that this is an example of the mother serving a vital regulatory function, guiding the problem-solving activity of her child. Good examples of the mother assuming the regulatory role are statements 2, 3, and 9, where she functions to keep the child on task and to foster goal-relevant search and comparison activities. This protocol represents a mid-point between early stages, where the mother and child speak to each other, but the mother's utterances do not seem to be interpreted by the child as task relevant, and later stages, where the child assumes the regulatory functions herself, with the mother functioning as a sympathetic audience. Detailed observations of adult executive control come from such divergent situations as those of language acquisition (Greenfield, 1984; Scollon, 1976), picture book reading (DeLoache, in press; Ninio & Bruner, 1978), memory tasks (Rogoff & Gardner, 1984), story telling (McNamee, 1981), reading comprehension (Au & Kawakami, in press; Palincsar & Brown, 1984), and number games (Saxe, Gearhart, & Guberman, 1984), as well as block play.

Shared Task and Goal Structures

Especially with very young children, social interactions do not always serve to highlight executive control of action patterns in a clearly defined problem space. In order to be sensitive to the gradual transfer of the executive role the child must have a quite sophisticated concept of what the task is. Often, however, children and adults share very different concepts of the goal structure of the problem, and what appears to be joint activity on a common task is much more akin to parallel play: adult and child interact with the concrete task but share little in the way of a common goal; indeed, they may often fail to share a common attentional focus.

Under such circumstances, either the adult or the child must begin an interaction by catching the attentional focus of the other. Excellent examples of these preliminary goal setting activities have been recorded by Rogoff observing adults' interactions with her twins (Rogoff, Malkin, & Gilbride, 1984). Adults attempt to elicit mutual gaze with 4-7 month old twins by such common attention getters as "did you see that?" "what happened?" "lookit," etc., just as four-year-olds do with two-year-old playmates (Shatz & Gelman, 1973). But as Rogoff et al. (1984) point out, this orchestration of shared attention does not always proceed strictly from adult to child as the children themselves actively involve themselves in situations that allow learning to occur. "Together the adult and child calibrate the appropriate level of participation by the child" (p. 43). One example of the child controlling the interaction appears when the boy twin, at nine months, is playing when he catches sight of an attractive toy, a Bugs Bunny Jack-in-the-Box. He pushes it toward the adult and continues to pat the top until the adult is drawn into the game and works the mechanism for the baby. After the Jack has popped out, the adult tries to draw the child's attention to another game, but the baby "fidgets and whines." As the adult persists in the alternate game, the baby "grabs the box again, whining louder." This struggle of wills continues until the baby "raises his hands over his head in frustration and fatigue!" The adult capitulates and turns the handle of the desired box, asking sympathetically, "Is that what you wanted?" The toy is activated: the baby smiles; pulling the toy toward him, now calm (Rogoff, 1982).

Rogoff provides a variety of examples of the child as the participant who determines which toy will be selected; the baby initiates the action, the adult follows his lead. In the example above, the baby seems to have been determined to play with the Jack-in-the-Box, not settling for the adult's attempts to interest him in other games. The baby was active in choosing the toy and seeking participation in its use. It would be erroneous to characterize the child's part in such interactions as the passive recipient of others' goals and instructions.

In general, however, the child's goal structure is the one that undergoes the major adaptation because it is usually the adult who has a clearly defined goal in mind; this is particularly true when the adult is engaged in deliberate teaching of academic-like skills. A major role of the "expert" in such situations is to get children to change their conception of the task in favor of a more strategic, economic or academically sound approach. Wertsch (1984) has argued that one of the major changes that children undergo in the zone of proximal development is that they accept a qualitatively different interpretation of the goal of the joint activity. It is the expert's role to define an appropriate goal, to segment the task into manageable subunits, to arrange interactions at the child's level, and to change her demands in keeping with the child's growing expertise. This implicit teaching role is more clearly seen in activities that are similar to academic learning settings, when the child is playing a game with number correspondence (Saxe et al., 1984), reading (Palincsar & Brown, 1984), or story telling (McNamee, 1981). In other situations that are more clearly play-like, the adult's role can be much more like that of an equal, engaged in parallel play or often taking the lead of the child.

The Centrality of Instruction

One common feature of the type of interactive situations in which children often find themselves is that adults adopt, either implicitly or explicitly, a teaching function. It is this natural instructional role that is a mainstay of development. As Wertsch (1984) points out, the Russian word obuchenie actually means the "teaching-learning process," and it is this symbiotic function that is central to Vygotsky's theory (see Wertsch, 1984, for a detailed discussion). Obuchenie "creates the zone of proximal development," it

> rouses to life, awakens and sets in motion a variety of internal processes of development in the child. At this point, these processes are still possible for the child only in the sphere of interaction with surrounding people and in the sphere of collaboration with peers. But these processes, which constitute the course of internal development, then become the internal property of the child himself or herself. (Vygotsky, 1962, p. 450)

It is important to note that the teaching function of interactional situations need not be explicit, or be the central agenda of the activity. We have already seen that a group problem solving setting is said to provide a learning forum for its members, even though the guiding activity is successful problem solution, regardless of individual contributions or the potential for personal development. Similarly, many of the situations examined by those interested in the zone of proximal development are informal apprenticeship settings where the teaching function is a minor part of the total activity. Typical of learning in informal settings is a reliance on proleptic teaching (Brown & Campione, in press; Rogoff & Gardner, 1984; Wertsch & Stone, 1979). Proleptic means "in anticipation of competence" and in the context of instruction refers to situations where novices are encouraged to participate in a group activity before they are able to perform unaided, the social context supporting the individual's efforts. The novice carries out simple aspects of the task while observing and learning from an expert, who serves as a model for higher level involvement.

In many cultures children are initiated into adult work activities such as weaving (Greenfield, 1980, 1984), tailoring (Lave, 1977), marketing (Lave, Murtaugh, & de la Rocha, 1984), etc. without explicit formal instruction (Cole & Bruner, 1971; Cole & Scribner, 1975). The expert members of the group have as their main agenda the task of weaving, tailoring, etc. and are only secondarily concerned with initiating the novice, or overseeing the progress of the apprentice. It is the adult who take on most of the responsibility for getting the task done with the child participating as a spectator, then a novice responsible for very little of the actual work (Laboratory of Comparative Human Cognition, 1983). As the apprentices become more experienced and capable of performing more complex aspects of the task, aspects that have been modeled by adults time and time again, they are ceded greater and greater responsibility until they become experts themselves. Within these systems of tutelage, novices learn about the task at their own rate, in the presence of experts, participating only at a level they are capable of fulfilling at any point in time.

The main features of informal proleptic instruction are very different from formal schooling. In informal learning situations the group has responsibility for getting the job done, or at least an illusion of joint responsibility is maintained. Children join in, often on their own initiative or with seemingly little pressure from the adults; they participate only at the level they are currently able to perform, or just beyond. They are rarely allowed to fail because errors are costly to production of a concrete product, the major task at hand. Everyone has the same, clearly-defined agenda, the name of the game is known to all, the goal is clear. The adults (experts, mastercraftsmen) model appropriate behavior and occasionally guide novices to increasingly more mature participation. There is rarely any demand for solo performance on the part of children, indeed it is often difficult to measure any child's individual contribution because everyone is participating at the same time. Children perform well within their range of competence; rarely are they called upon to perform beyond their capacity; the adults do not expose the children's ignorance, but jointly benefit from their increasing competence. Above all, such teaching is implicit; a Zinacanteco woman (expert weaver), asked how girls in her society learn to weave, claimed that they learn by themselves! (Greenfield, 1984).

Although adults in apprenticeship systems may not be aware of their instructional function, closer examination certainly reveals that they do teach, and the teaching style they adopt has a readily identifiable structure. Greenfield (1984; see also Wood, 1980; Wood & Middleton, 1975), in examining common features of informal instruction in language acquisition and in weaving, identifies six common elements to the two informal learning situations: (a) the degree of aid, or scaffolding, is adapted to the learner's current state; (b) the amount of scaffolding decreases as the skill of the learner increases; (c) for a learner at any one skill level, greater assistance is given if task difficulty increases, and vice versa; (d) scaffolding is integrated with shaping, i.e., local correction and aid are given in response to the child's current performance; (e) the aid or scaffolding is eventually internalized, permitting independent skilled performance; and finally (f) in both the language and weaving contexts, the teachers appear to be generally unaware of their teaching function.

The instructional role, however, can sometimes be quite explicit and this has been the general rule in American studies of mother-child, teacher-child interactions, for the mothers/teachers have been set to teach the child explicitly by the experimental context. But even given the change from an implicit to explicit teaching role, Greenfield's six elements describe the proleptic teaching role quite well (see Au & Kawakami, in press; Brown & Palincsar, in press; Palincsar & Brown, 1984, Tharp et al., 1984). To illustrate, we will give one example of mother-child interaction (Saxe et al., 1984) and one of teacher-child dialogues (Palincsar & Brown, 1984).

Saxe, Gearhart, and Guberman (1984) examined mothers as they attempted to teach their 2 1/2-5 year old children a number reproduction game. The goal was to match pennies with cookie monsters; a number of cookie monster pictures (set sizes 3, 4, 9, and 10) was placed on a board and the child's task was to select from a set of 15 the same number of pennies, put them in a cup and take them to the mother. The mothers introduced and controlled the task differently as a function of the starting competence of the child. Mothers of low ability children began with a single array subgoal, such as, "count the cookie monsters." With higher level children, however, they began with statements such as, "You have to get the same number of pennies as there are cookie monsters," and indirect requests intended to help focus the child on the need to achieve a numerical representation of one of the arrays without specifying the means for doing this. In short, the mothers adjusted their degree of aid to the learner's current status.

Mothers also adjusted their degree of aid as a function of task difficulty, e.g., increasing set size, by giving more direct assistance and more explicit prompts. Some mothers of high ability children referred back to previous easy set sizes in order to guide their children. Mothers also organized the task differently as the child became more competent. In addition, they responded locally to each individual move on the part of the child; they shifted down to a goal directive simpler than, and subordinate to, the previous higher one if the child produced an inaccurate count and shifted up to a superordinate, less explicit, directive if the child had succeeded. Just as did the weavers in Greenfield's studies, the mothers provided scaffolding and shaping for their child's efforts. They adjusted the goal structure (superordinate or subgoal) to the child's level, shifting it up or down depending on the child's attainments and the perceived task difficulty.

Next, we will consider one example from our own work of an explicit attempt to make instruction in the schools more like the natural tutoring procedures of proleptic teaching (Brown & Palincsar, in press; Palincsar & Brown, 1984). Junior high school poor learners, with particularly depressed reading comprehension scores, were taken from their traditional formal reading instruction and placed in a reciprocal teaching environment (Brown & Palincsar, 1982, in press; Palincsar & Brown, 1984). In reciprocal teaching, students of varying levels of competence and an adult teacher take turns "being the teacher," that is leading a dialogue on a segment of text they are jointly attempting to understand and remember. The "teacher" responsible for a particular segment of text leads the ensuing dialogue by stating the gist in her own words, asking a question on that segment, clarifying any misunderstandings and predicting what might happen next. All of these activities are embedded in as natural a dialogue as possible, with the adult teacher and students giving feedback to each other.

Close inspection of these dialogues revealed repeated examples of guided learning, i.e., where the adult teacher provided modeling, feedback, and practice to students at a level that appeared to match the student's current need. As students became better able to perform some aspects of the task, the teacher increased her demands accordingly, until the students' behavior became increasingly like that of the adult model, who in turn decreased her level of participation and acted as a supportive audience.

One example of such an interaction is shown in Table 1. This dialogue took place between an expert teacher and a seventh grade minority student, Charles (IQ = 70, Reading Comprehension grade equivalent = Third Grade).

Insert Table 1 about here.

At the beginning of the training session, Charles was unable to formulate a question. The teacher, estimating that he is having more than usual difficulty with the task, opens her interaction by stating the main idea (Statement 2). She continues to lead him, asking for a "why" question (4) but, receiving no response, she resorts to forming a question for him to mimic (6). Even imitating a fully formed question is difficult for Charles (7, 9). Again, on Day 4, the teacher formulates the question (20), but this time she waits until Charles comes very close to an adequate question by himself. As Charles improves, the teacher demands more from him. On Day 4, the teacher does not open by providing the main idea, she probes for it (14) and probes for a question (16, 18), which she corrects (20). Note, however, that although the teacher actually produces the questions on both Day 1 and Day 4, on Day 4 she waits until Charles has contributed most of the elements himself.

As Charles' ability to participate increases even further, the teacher again increases the level of participation that she demands from him. On Day 7, she requests a modification to his question form (23), but he formulated the question (24). By Day 11, she receives two excellent questions, but now demands only one (27), i.e., she requires him to stick to the exact rules of the game. Finally, by Day 15, Charles can perform his part unaided.

Charles and Sara were part of a reading tutorial which met regularly with the same expert teacher. Charles was a particularly weak student at the start, unable to formulate questions at all. Sara, in contrast, began the intervention with a clear notion of the kinds of questions that occur in school—"fill in the blanks." Excerpts from her protocol are shown in Table 2. On Day 2, the teacher, who has tolerated "fill in the blanks" questions until this point, attempts to take the student beyond this level (2) and asks for a main idea rather than a detail question.

Insert Table 2 about here.

On Day 3, Sara comes up with a main idea question as requested (3), so again the teacher increases her demands by suggesting that, instead of selecting a line from the text, the student summarize in her own words, a process called invention (Brown & Dav, 1983) that is difficult for weaker students to handle. For the remainder of the sessions, Sara's questions are classified primarily as inventions. The teacher has been modeling inventions, and the student has followed suit.

Turn now to observations of a regular classroom teacher leading her reading group according to the reciprocal teaching method. In Table 3, we see excerpts from the third day of instruction using this method and in Table 4 are excerpts from the thirteenth instructional day. The group consisted of one adult teacher and five seventh grade poor readers.

Because of the larger group size, compared with the tutorial, the students were able to provide modeling and feedback for each other, learning from their peers as well as from their teacher. As the sessions progressed, the teacher was able to hand over a great deal of the work to the students and serve more as a coach than a teacher. An illustration of this change is shown in the contrast between the dialogue samples in Table 3, where the teacher is in control and the students interact almost exclusively with her, and that of the later session from the same group, shown in Table 4, where the students respond to each other with encouragement from the teacher.

Insert Table 3 and 4 about here.

Both the Day 3 and Day 13 dialogues attest to the fact that the students and teacher were able to engage in a smooth flowing discussion. On Day 3, however, the teacher is very much the pivotal participant. As can be seen in Table 3, one session of the silent reading is followed by one extensive dialogue, where the students interact with one another only once (statements 1 - 3); the remainder of the runs are S-T, S-T, student followed by teacher. The students interact individually with the teacher, not with each other. Note also that the entire interaction focuses on one segment of text and on one disputed point--the use of snakes' tongues. Interestingly, other reading groups had problems with this segment, one student reading, "No snake's tongue is completely harmless," instead of the correct, "No, - snakes' tongues are completely harmless," thus generating an interesting confusion and occasion for clarification.

The same group is seen again, ten intervention days later, in the dialogue shown in Table 4. Here, four reading-dialogue sets are included in 29 statements, rather than only one as in Table 3. Now the majority of the "runs" are student-controlled, with the teacher interspersing praise and encouragement (4, 10, 12) and some management (4, 14, 21). The teacher only intercedes with advice and modeling when a student misses the point and the other students do not catch it (statements 18, 26, 28). The teacher has moved from the pivotal role of responding individually to each child, to a coach who sits in the background, offers encouragement, and occasionally pushes for a better interpretation of the text. The expert provides just the degree of scaffolding necessary for the dialogues to remain on track, leaving the students to take as much responsibility as they can.

In practical terms, the results of the reciprocal teaching intervention were dramatic. The students clearly internalized the types of interactions they had experienced, improving not only in their ability to paraphrase the gist and ask questions of clarification, interpretation and prediction, but also in their ability to assume the role of teacher, producing their own questions and summaries, and evaluating those of others. In addition, the intervention resulted in dramatic improvements on laboratory, classroom, and standardized tests of comprehension. The participating students progressed from the very poorest performers in the class to the average level set by their normally achieving age mates. But perhaps more important, the child's feelings of personal competence and control improved dramatically, enabling them to go farther and improve their skills on their own (Brown, Palincsar, & Purcell, in press; Reeve & Brown, in press). The teachers also adhered to the six steps described by Greenfield (1984), adjusting their level of control to the child's products and the difficulty of the task. The students gradually internalized the teacher's procedure so that they could perform unaided. Expert teachers perform these adjustments without necessarily being aware of the fine-tuning of the reciprocal interaction in which they are engaged.

Interactions such as these examples of mother-child, teacher-child, expert-novice dialogues have a central place in learning and provide a major impetus to cognitive growth. According to Vygotsky (1978), teaching-learning, or obuchenie, creates development, which in turn determines the level at which teaching-learning can be directed. Learning and development are interwoven in a complex spiral pattern, none of the four alternatives mentioned in the introduction fully capture the flavor of this relationship. Certainly, however, such a position is not consistent with either the position that learning and development are unrelated or that they are identical. Instruction creates a zone of proximal development within which learning can occur.

> Learning is not development; however, properly organized learning results in mental development and sets in motion a variety of developmental processes that would be impossible apart from learning. Our hypothesis elaborates the unity but not the identity of learning processes and internal developmental processes. (Vygotsky, 1978, pp. 90-91)

Needless to say, there remain many unanswered questions concerning social interactions as contexts for individual development. Stimulating as Vygotsky's ideas might be, the zone of proximal development is a concept in need of validation. Social interactions do not always create new learning; some parents are surely more effective teachers than others; peer interactions vary enormously, only some creating ideal learning experiences. We need a great deal more research addressing such questions as: (a) What kinds of interactions are maximally effective at inducing cognitive growth? (b) Can optimal interactions be orchestrated deliberately? (c) To what extent do social collaborations lead to independent competence? (d) What are the mechanisms underlying internalization? etc. In short, Vygotsky provided a blueprint for research, but supportive contexts need to be delineated in far greater detail.

Dynamic Assessment

Implicit in the adult-child dialogues we have been considering is the notion of on-line diagnoses. In order to be responsive to the child's "region of sensitivity to instruction" (Wood & Middleton, 1975), the expert must continually define and refine her theory of the child's existing state of learning. As such, the interactions in the zone of proximal development must involve an implicit diagnostic activity.

Vygotsky was also concerned with a more explicit diagnostic function; he had a pressing practical interest in using the concept of a zone of proximal development for diagnostic purposes. As Director of the Institute of Defectology in Moscow, Vygotsky was faced with the practical task of designing educational assessment procedures that could take the place of Western IQ measures, which, as we have seen, he regarded as retrospective estimates of past learning rather than prospective predictions concerning potential developmental trajectories. Therefore, the notion of a zone of proximal development had a central place in Vygotsky's work on assessment, and it continues to play a major role in Soviet clinical diagnoses and remedial training (Egorova, 1973; Vlasova, 1972; Wozniak, 1975; Zabramna, 1971).

For practical reasons then, Vygotsky needed a way of estimating both actual and potential developmental levels, and this is reflected in the passage quoted previously where he gives the example of two ten-year-olds with actual mental ages of eight years, one of whom can, with the experimenter's help, perform at a twelve-year-old level and the other who can perform only at a nine-year-old level. If a practical method could be found where such differences could be measured, Vygotsky believed they would have both diagnostic and instructional significance (Brown & French, 1979; Vygotsky, 1978; Wozniak, 1975).

In the work on the zone of proximal development described so far, the primary interest has been in observing the child's assisted progress in the zone of proximal development created by various forms of social interaction. Rarely have investigators considered the other aspect of Vygotsky's theory, that the fruits of the zone of proximal development created in the interaction will be internalized and become part of the independent repertoire of the child and this change can be measured. One exception is the work of Palincsar and Brown (Brown & Palincsar, in press; Palincsar & Brown, 1984) where independent measures of learning and transfer were taken in addition to estimates of progress within the interaction. But for assessment purposes, one needs to estimate independent progress, i.e., Vygotsky's imaginary ten-year-old who gains four years is different from the one who gains only one. Although both children "failed" in their unassisted attempts to solve the problem, both benefited from instruction, but the first child was far more "ready" to receive instruction than the second. The subsequent careers of spectacular "gainers" (Budoff, 1974) is the central interest of many psychologists concerned with dynamic assessment; the most notable proponent being Reuven Feuerstein (1979, 1980), who also developed his Learning Potential Assessment Device when faced with the practical assessment problem of evaluating children in displaced person camps who had spent years without systematic formal education (Feuerstein & Richelle, 1963). Static standardized ability and achievement tests are even less appropriate for children for whom the assumption of appropriate consistent formal education cannot be held (Brown & French, 1979).

In our own work on diagnostic zones of proximal development (Brown & Campione, in press; Brown & Ferrara, in press; Campione, Brown, & Bryant, in press; Campione, Brown, Ferrara, & Bryant, 1984), we have taken the idea of systematically measuring aspects of assisted learning one step further. Like Vygotsky and contemporary Soviet investigators (Egorova, 1973; Vlasova, 1972), we assess children's independent performance first on variants of a problem to estimate a level at which they cannot perform without assistance and then on other variants, after the interactive sessions. In addition, however, we also measure the degree of assistance a particular child requires during the interactions. For example, a child is set to learn an inductive reasoning problem such as a series of matrices problem similar to the Raven Progressive Matrices test of intelligence (Raven, 1938), or a double classification task (Bryant, Brown, & Campione, 1983), or a series completion task (Ferrara, Brown, & Campione, 1981; Simon & Kotovsky, 1963). Initially the child performs poorly; she is then given a series of such problems accompanied by a standard set of prompts or hints. The hints are structured in a general to specific sequence with the initial hints being quite nonspecific, "Is this problem like any other you have seen?" "Can you see a pattern?" Subsequent hints, which become more and more concrete and specific, are given as the child needs them. We estimate the amount of help needed on both learning and transfer sessions.

Consider some concrete examples. The problems shown in Figure 1 are matrices type problems. The child's job is to figure out how the missing figure in the lower-right corner of each problem should look. A computerized testing situation was developed in which the child could construct the missing figure using a touch-sensitive panel and could receive graduated animated hints from the computer with the touch of a button (Campione, Brown, Ferrara, Jones, & Steinberg, in press).

Insert Figure 1 about here.

Initially, the children learned each of three rules--rotation, addition (imposition), and subtraction. The top problem in Figure 1 is a rotation problem. In such problems, the left-most figure in each row is rotated 90 degrees to the right to obtain the figure in the center, and that figure is then rotated another 90 degrees to the right to obtain the right-most figure. The second problem in Figure 1 is an addition problem and the third problem a subtraction example. The children were provided with a practice box in which they could try out various manipulations (e.g., rotation) on the various items. If the children could not solve a problem unaided, they requested and received a series of hints from the computer (in one study, or from an experimenter in another). These hints ranged from general to specific, and later hints in the series consisted of an animated demonstration of the rotation, addition, or subtraction movement. The children continued using the practice box, generating solutions and requesting hints, until they could solve two consecutive problems of each type without aid.

Following learning, maintenance and transfer sessions were given. In the first session, the students attempted to solve maintenance problems. These were the same three types already learned to criterion--rotation, addition and subtraction--but they were presented in a random order. The students had to identify the type of problem, i.e., discover which rule applied, and then construct the correct answer.

On subsequent sessions, both maintenance and transfer items were given, the maintenance items interspersed among novel transfer items. Transfer matrices are illustrated in the fourth problem in Figure 1, they involved a combination of two of the rules learned initially in the context of separate matrix problems. The answer to the example in Figure 1 would involve rotating the left-most figure in each row 90 degrees to the right and superimposing that rotated figure on the one in the middle column to generate the right-most item. Items of this type appear on the adult superior version of the Raven's matrices test.

In a series of such studies, we have found that the degree of aid needed to learn and transfer solutions in inductive reasoning domains is an extremely sensitive index of individual differences. Slower and younger children need more aid to reach the same degree of initial learning. As the degree of change from the initial learning situation to the transfer probes increases, ability-related differences also increase. Of greater importance is that learning and transfer efficiency, measured as degree of help given by the adult (or adult plus computer), is a sensitive predictor of long-term improvement within the domain. For example, using a double classification matrices task with five-year-old children, Bryant, Brown, and Campione (1983) considered the change from static pre-test to static post-test that took place after the interactive sessions. Even after the effects of IQ, pre-test scores, scores from the Raven Coloured Progressive Matrices (another intelligence test) on the gain scores were statistically removed, a considerable amount of the variance in improvement was attributable to the amount of aid needed to learn and transfer (approximately 20% in each case). Alternatively, if one looks at simple correlations, the best predictor of improvement from the pre- to the post-test was performance on far transfer items, followed by transfer indices and then learning efficiency. It would appear that individual differences in the degree of assistance needed for learning and transfer in interactive sessions is an important predictor of independent improvement within a domain. As such, these indices serve important diagnostic functions over and above that which could be provided by static tests, as Vygotsky predicted.

This diagnostic function would be particularly important if guided learning and transfer assessments such as the above could be designed to test readiness within common academic subject areas. If a teacher, in addition to knowing a child's static test scores, could also gauge a particular child's readiness to learn in situations such as mathematics or reading, she could tailor her instruction accordingly. Diagnosis is only important if it leads to remediation (Binet, 1909; Brown, in press). For this reason, we are currently devising dynamic assessment measures of early mathematic skills as well as extending our work on reading comprehension.

Children as Creators of their own Zones of Competence

In the previous section we have emphasized the importance of social interaction for creating zones of proximal development; guided by an expert who provides the essential scaffolding, the child progresses to greater levels of first social and then independent competence. But we should not overlook the fact that microgenetic analyses of children working alone suggest that children create and extend their own zones of competence without aid from others. Of course one could argue, as did Piaget and Vygotsky, that even when apparently working alone, the child is interacting with an imagined, internalized audience.

We believe that it would be a mistake to overemphasize the conception of children as other-directed, i.e., always guided in their learning by outside forces. Behaviorist theories were also theories of other-directed guidance, guidance conceived in terms of a variety of external reinforcements that shape behavior, and a simple interpretation of Vygotsky's theory could also lead to an overemphasis on guided learning where parents, peers and instructors always instigate development. Interesting and important though these guided learning situations may be, we should be careful not to concentrate exclusively on external pressures in knowledge acquisition. Even though children are undoubtedly observers and imitators of adult behavior; even if they learn primarily in this fashion, they are also capable of actively orchestrating their own learning. We have seen this is true even for the very young learner in interactive situations, witness Rogoff's example of the nine-month-old initiating the game of Jack-in-the-Box. It is equally important to acknowledge that children learn in situations where there is no obvious guidance, no feedback other than their own satisfaction, and no external pressure to improve or change. In a very real sense they act as little scientists, creating theories-in-action (Karmiloff-Smith, in press) which they challenge, extend, and modify on their own. The child is not only a problem solver but a problem creator--a metaphor that has much in keeping with scientific thinking.

Some of the best evidence of self-motivated learning comes from situations in which children are observed as they operate on a problem, over considerable periods of time, without external pressure, and seemingly with no motivation other than to improve the theory on which they are working. In this section we will illustrate this point by describing some examples of our own work on self-directed learning followed by a discussion of neo-Genevan microgenetic studies of learning (Karmiloff-Smith & Inhelder, 1974/75; Karmiloff-Smith, in press).

Errors and Self-Correction

In collaboration with Judy DeLoache, Mary Jo Kane, and Susan Sugarman, we have conducted a series of studies on young children's self-directed learning. We have been particularly interested in error correction procedures as a function of age and task complexity, and in the similarity of the microgenetic progression within and across ages that children seem to undergo when they operate on an interesting problem, producing and correcting errors and solutions on their own volition. Consider first a group of 24-48 month old children videotaped as they engaged in free play with a set of five nesting cups (DeLoache, Sugarman, & Brown, in press). Although the children saw the cups nested before they began to play, there was no real need for them to attempt nesting themselves; however, they did so, working long and hard in the process, and there were no age differences in the likelihood that they would eventually achieve a correct seriation. There were, however, interesting differences with age in the children's strategies for improving their systems.

The most primitive strategy, used frequently by children below 30 months, was brute force. When a large cup was placed on a smaller one, the children would press down hard on the non-fitting cup. Variants of brute pressure were twisting and banging, but the same principle held; the large cup will fit into the smaller one if only one can press hard enough.

A second strategy initiated by some of the younger children was that of local correction. After placing two non-fitting cups together children removed the top cup and did one of two things: They either looked for an alternative base for the non-fitting cup or tried an alternative top for the original base. Both ploys involved minimal restructuring and necessitate considering the relation between only two cups at any one time. The third characteristic ploy of children below 30 months was to respond to a cup that would not fit into a partially completed set of cups by dismantling the entire set and starting again.

Older children (30-42 months) faced with a non-fitting cup engaged in strategies that involve consideration of the entire set of relations in the stack. For example, one sophisticated strategy was insertion; the children took apart the stack at a point that enabled them to insert the new cup in its correct position. A second strategy, reversal, was also shown by older children. After placing two non-fitting cups together, children would immediately reverse the relation between them (5/4 immediately switched to 4/5).

The rapidly executed reversal strategy was not shown by the younger group. Some young children would repeatedly assemble, for example, cups 4-1, starting with 4 as a base and then inserting 3, 2, and 1. Then they encountered the largest cup, that is, 5, and attempted to insert it on top of the completed partial stack, pressing and twisting repeatedly. When brute force failed, they would dismantle the whole stack and start again. Similarly, having assembled 1, 2, 4, and 5 and then encountering 3, the younger children's only recourse was to begin again.

Although there are clear age differences in the efficiency with which the children strived to achieve a seriated stack, note that even the very youngest children persisted at the task, corrected their own errors, and made progress toward a goal, without any obvious external pressure to do so; that is, they formulated and tested their own theories-in-action.

It would appear that this form of progression, from brute force and local correction to a consideration of the problem as a whole, is a general acquisitio.. mechanism. For example, a very similar trend is seen in older (4-7 years) children attempting to construct a railway circuit (Karmiloff-Smith, 1979a; Kane & Brown, work in progress). Children are shown cardboard pieces of track that, if assembled correctly, will make a railway circuit for a small toy train. They are then shown a more complex version, and, given tracks, asked to make one like that themselves. One solution is to alternate the straight and curved pieces. Another is to put together four curved pieces into arches at the top and bottom and join each arch with two straight pieces. These correct constructions are shown as (a) and (b) in Figure 2. The children are left alone to complete the circuit.

Insert Figure 2 about here.

Many of the youngest children begin by placing any randomly selected piece next to any other and hence end up in a position that cannot possibly lead to solution. Examples are shown in panels (c) and (d) of Figure 2. Of interest is what the children do now. Even the youngest persist in their efforts, but their strategies change with age and experience in a way quite analogous to the stacking cups task described above.

The first line of attack is the brute force approach; the children try to make the tracks fit by firmly pushing them together to close up gaps. This is followed by local correction, the children remove the last few pieces and try to fix them but ignore the rest of the construction that is equally in need of work. The third stage is the one where the children, seeing the trouble they are in, disassemble the entire construction, and start again, even though part of the construction could be salvaged. These early strategies are essentially identical to those developed by much younger children as they attempt to seriate nesting cups.

The more mature strategies on the railway task also parallel those developed to deal with the cups assembly task. These strategies involve viewing the construction as a whole, thus enabling the children to rearrange only those pieces that need rearranging, leaving correct sections intact. Often the corrections involved the strategic reversal of already joined pieces, or insertion of a critical straight (curved) piece. Finally, some efficient learners actually dismantled a perfectly workable system and reconstituted a new version, pointing out that there were several solutions to the one problem. This developmental progression was seen both across ages (macrogenetic change) and within an age group (microgenetic change) when children were given a long time to work on the problem (Karmiloff-Smith, 1979a). It was also seen when children were asked to fix up disasters created by other children; and hence the level of problem difficulty could be kept constant across ages (Kane & Brown, work in progress).

Similar microgenetic trends can be seen if one considers much older children (12 years old) revising their own written compositions. An early correction strategy is again local correction, trying to fix up one local error even though the entire production is much in need of revision. This is followed by the disassembly ploy, where, realizing the need for massive revision, the child jettisons his whole initial efforts and starts again, even though parts are salvagable. Finally, with practice at revising, the child comes to master the type of activities that result from a consideration of the product as a whole, inserting needed clarification and reversing the order of existing segments. Although the analogy with the two-year-old nesting cups is somewhat far-fetched, the similarity in the microgenetic pattern is intriguing.

For all of these examples, we can ask, why do the children bother? Implicit in the situations is the goal: that the cups should be seriated, a workable railway should be constructed, an acceptable composition should be written, etc.; but the children, remain free to leave the field whenever they like. But they persist; they persist even in the face of frustration; they persist for long periods of time; they persist, correcting their own errors time and time again. Perhaps even more impressive evidence of this persistence and self-control comes from studies by Annette Karmiloff-Smith (1979a, 1979b, in press) where young children are seen correcting and perfecting their productions even after a perfectly adequate solution has been reached. Reorganization and improvement in strategies are not solely responses to failure, but often occur when the child has quite adequate functioning procedures but seeks to improve them. It is not failure that directs the change, but success--success that the child wishes to refine and extend. We will illustrate this point with one example from Karmiloff-Smith.

Theories in Action

In a landmark paper, Karmiloff-Smith and Inhelder (1974/75) examined children, from four to nine years of age, as they played with a set of balancing blocks. Their task was to play with the blocks and balance them on a narrow metal rod fixed to a long piece of wood (see Figure 3). These were no normal blocks,

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Insert Figure 3 about here.

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however. Standard blocks had their weight evenly distributed, and the correct solution was to balance them at the geometric center. Weight blocks had the weight of each "side" varied either conspicuously (by gluing a large square block to one end of the base rectangular block) or inconspicuously (by inserting a hidden weight into a cavity on one end of the rectangular block).

At first, the children made the blocks balance by brute trial and error using proprioceptive information to guide action. Behavior was purely directed at the goal of balancing. This ploy was obviously successful; the children balanced the blocks. In this sense they had met the goal set them, the blocks all balanced; they could stop at this point. But they didn't stop here even though by some criteria they had "finished" the game; they had met the goal of achieving balance. Without any external pressure to do so, they set about testing and revising theories to uncover the rules governing balance in the miniature world of these particular blocks. Their initial theories involved incomplete rules that produced errors. A common early theory was to concentrate exclusively on the geometric center and attempt to balance all blocks in this fashion. This works for standard unweighted blocks but not for weighted blocks of either kind. Here the theory did not result in balance, so the weighted blocks were discarded as exceptions ("impossible-to-balance"), even though the child had previously been able to balance them all.

After this theory was well established and working well for unweighted blocks the child became discomfited by the number of, and regularity of, the impossible-to-balance set. A new juxtaposed theory was then developed which incorporated the conspicuous weight blocks. For these, the children compensated for the weight that was obviously added to one end and adjusted the point of balance accordingly. Inconspicuous weight problems still generated errors; they looked identical to the unweighted blocks and were, therefore, subjected to the dominant geometric center rule. When they did not conform to the theory they were discarded as anomalies that were "impossible-to-balance." The children's verbal responses reflected these juxtaposed solutions, with exclusively length justifications given for unweighted blocks and weight justifications given for conspicuously weighted blocks.

After establishing and practicing the juxtaposed theory, the young theorists were again made uncomfortable by the remaining exceptions to their own rules and began to seek a rule for them. In so doing, a reorganization was induced that resulted in a single rule for all blocks. The children paused before balancing any block and roughly assessed the point of balance. Verbal responses reflected their consideration of both length and weight, e.g., "You have to be careful, sometimes it's just as heavy on each side and so the middle is right, and sometimes it's heavier on one side." After inferring the probable point of balance, and only then did the children place the block on the bar.

The progression from procedures that fail to procedures that work, shown in the stacking cups and railway track examples, can be explained in terms of goal-directed learning, the child wishes to correct errors. But in the blocks example, the pressure to work on adequate partial theories to produce more encompassing theories is very similar to what occurs in scientific reasoning. Like scientists, it is essential that children first gain control of simple theories in their quest for a more complex and more adequate theory. Karmiloff-Smith and Inhelder refer to this as creative simplification:

> The construction of false theories or the overgeneralization of limited ones are in effect productive processes. Overgeneralization, a sometimes derogatory term, can be looked upon as the creative simplification of a problem by ignoring some of the complicating factors (such as weight in the block study). This is implicit in the young child's behavior but could be explicit in the scientist's. Overgeneralization is not just a means to simplify but also to unify; it is then not surprising that the child and the scientist often refuse counterexamples since they complicate the unification process. However, to be capable of unifying positive examples implies that one is equally capable of attempting to find a unifying principle to cover counterexamples. (Karmiloff-Smith & Inhelder, 1974/75, p. 209)

Progress comes only when the inadequate partial theory is well established and the learner is free to attempt to extend the theory to other phenomena. In this way the theorists, be they children or scientists, are able to discover new properties that in turn make it possible for new theories to be constructed.

There can be little doubt that children, even very young children, do work unaided on their own theories, creating and extending their own levels of competence and sophistication as they do so. Note, however, that these self-directed improvements would not be apparent if one were to maintain the tradition of considering only one-shot, static estimates of the child's competence Indeed, Karmiloff-Smith has emphasized that cross-sectional age trends are often indistinguishable from microgenetic changes within a child over relatively short periods of time (Karmiloff-Smith & Inhelder, 1974/75; Karmiloff-Smith, 1979a, 1979b, in press). To estimate a child's current cognitive status, one must be very careful in the type and extent of performance one captures in order to estimate competence. An added complexity is that just as similarities in processing, such as revealed in the nesting cups and railway track examples, do not necessarily result in identical end products, identical end products do not necessarily implicate the same underlying processes. Evidence of early competence does not necessarily imply an equivalence in the underlying cognitive processes that are used to solve easy and difficult versions of the same task (Thornton, 1982); modified versions of traditional tasks may not be conceptually equivalent to traditional tasks (cf. Dean, Chabaud, & Bridges, 1981). By the same token, similar performances on a single task should not be taken as evidence for similar cognitive processing in two different age groups. Again, a microgenetic approach in the more likely method to reveal similarities and differences in process and product alike. The notion of zones, or bandwidths of competence through which the child navigates, with or without assistance, could be a more fruitful metaphor for theory development than that of a static, frozen, snapshot in time which predominates in the developmental literature.

Task Environments and Supportive Contexts

Demonstrating Cognitive Precosity

Developmental psychologists also collaborate with children to reveal bandwidths of competence by providing contexts that vary in the support they provide for learning. Indeed, a predominant interest of developmental psychologists in the past few years has been the game of demonstrating that contrary to theory X, Y, or Z, preschool children have much more competence than was supposed (see Gelman, 1978; Gelman & Brown, in press, for reviews). This controversy for Piagetians centered around the transition from preoperational thought to concrete operations said to "occur" between five and seven years of age (roughly), and for learning theorists of several persuasions, it also took the form of questions concerning a putative five-to-seven shift (White, 1965). Disputed were such issues as whether a qualitative shift occurred between non-mediated learning in the preschooler to mediated learning in the older child (Kendler & Kendler, 1962; Zeaman & House, 1963). Similarly, a shift from absolute to relational learning was also under contention (Brown & Scott, 1972; Kuenne, 1946; Reese, 1968). For those interested primarily in memory development, the controversy concerned the existence and extent of strategic processes prior to the onset of formal schooling (Brown, 1975; Brown & DeLoache, 1978; Wellman, Ritter, & Flavell, 1975).

In all of these domains, researchers had considerable success demonstrating preschool competence, and the methods they used were similar. The guiding principle was to look for evidence of cognitive precosity, not only in the traditional laboratory tasks, but also in situations where preschool competence could most readily be shown. To considerably oversimplify the comparative literature, the two major techniques used to expose early competency have been (a) to strip away all but the most essential elements of the task in order to reveal its cognitive demands in the simplest possible form and (b) to situate the experiment in the familiar, i.e., in task settings compatible with preschoolers' interests and knowledge.

A combination of these two techniques marks the better cross-cultural experimental work (Laboratory of Comparative Human Cognition, 1983) and also reveals early competence in preschool children. For example, Shatz (1978) argued cogently that earlier (or later) competence in communicative situations can readily be accounted for by the excess baggage of the task. In unfamiliar situations, with arbitrary stimuli, where the children must expend considerable cognitive effort identifying the items and comprehending the nature of the game, they appear unable to communicate adequately with a peer. In situations where the game is familiar, the information to be conveyed is meaningful and, therefore, cognitive "capacity" is freed for the communicative aspect of the task, the younger children look far more reasonable; they communicate well. Flavell and his colleagues (Salatas & Flavell, 1976; Flavell, 1977) have also shown that complexity and familiarity are important factors leading to a diagnosis of egocentricism in children. Similarly, Gelman and her colleagues (Gelman, 1978, 1983; Gelman & Baillargeon, 1983; Gelman & Gallistel, 1978) have made this point quite graphically for several "concrete" operational tasks. And many investigators have shown the importance of complexity and familiarity in revealing or disguising the memorial sophistication of small children (Brown & DeLoache, 1978; Deloache, 1980, in press; Perlmutter & Myers, 1979; Sophian, in press; Wellman & Sommerville, 1982).

We will illustrate this research trend with a glance at the history of one problem solving task, first examined in rats, and then entended to more and more child centered versions of the basic problem (Crisafi & Brown, 1983). The task, originally a Hullian (1952) classic, was said to measure inferential reasoning

(Maier, 1936), though not by Hull. It involved the ability to combine two separately learned pieces of information to reach a goal. A schematic version of the original Hullian maze is shown in Figure 4. For example, a hungry rat would be placed at box

Insert Figure 4 about here.

B and trained to run to G, the goal, for food. In a second separate part of the study, the rat, now thirsty, would be placed at A and trained to run to either B or Y where it would find water. In the final stage of the study, the rat would be placed in A. If thirsty, it would run with equal probability to B or Y, the water sources; if hungry, it would run only to B, the connecting route to G, the food box. The fact that rats could piece together this information was taken as evidence of a simple form of inferential reasoning, the ability to piece together two separately learned items of information to reach a goal.

Maier (1936) extended this paradigm to more elaborate mazes suitable, he thought, for work with both rats and children. The actual details of Maier's studies need not concern us here. Suffice it to say that the problem he developed to test the subject's inferential skill involved a maze like the one illustrated in Figure 5. The maze was child-size (an identical rat size maze was available for rats), and consisted of

Insert Figure 5 about here.

darkened runways through which the child was expected to complete routes to reach goal boxes in a similar inferential pattern to the Hull studies. Children below six did not fare well in this estimate of their maze running abilities; as can be seen in Figure 6, it is not until well into the school years that children perform as well as rats!

Insert Figure 6 about here.

The fact that running in a darkened maze in a basement laboratory may be a task setting suitable to no organism, but better suited to rats than preschoolers, was not open to a great deal of debate in the early years of child psychology.

Things improved considerably in the 1960's, when there was considerable upsurge of interest in children's learning in paradigms originally developed for the study of rats, pigeons, and monkeys (Stevenson, 1970; White 1970). As an example of the better work of that period, Kendler and Kendler (1967) adapted the basic Hullian task for use with children. They used an apparatus similar to that shown in the top half of Figure 7. It consisted of an automatic box with three distinctively colored

Insert Figure 7 about here.

panels, each of which could be covered by a plain aluminum outer panel. At the outset of the learning situation, only the two outside panels of the box were opened. The child learned to press a button on the red side to obtain a marble and to press a button on the blue side to get a steel ball. After learning these responses to criterion, the side panels were closed and the center panel was opened. Now the child learned to deposit one of the items, for example the marble, into a slot in the center panel so that a toy charm would be dispensed. The order of acquisition of the two problem parts proved to be immaterial. On the critical test trials, all three panels were opened for the first time, and the child was asked to make the toy charm come out as quickly as possible. A correct response required that the child combine the information regarding which item obtained the charm (the marble) with the information concerning its location (the red side). In a series of studies using this task, the Kendlers found that only 6% of the kindergarteners tested could solve the problem unaided, a result that has been replicated many times by many investigators.

Crisafi (1980) attempted to make the task more hospitable for very young learners by introducing familiar objects and already-known connections between locations and tokens, ploys that had resulted in increased rates of learning in cross-cultural studies (Cole, Gay, Glick, & Sharp, 1971). In Crisafi's first task (shown as B in Figure 7), the child learned to find a penny or dime in a purse or a piggy bank and then learned that the insertion of the correct coin into a gumball machine produced a gumball. The inference task required combining the correct item, for example the penny, and its location, the purse, to get a gumball. The objects in this task were chosen to be familiar and the relations among them to be consistent with the child's previous experience (pennies are found in purses and are used to operate gumball machines). The second task (shown as C in Figure 7) demanded the same solution. It involved a specially designed truck that dumped a candy a grey token (located in either a milk container or a saucepan) was inserted. These objects were also familiar and attractive, but the relations among the constituent elements were novel. Crisafi's third task was similar to the automated box apparatus designed by the Kendlers and described above. The objects and relations were arbitrary and unfamiliar. The logical structure of the three tasks is shown in Table 5.

Insert Table 5 about here.

Thus, the three versions of the task were designed to form an easy-to-hard sequence of three instantiations of the same rule. The difficulty of the presumed sequence was confirmed. The ability of two-year-old subjects to combine the two pieces of information was dramatically influenced by the familiarity and compatibility variables. Unaided inferential solutions were shown by 89% of the children on the gumball task, 67% on the truck task, and 0% on the automated box task. Obviously, two-year-olds are capable of this simple form of inferential reasoning under optimal circumstances. Armed with these learning environments, ranging from easy to difficult analogues of the same problem, Crisafi and Brown (1983) were able to aid very young children to transfer the solution to the more difficult versions.

The moral of this brief history is, of course, the dramatic change in psychologists' estimates of the cognitive capacity of the preschool child faced with a simple inferential reasoning task. Note that the data base is not in question, children below five do have extraordinary difficulty solving the Kendlers' (1967) version of the task and we have no doubt, although we have not tested it ourselves, that they would prove somewhat recalcitrant maze runners! This well established fact is as much a part of our picture of children's learning as is their precosity in solving gumball and truck version of the problem (Crisafi & Brown, 1983). There is no doubt that cognitive activities revealed in supportive contexts may be obscured in unfamiliar task formats that are perhaps more suitable for other species of learners (Maier, 1936). Similarly, differences in efficiency such as those displayed on the gumball and automated version of the task by three-year-olds, but not by six-year-olds, are an important aspect of the learning profile that differentiates age groups. Again, it is bandwidths of competence across and within settings that reveal age differences, rather than static estimates of "capacity" on a single task variant appropriate to a restricted age range.

What Does it Mean to Call a Context Supportive?

Findings such as the above, that very young children have the competence to perform logically, strategically, operationally, etc. on very simple task formats are fairly representative of the recent developmental literature and are the kind of evidence that has been used to call into question general notions of stages of development. But what do such findings really tell us? What are we doing, as experimenters, when we render a task suitable for two-year-olds, or unschooled Kpelle (Cole et al., 1971). In many demonstrations of early competence, there is a suspicion of circularity in the arguments proposed to explain the phenomena; if the contextual support manipulations work, then that task instantiation is judged suitably indigenous for preschoolers or unschooled others; if the manipulation does not work, then the context is judged unsuitable for revealing competence that we now assume to be "there," somewhere! Clearly what is needed is some a priori analysis of what is manipuated when we induce early competence and a detailed specification of the difference between earlier and later forms of competence.

Why does the three-year-old fail on the task versions readily solved by the six-year-old? Various theorists have argued that the memory load is too high, that the younger child's processing capacity is overburdened, or that the task is incompatible with the child's existing knowledge base. Any or all of these may be true, but we need some systematic method of determining what we mean by increased memory load or overburdened processing capacity, and we need some systematic way of mapping the knowledge base. Some attempts at systematic a priori analyses exist already. For example, Case, extending the theory first expoused Pascual-Leone (1970), has attempted to estimate the processing load of a variety of cognitive tasks. Case (1978, 1982) has been one of the most elcquent supporters of the position that cognitive development is constrained by the growth of working memory and of central processing capacity. Although it is widely recognized that a construct akin to working memory is essential in a theory of development (Flavell, 1978, 1982), such a concept is not without its difficulties. Reviewing the literature on age differences in basic capacity, Brown, Bransford, Ferrara, and Campione (1983) concluded that at this point in time, the evidence is moot, existing data could be explained in terms of change in knowledge or processing strategies, just as readily as changes in underlying capacity (Chi, 1976). And, Flavell (1978) rightly queried "How are we to decide, in a consistent fashion, exactly what constitutes an "item" in working memory for any given problem-solving strategy, and hence, how are we to decide exactly how much memory load use of that strategy imposes?" (p. 100).

More recently, Case and his colleagues (Case, 1982; Case, Kurland, & Goldberg, 1982) have emphasized the importance of "operational efficiency" which, they suggest, controls the growth of processing capacity. In the modified position total capacity remains constant with performance being determined by a trade-off between storage requirements and the efficiency of mental operations. Decrements in necessary operating space occur as a result of the growing speed, efficiency, and automaticity of basis processes (e.g., storage and retrieval).

Although Case's recent position emphasizes the importance of separating the structural and the processing components of the developing problem-solving system, it does not completely clarify his overall theoretical position. Indeed, Flavell (1978) focused on the main point of difficulty, by asking of Case's view, "Won't it be even harder to decide that a mental operation is "sufficiently automatized" than to decide how many such operations have to be held in working memory during the execution of a strategy?" (p. 101). Reliance on the concent of changes in working memory capacity to "explain" task varient effects is to raise rather than to answer the basic question.

Flavell's research on perspective taking skills takes another approach to explaining rather than just demonstrating precocious processing. The perspective taking task has an interesting history in the light of arguments concerning early competence. According to Piagetian researchers, visual or spatial perspective taking is a developmentally advanced accomplishment coinciding with the emergence of logical thinking skills in middle childhood. Piaget and Inhelder (1956) developed the three mountain problem to assess whether children could predict the perspective of an individual other than oneself. In this task the child has to infer how an array of objects looks to an observer who views the array from a different position to that of the subject. The failure of young children to adopt the perspective of another on the three mountain task was attributed to egocentrism which is considered to be characteristic of preoperational thinking.

More recently, however, it has been demonstrated that a variety of contextual manipuations affect children's judgments on perspective taking tasks, casting doubt on the Piagetian claim that young children lack the cognitive structures necessary for perspective taking (Fehr, 1978; Rosser, 1983). For example, if four-year-olds are allowed to rotate a second array, mounted on a lazy-susan device, they can accurately judge perspective (Borke, 1975), and if they are allowed to view the test array from all possible perspectives, they make fewer errors than if they make perspective judgments without having first viewed all aspects of the array (Eiser, 1974). In addition, Nigl and Fishbein (1974) found that children are better able to coordinate perspectives when three- rather two-dimensional choice stimuli are used. This is an interesting finding because in the typical perspective taking tasks two-dimensional photographs are used as judgment stimuli. As a final example of a factor that affects perspective taking skill, Cox (1975) found that children are more likely to make correct responses if they are judging what a human sees rather than a doll. In sum, it seems that children as young as four years of age are able to coordinate relatively complex perspectives provided the task setting is conducive, a fairly robust example of the influence of contexts in learning.

This selective summary of some of the task factors that affect the developmental emergence of perspective taking skill again leaves unanswered the question of _why_ certain task contexts are more conducive than others, and _how_ perspective taking skills develop. It is to these questions that Flavell and his colleagues have addressed themselves. Their work goes beyond the descriptive and offers analyses over and above simple demonstrations that Piaget must have been wrong.

As Flavell (1977, p. 45) pointed out, Piaget and Inhelder's Three Mountain problem "appears in hindsight to be a rather 'noisy,' insensitive measure of the basic ability it was designed to assess." Flavell (1977) argued that one would expect a developmental sequence in the emergence of perspective taking of the following form: (a) the child would first understand that another's experience is different from that of their own without being able to determine the exact nature of the other person's experience; and (b) the child would subsequently become able to infer the other's experience (Flavell, 1977; Flavell, Everett, Croft, & Flavell, 1981; Lempers, Flavell, & Flavell, 1977). In the earlier developing _Level 1_ knowledge, children can infer what object a person does or does not see, and are also capable of saying what objects can be seen by them and not by another person. At the later developing Level 2, children are aware that an object gives rise to differing images, depending on the point from which it is viewed. This two stage sequence is not independent of task complexity; Flavell, Botkin, Fry, Wright, and Jarvis (1968) have shown that even adults are unable to infer another's perspective if the task is sufficiently complex. Nevertheless, working with relatively simple stimuli, Flavell has provided supportive data for the two stage development of perspective taking skills.

In support of their claim for the Level 1-Level 2 distinction, Flavell et al. (1981) showed that three-year-old children performed well on tasks that call for Level 1 knowledge but poorly on tasks requiring Level 2 knowledge. The Level 1 task involved presenting children with a card with a picture on each side of it (e.g., a dog on one side and a turtle on the other). The child had to say what picture the experimenter saw. The Level 2 task involved placing a picture on a table (e.g., a picture of a turtle) so that it was either right side up for the experimenter or the child. The task was to indicate which of the two orientations the experimenter saw. Three-year-old children continued to perform poorly even when the task was changed to be more familiar with their everyday experiences and even after training.

A second kind of developmental sequence in perspective taking is the distinction between Rules and Computation (Flavell, Omanson, & Latham, 1978; Salatas, & Flavell, 1976). Computation refers to the cognitive processes invoked to solve many perspective taking problems (e.g., mental rotation). In contrast, Rules refers to knowledge of the general invariant relational properties that hold for all arrays (e.g., if I know that you are examining an array from a different postion to me, I do not have to look at the array to know that your view will be different from mine--it is an invariant rule that is known to be true). The distinction between Rules and Computation is important because if a child fails on a perspective taking task, the error may be due to inadequate rule knowledge, inappropriate computation strategies or some combination of both (Flavell et al., 1978).

The distinction between rules and computation was examined by Flavell et al. (1978) by having first, third, and fifth grade children identify which of two photographs represented an observer's view of an array of three dolls. The amount of prior information given to the children about the positioning of the three dolls was varied so that, in principle, they could identify the correct photograph without seeing the array. In fact, in one condition, children did have to choose which was the correct photograph without seeing the array. The purpose of this manipulation was to determine whether children could apply their rule-based knowledge. In a second condition, however, the children were allowed to see the array after receiving the hints to see whether they would decide which photograph was correct on the basis of computation or on the basis of their knowledge of perspective taking rules. The results were clear. First, few first grade children did well on the rule condition. Second, children who understood the perspective rule, as indexed by performance on the rule condition, continued to use that knowledge even when presented with the opportunity to observe the array; that is, they saw no need to confirm by computation what they already knew. Furthermore, Flavell et al. (1978) found that nearly all children who made rule-based decisions, as indicated by their speed of choosing the correct photograph, were able to articulate the nature of the rule. As Flavell et al. (1978, p. 464) noted, for "older subjects . . . such rules . . . become explicit, completely general, semi-necessary truths."

Some a priori distinctions concerning what would make a context simple or difficult, of the type used by Flavell and Case, are clearly needed if we are to avoid the circularity of the arguments often proposed to explain early and partial competence. But in addition, we need to go farther and ask whether the early competence we see is principled, in the sense that under a variety of easy instantitations the child can perform well. For example, if it were possible to reduce the memory load, or processing capacity demands equally for two or three tasks, would the child perform consistently well? And if we then increase the processing load, would the child show less and less competence proportionally? We do not know the answers to these questions and will not come to know them unless we undertake systematic examination of what supportive contexts are.

It is also an interesting question whether the creation of a principled set of task environments, some that tap newly emergent understanding, some partial knowledge, and some complete flexible comprehension of "the explicit, general semi-necessary truths" kind, could serve to create development through learning. This point has not been addressed systematically, although Crisafi and Brown (1983) have shown that it is possible, through analogical transfer, to teach three-year-olds to perform well on difficult versions of the inferential reasoning tasks in question. Would the provision of a guided tour through a set of ever more complex tasks variants lead to more mature performance in young children on the difficult, process-demanding versions of a particular problem? i.e, would the child learn to deal with progressively more difficult instantiations? Or is performance totally determined by the processing load factors? These questions remain to be answered.

A central question for further research is whether early competence is really fleeting, is really of the "now you see it, now you don't" quality or whether its emergence and maintenance is governed by a systematic set of discoverable rules. Also, an important issue is the extent to which early competence is domain specific or domain general. Similarly, we need to consider carefully whether the results of learning in easy-to-hard contexts, in social interactions, etc. have any generality or stability? In short the questions concerning the developmental status of precocious thinking, however it is induced, are only now being raised in systematic ways. Demonstrations of early competence that show that Piaget was wrong in his estimate of when competence should emerge are legion. What is needed now is the development of a consistent theoretical rationale of what governs the emergence of competence within and across domains.

Conclusion

Learning and development are interwoven in a complex spiral such that none of the four alternatives mentioned in the introduction fully capture the flavor of the relation. As Vygotsky argued, learning in contexts, including the social, creates development which in turn determines the level of learning and teaching for which the child is ripe.

Thus, a main theme of this paper is that contexts create learning and development. Any estimate of developmental status must depend critically on the environment in which it is revealed. Important environmental factors include the social, in which parents, teachers, peers, and experimenters provide degrees of contextual support for learning, sometimes deliberately and sometimes without conscious intent to do so. These interactional accomplishments are an important driving force of cognitive development. But in addition, we should not overlook the fact that a great deal of development is instigated by the enquiring mind of the child herself. Developmental status cannot be assessed in a vacuum and the contexts used to reveal or disguise competence must come to figure more prominently in theories of cognitive development. Supporting environments are the things to be understood, not an explanation of development.

The second main theme of this paper has been the emphasis on microgenetic analysis, the method of observing development taking place in children "right before one's eyes." Much of the picture of developmnet described in this chapter came from a consideration of short-term changes in children, developing and learning, with or without the help of others. We have argued that the concept of bandwidths of competence through which the child navigates over time and across settings is a more fruitful metaphor for cognitive development than the legacy of a poorly understood stage theory, i.e., a reliance on static snapshot descriptions of developmental status frozen in time and welded to a particular task environment.

We believe that a main agenda for developmental psychologist is to expand their theories to accent for environments in which learning and development occur. As developmental psychologists, if we can come to understand: (a) self-directed learning, (b) sensitive methods of assessing readiness for change, (c) the dynamics of social situations that are successful in inducing change, and (d) supportive experimental contexts, we will have gone a long way in unraveling the complex interactions of learning and development. This agenda is the one set by Vygotsky, a pioneer in the development analysis of human cognition.

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Table 1

The Acquisition of Question-Asking by a Weak 7th. Grade Student (Charles)

Day 1:

TEXT: The water moccasin, somewhat longer than the copperhead, is found in the southeastern states. It lives in swampy regions. It belongs, as do also the copperhead and the rattlesnakes, to a group of poisonous snakes called pit vipers. They have pits between their eyes and their nostrils which, because they are sensitive to heat, help the snakes tell when they are near a warm-blooded animal. Another name for the water moccasin is "cottonmouth." This name comes from the white lining of the snake's mouth.

1) S: What is found in the southeastern snakes, also the copperhead, rattlesnakes, vipers - they have. I'm not doing this right.
2) T: All right. Do you want to know about the pit vipers?
3) S: Yeah.
4) T: What would be a good question about the pit vipers that starts with the word "why?"
5) S: (No response)
6) T: How about, "Why are the snakes called pit vipers?"
7) S: Why do they want to know that they are called pit vipers?
8) T: Try it again.
9) S: Why do they, pit vipers in a pit?
10) T: How about, "Why do they call the snakes pit vipers?"
11) S: Why do they call the snakes pit vipers?
12) T: There you go! Good for you.

Day 4:

TEXT: Spinner's mate is much smaller than she, and his body is dull brown. He spends most of his time setting at one side of her web.

13) S: (No question)
14) T: What's this paragraph about?
15) S: Spinner's mate. How do spinner's mate...
16) T: That's good. Keep going.

Table 1 (cont'd.)

17) S: How do spinner's mate is smaller than...How am I going to say that?
18) T: Take your time with it. You want to ask a question about spinner's mate and what he does, beginning with the word "how."
19) S: How do they spend most of his time sitting?
20) T: You're very close. The question would be, "How does spinner's mate spend most of his time?" Now, you ask it.
21) S: How does spinner's mate spend most of his time?

Day 7:

TEXT: Perhaps you are wondering where the lava and other volcanic products come from. Deep within our earth there are pockets of molten rock called magma. Forced upward in part by gas pressure, this molten rock continually tries to reach the surface. Eventually--by means of cracks in the crustal rocks or some similar zone of weakness--the magma may break out of the ground. It then flows from the vent as lava, or spews skyward as dense clouds of lava particles.

---

22) S: How does the pressure from below push the mass of hot rock against the opening? Is that it?
23) T: Not quite. Start your question with, "What happens when?"
24) S: What happens when the pressure from below pushes the mass of hot rock against the opening?
25) T: Good for you! Good job.

Day 11:

TEXT: One of the most interesting of the insect-eating plants is the Venus's flytrap. This plant lives in only one small area of the world -- the coastal marshes of North and South Carolina. The Venus's flytrap doesn't look unusual. Its habits, however, make it truly a plant wonder.

---

26) S: What is the most interesting of the insect eating plants, and where do the plants live at?
27) T: Two excellent questions! They are both clear and important questions. Ask us one at a time now.

Table 1 (cont'd.)

Day 15:

TEXT: Scientists also come to the South Pole to study the strange lights that glow overhead during the Antarctic night. (It's a cold and lonely world for the few hardy people who "winter over" the polar night.) These "southern lights" are caused by the Earth acting like a magnet on electrical particles in the air. They are clues that may help us understand the Earth's core and the upper edges of its blanket of air.

---

28) S: Why do scientists come to the south pole to study?
29) T: Excellent question! That is what this paragraph is all about.

Table 2

Improvement in Question-Asking by a More Competent 7th. Grade Student (Sara)

Day 2:

TEXT: HOW CAN SNAKES BE SO FLEXIBLE?

The snake's skeleton and parts of its body are very flexible--something like a rubber hose with bones. A snake's backbone can have as many as 300 vertebrae, almost ten times as many as a human's. These vertebrae are connected by loose and rubbery tissues that allow easy movement. Because of this bendable, twistable spinal construction, a snake can turn its body in almost any direction at almost any point.

---

1) S: Snakes' backbones can have as many as 300 vertebrates - almost _ _ _ times as many as humans.
2) T: Not a bad beginning, but I would consider that a question about a detail. Try to avoid "fill in the blank" questions. See if next time you can fine a main idea question and begin your question with a question word - how, why, when....

Day 3:

TEXT: There are snakes in nearly all parts of the world. Some snakes prefer warm, arid desert areas. Others prefer leafy forests, fields, and woodlands. Some stay in areas near water and are fine swimmers. Then there are several varieties that live all their lives in the sea.

---

3) S: Can snakes live their whole lives in seas?
4) T: See if you can ask a question using your own words.

Table 2 (cont'd.)

Day 4:

TEXT: The other kind of camel--the one with two humps--is the Bactrian. Its home country is the Gobi Desert of northeastern Asia. The Bactrial has shorter legs and longer wool than the one-humped camel. It also has stronger, more rugged feet. This is important because instead of having sand to walk on, the Bactrian camels live in rough and rocky parts of the world.

5) S: Where is the Bactrian found?
6) T: Good for you.

Day 6:

TEXT: When most full-grown spiders want to travel, they have to walk on their eight legs. But some small kinds of spiders, and many young ones, use an easier way. They climb up on bushes, fence posts, or weed stems and spin streamers of silk. When the wind catches the silk and blows it away, each spider tightly holds onto his own streamer. The silk streamer carries him through the air as if it were a parachute or a balloon.

7) S: I think I have another. When it's traveling, what do they compare the spider to?
8) T: An interesting question.

Day 11:

TEXT: The young caterpillar's first meal is its own eggshell. Then it eats a leaf and each day eats more and more food. After a few days, the caterpillar becomes too large for its skin. A new skin forms beneath the first one, the old skin comes open and, like a snake, the caterpillar wriggles its way out of the split skin. Then the caterpillar goes on eating leaves or other kinds of food. When the new skin becomes too tight for the growing body, it again splits and comes off. By then the caterpillar is covered by another skin. This eating and shedding goes on for several weeks. The old skin may be replaced by a new one four or five times. Each time the skin is shed, the size and color of the caterpillar change.

9) S: Why does the caterpillar's skin split?
10) T: Excellent question. That was the point of the entire paragraph.

Table 3
Reciprocal Dialogue from an Early Session; Study 2, Group 3, Day 3.

TEXT: CAN SNAKES STING WITH THEIR TONGUES?
No--snakes' tongues are completely harmless. They're used for feeling things and for sharpening the snakes' sense of smell. Although snakes can smell in the usual way, the tongue flickering in the air picks up tiny particles of matter. These particles are deposited in two tiny cavities at the base of the nostrils to increase the snakes's ability to smell.

---

1. A: Do snakes' tongues sting?
2. K: Sometimes.
3. A: Correct.
   This paragraph is about do snakes sting with their tongue, and different ways that the tongue is for and the senses of smell.
4. *T: Are there any questions?
5. C: Snakes' tongues don't sting.
6. *T: Beautiful! I thought, boy, I must have been doing some fast reading there because I missed that point. A_____, could you ask your question again?
7. A: Do snakes' tongues really sting?
8. *T: Now, A_____, since you have asked the question, can you find in that paragraph where the question in answered?
9. A: No, snakes' tongues are completely harmless.
10. *T: So we'll try it again. Can you generate another question that you think a teacher might ask?
11. A: What are the tongues used for?
12. *T: Good!
13. L: The sense of smell.
14. *T: Is that correct? A_____, do you disagree? Yes.
15. A: That answer was right, but there are other things that the tongue can do.
16. L: But she only said tell one, she didn't say tell all of them.
17. *T: O.K.
18. B: It is used to pick up tiny particles.
19. *T: O.K. I think that this is an important point. You have the basic concept which is correct, O.K., but what the question really is saying is, is it used for smell? O.K.?
20. B: They are used for feeling things for sharpening snakes' sense of smell.
21. *T: O.K. They are used for sharpening the snakes' sense of smell. Are they used for smelling? That's the point we aren't clear on.
22. L: In my answer I said it is for the sense of smell.

Table 3 (cont'd.)

23. *T: This is fine; this is what the technique is all about. What it means is not that you are right or wrong or good or bad. What it says is that we have just read something and have had a disagreement about what it says. We need to work it out.
24. A: My prediction is that they will now talk about the different things about snakes. Where they live, and what they eat and stuff like that.
25. *T: O.K. Good. What do you think they eat?
26. A: Animals.
27. A: Deserts.
28. C: I challenge. Snakes, all of them, don't live in the desert. They live in the woods and in swamp areas.

---

* Indicates turns taken by adult teacher

Table 4

Reciprocal Dialogue from a Later Session; Study 2, Group 3, Day 13

TEXT: In the United States salt is produced by three basic methods: solar (sun) evaporation, mining, and artificial heat evaporation. For salt to be extracted by solar evaporation, the weather must be hot and dry. Thus, solar salt is harvested in the tropic-like areas along our southern ocean coasts and at Great Salt Lake.

---

1. C: Name three different basic methods how salt is produced.
2. A: Evaporation, mining, evaporation ... artificial heat evaporation.
3. C: Correct, very good. My summary on this paragraph is about ways that salt is being produced.
4. *T: Very good. Could you select the next teacher?
   (Student selects another student)

TEXT: The second oldest form of salt production is mining. Unlike early methods that made the work extremely dangerous and difficult, today's methods use special machinery, and salt mining is easier and safer. The old expression "back to the salt mine" no longer applies.

---

5. L: Name two words that often describe mining salt in the old days.
6. K: Back to the salt mines?
7. L: No. Angela?
8. A: Dangerous and difficult.
9. L: Correct. This paragraph is all about comparing the old mining of salt and today's mining of salt.
10. *T: Beautiful!
11. L: I have a prediction to make.
12. *T: Good.
13. L: I think it might tell when salt was first discovered, well, it might tell what salt is made of and how it's made.
14. *T: O.K. Can we have another teacher?

TEXT: Table salt is made by the third method -- artificial evaporation. Pumping water into an underground salt bed dissolves the salt to make a brine that is brought to the surface. After purification at high temperatures, the salt is ready for our tables.

Table 4 (cont'd.)

15. K: After purification at high temperatures the salt is ready for what?
16. C: Our tables.
17. K: That's correct. To summarize: After its purification, the salt is put on our tables.
18. *T: That was a fine job, Ken, and I appreciate all that work, but I think there might be something else to add to our summary. There is more important information that I think we need to include. This paragraph is mostly about what?
19. A: The third method of artificial evaporation.
20. B: It mainly tells about pumping water from an underground salt bed that dissolves the salt to make a brine that is brought to the surface.
21. *T: Angela hit it right on the money. This paragraph is mostly about the method of artificial evaporation and then everything else in the paragraph is telling us about that process. O.K. Next teacher.

TEXT: For thousands of years people have known salt—tasting it, using it for their lives' needs. Sometimes it has been treasured as gold; other times it has been superstitiously tossed over the shoulder to ward off bad luck. Somehow people and salt have always been together, but never is the tie more complete than when the best people are called "the salt of the earth."

---

22. C: My question is, what are the best people called?
23. L: The salt of the earth.
24. C: Why?
25. L: Because salt and the people have been together so long.
26. *T: Chris, do you have something to add to that? O.K. It really isn't because they have been together so long; it has to do with something else. Brian?
27. B: (reading) "People and salt have always been together but never has the tie been so complete."
28. *T: Allright, but when we use the expression, "That person is the salt of the earth," we know that means that person is a good person. How do we know that?
29. B: Because we treasure salt, like gold.

---

* Indicates turns taken by adult teacher

Table 5

Design for Combining Information Tasks

Task Structure:	Container-Subgoal Relation (A-B, x-y)	Subgoal-Goal (B-G)	Combining Test (A-B-G)
Task Varient			
Familiar Objects:			
1. Know Relations (Gumball Machine)	bank-penny purse-dime	penny-gumball machine -> gumball	bank -> penny penny -> gumball
2. New Relations: (Truck)	carton-white button pan-grey button	white button-truck -> candy bean	carton -> white button white button -> candy bean
Unfamiliar Objects:			
3. New Relation (Box-Automated)	red panel-marble blue panel-ball bearing	marble-center panel -> M & M	red panel -> marble marble -> M & M

Figure Captions

Figure 1. Examples of matrices inductive reasoning proolems (from Campione, Brown, Ferrara, Jones, & Steinberg, in press).

Figure 2. Examples of correct and incorrect assemblies of the rail circuit task.

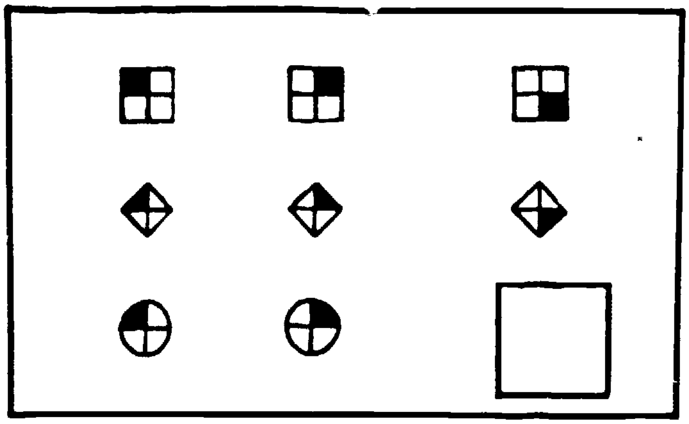
Figure 3. Examples of the block types used by Karmiloff-Smith and Inhelder (1974).

Figure 4. Schematic version of the A-B-G problem based on Hull (1952).

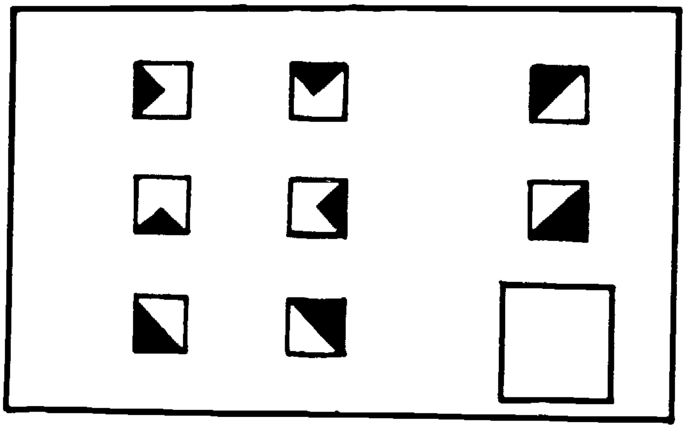
Figure 5. Schematic version of the A-B-G problem used by Maier (1936).

Figure 6. Data from rats and children in Maier's A-B-G maze (Maier, 1936).

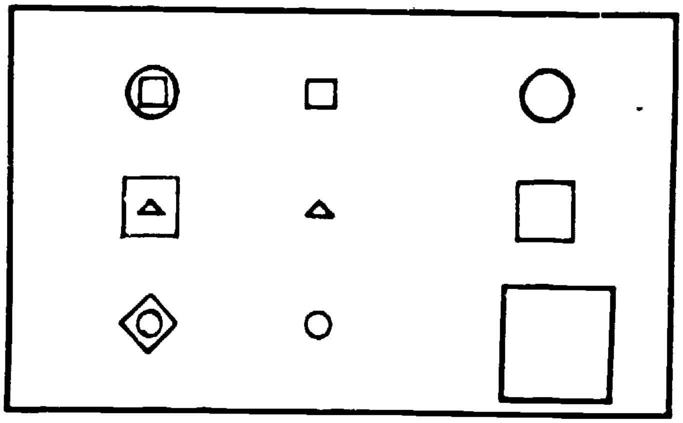
Figure 7. Three versions of the A-B-G problem used by Crisafi & Brown (1984).



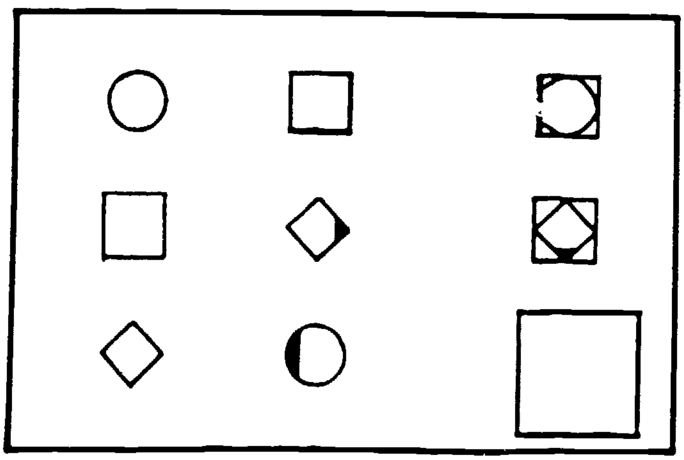
Rotation



Addition



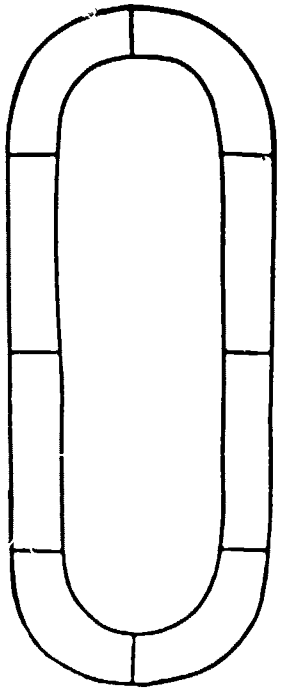
Subtraction



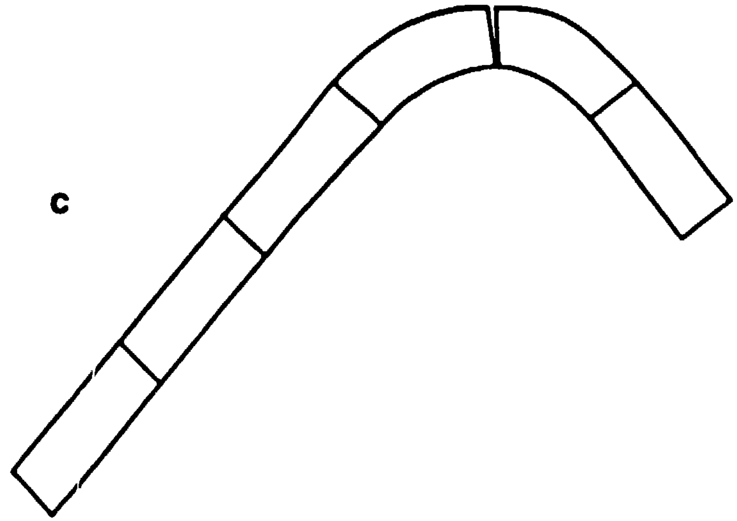
TRANSFER

Rotation and Addition

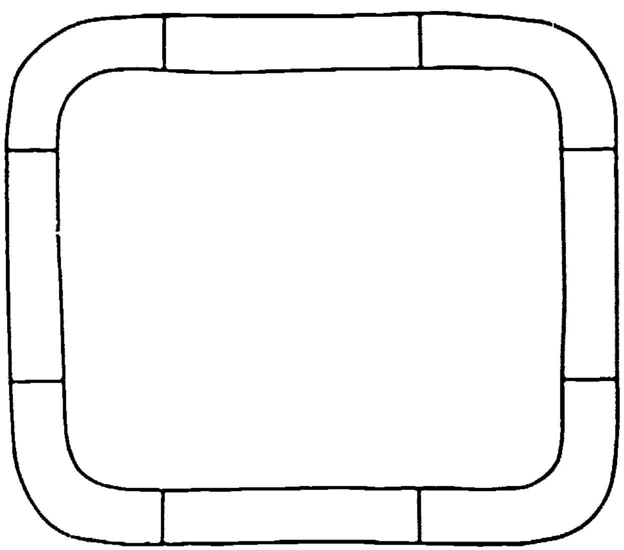
a



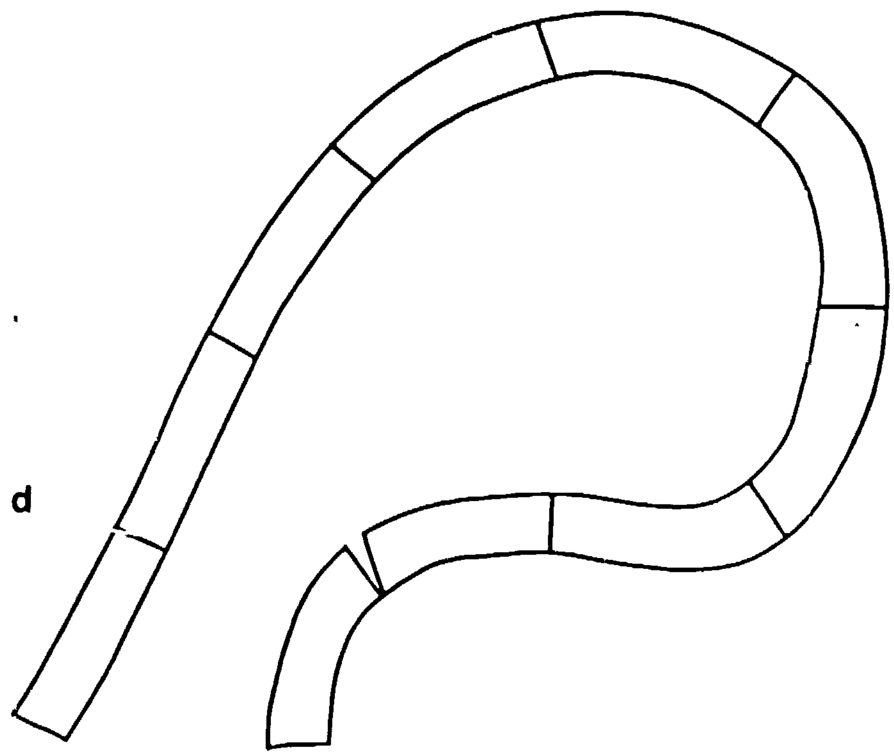
c

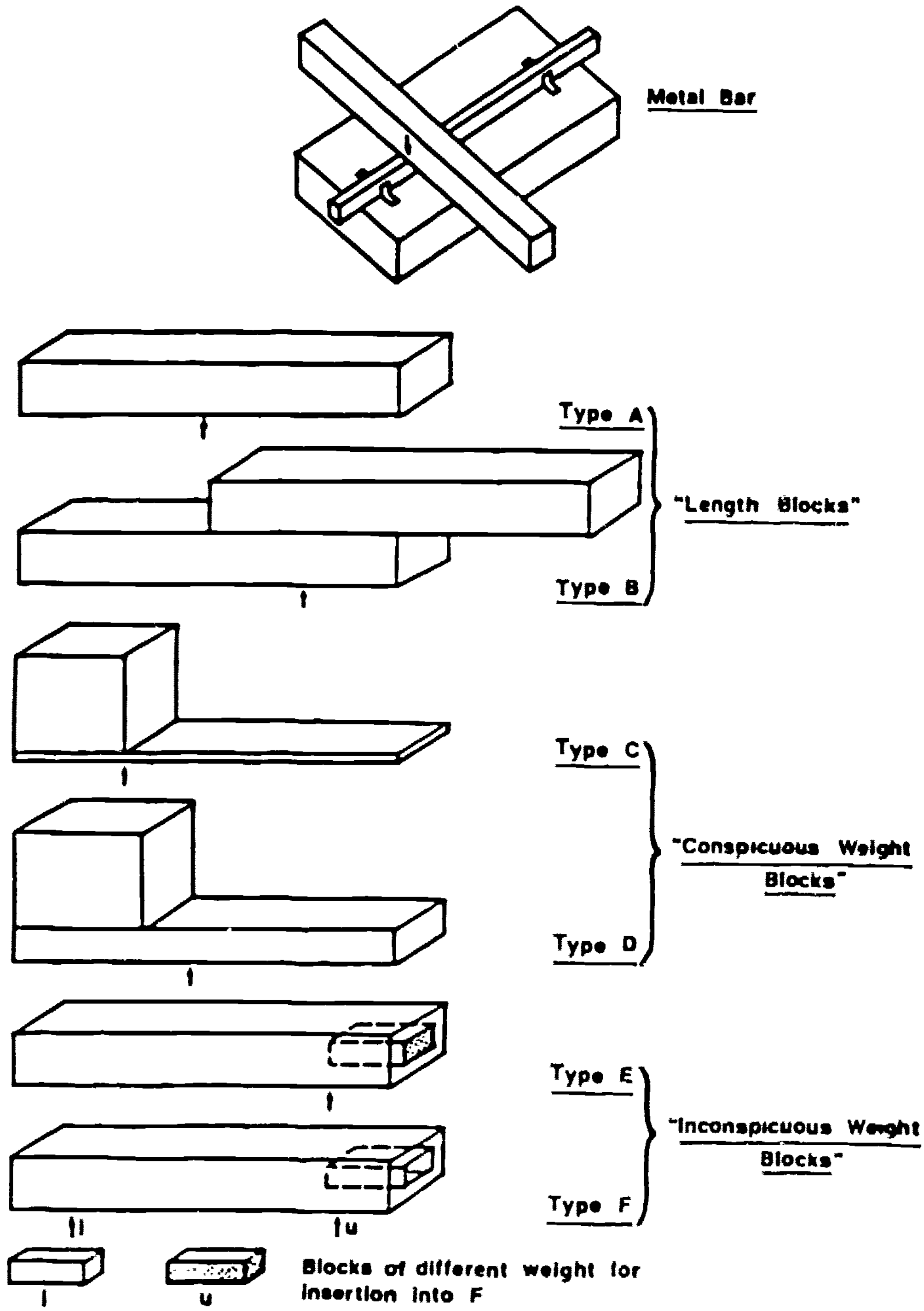


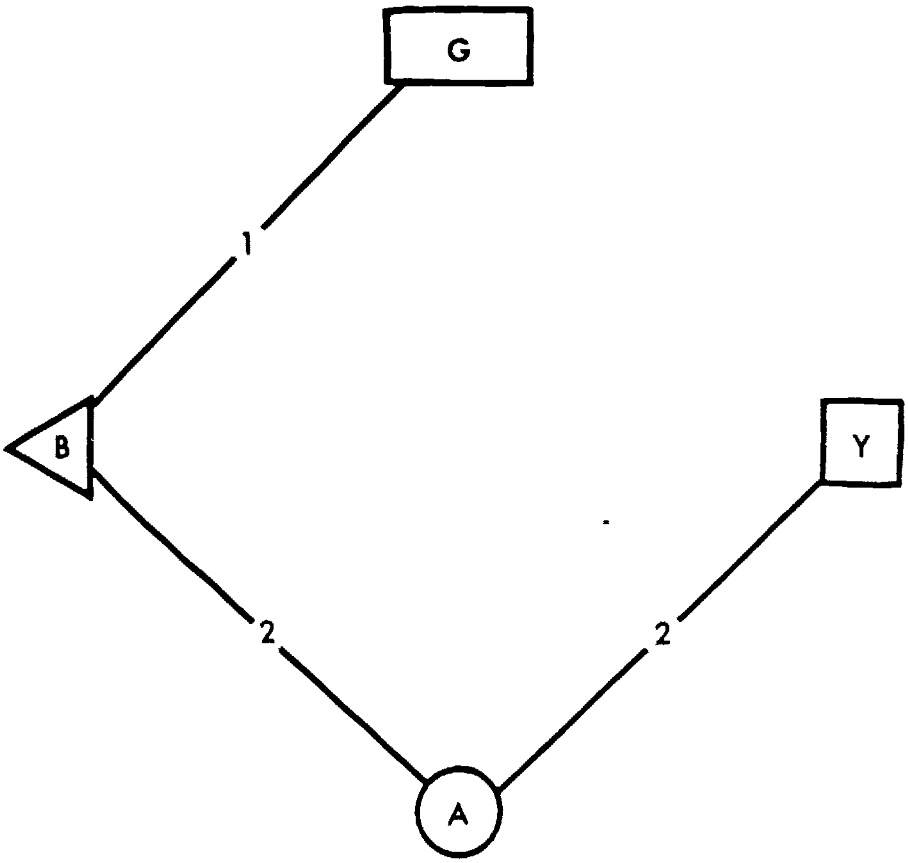
b



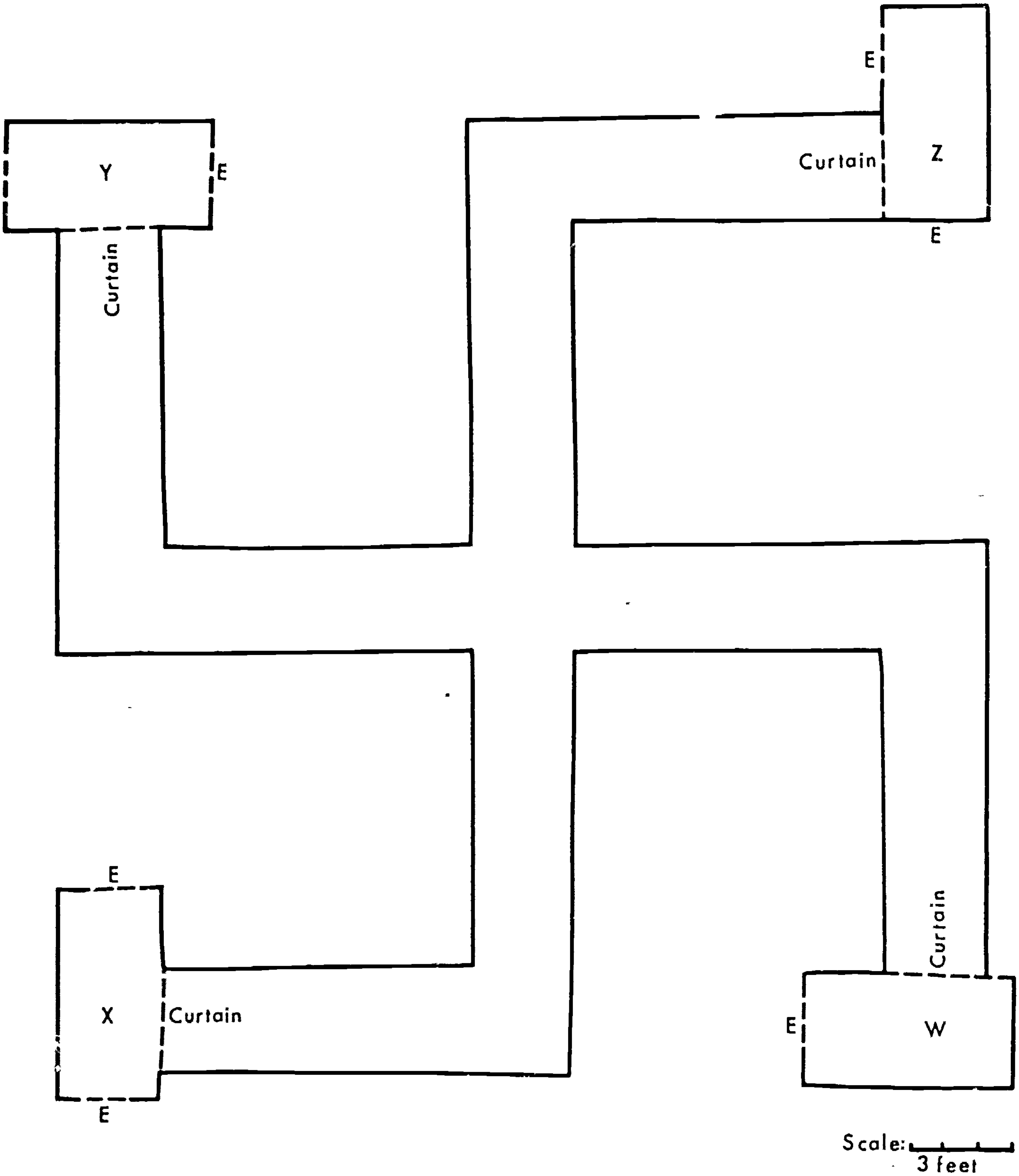
d

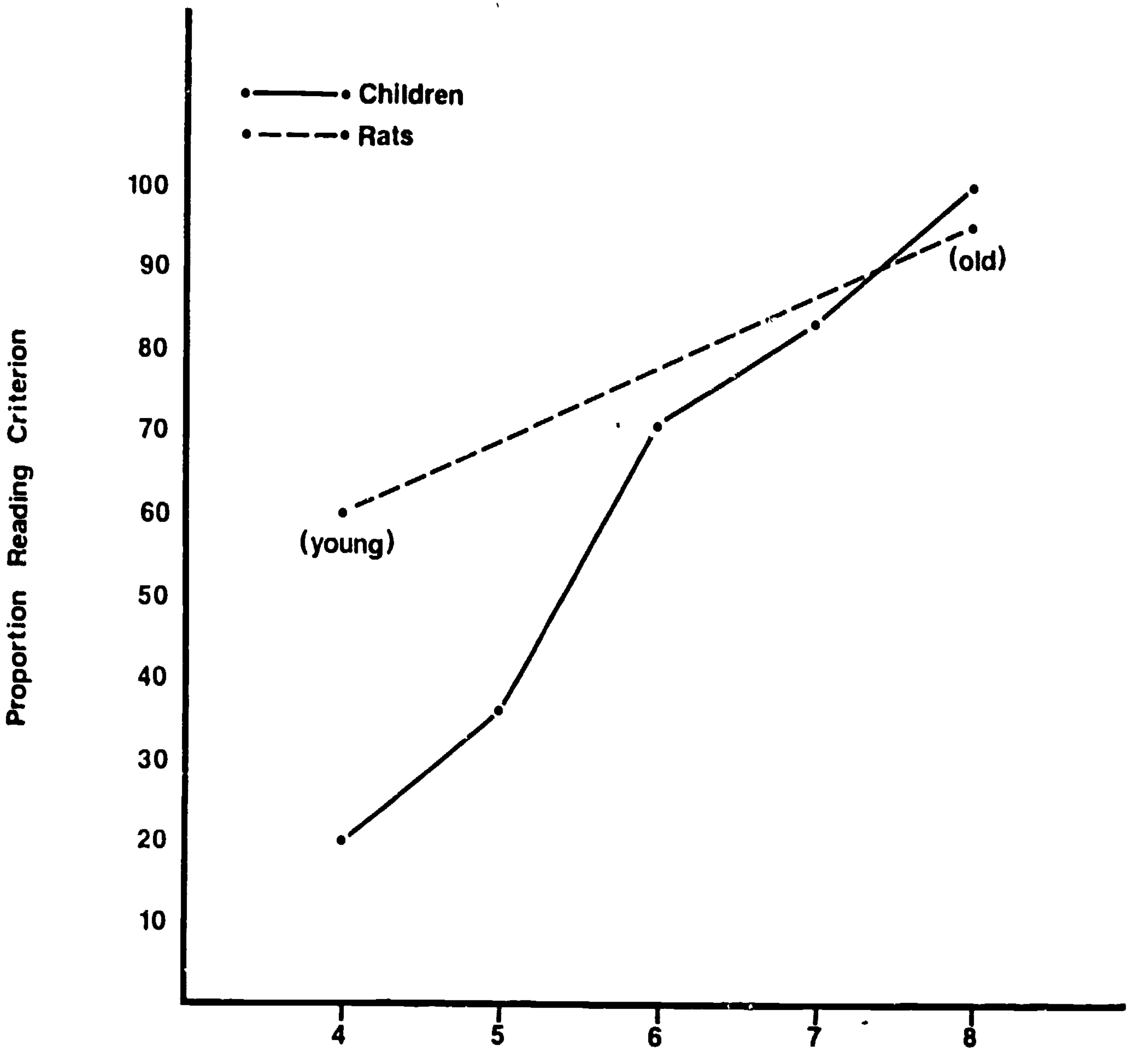



Metal Bar
Type A
"Length Blocks"
Type B
Type C
"Conspicuous Weight Blocks"
Type D
Type E
"Inconspicuous Weight Blocks"
Type F
l
u
l
u
Blocks of different weight for insertion into F



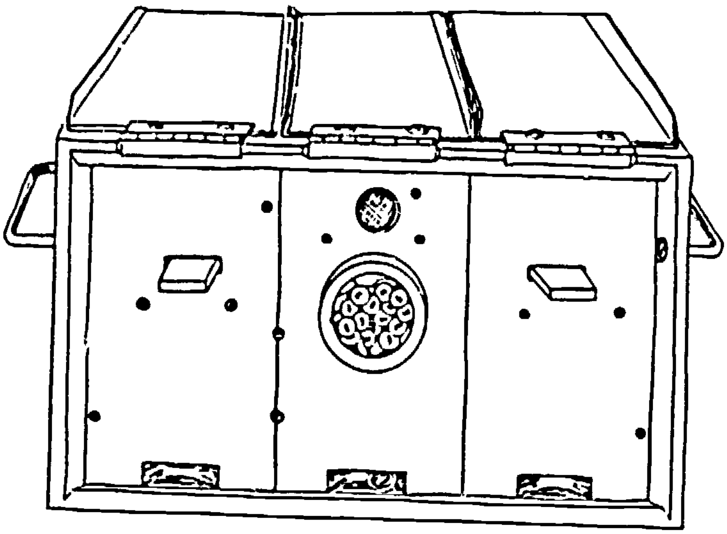
Schematic Version of the A-B-G Problem

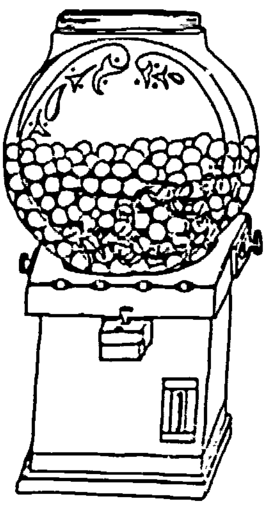

E
Y
E
Curtain
Curtain
Z
E
Curtain
E
X
Curtain
E
E
W
Scale:
3 feet

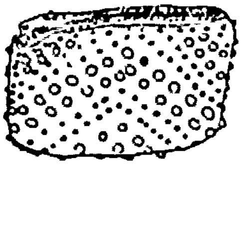


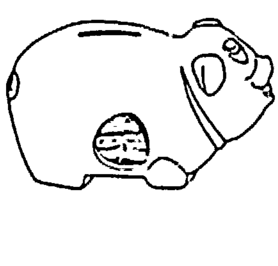
Children
Rats
100
90
80
70
60
50
40
30
20
10
Proportion Reading Criterion
(young)
(old)
4
5
6
7
8
Age

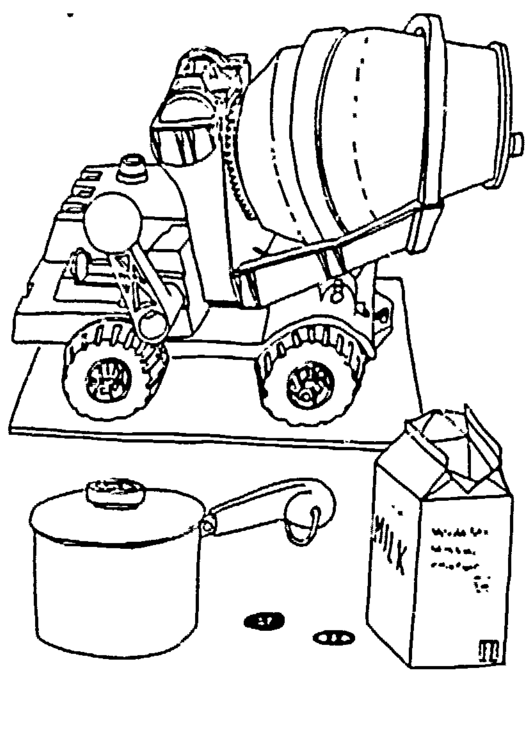
(Maier 1936)










MILK