Two important and related themes in Vygotsky’s writings are the social foundations of cognition and the importance of instruction in development:

An important point to note about Vygotsky’s ideas on the social origins of cognition is that it is at this point that he uses the notion of internalization. He is not simply claiming that social interaction leads to the development of the child’s abilities in problem-solving, memory, etc.; rather, he is saying that the very means (especially speech) used in social interactions are taken over by the individual child and internalized. Thus, Vygotsky is making a very strong statement here about internalization and the social foundations of cognition (Wertsch, 1981, p. 146).

If all the development of a child’s mental life takes place in the process of social intercourse, this implies that this intercourse and its most systematized form, the teaching process, forms the development of the child, creates new mental formations, and develops higher processes of mental life. Teaching, which sometimes seems to wait upon development, is in actual fact its decisive motive force.... The assimilation of general human experience in the teaching process is the most important specifically human form of mental development in ontogenesis. This deeply significant proposition defines an essentially new approach to the most important theoretical problem of psychology, the challenge of actively developing the mind. It is in this that the main significance of this aspect of Vygotsky’s enquiries lies (Leontiev & Luria, 1968, p. 365).

In all of Vygotsky’s writings with which we are familiar, the social relationship referred to as “teaching” is the one-to-one relationship between one adult and one child. When we try to explore Vygotskian perspectives for education, we immediately confront questions about the role of the student peer group. Even if formal education takes place in a group context only for economic reasons, because no society can afford a teacher for each individual child, the presence of
peers should not be ignored or relegated only to discussions of issues in classroom management and control.

We see two separate but related issues concerning the group presence. First, there are the problems posed for the teacher in carrying out direct teaching to a group of students; second, there are the questions raised for the teacher’s more indirect planning for the social organization of all work-related talk in the classroom setting, specifically the contribution that peers can make to each other. We focus on the second set of questions in this chapter. This is not to underestimate the importance of the first. If teaching is conceived as assistance to the child in the child’s zone of proximal development, then teaching to a group of children whose “zones” overlap only in part, or not at all, poses obvious problems. But to state the problem thus seems mainly to give new labels to the familiar problem of within-group variation in any group being taught. We focus instead on the less-discussed problem of the potential contribution of social interactions among the children themselves.

Understanding this contribution has both practical and theoretical significance. Practically, despite the fact that school classrooms are unusually crowded social environments, group work is rarely encouraged (Galton, Simon, & Croll, 1980), perhaps in part because there has been no clear rationale for its value. (See Sharan, 1980, for one review of arguments and evidence.) Theoretically, most developmental research studies in the United States have traditionally focused on the value of peer interactions in the socialization of behavior and personality and have said less about their possible value for cognition and intellectual learning. According to Lawler (1980), until recently the same has been true of most writing on education in the Soviet Union—for example, the work of Makarenko.

Interactions among peers focused on intellectual content can be placed on a continuum, depending on the distribution of knowledge or skill among the children, and therefore on the roles they take toward each other. At one extreme, one child knows more than the others and is expected to act as a peer tutor (or “consultant” in the recent Soviet work of M.D. Vinogradova and I.B. Pervin, summarized in Lawler [1980]). In the contrasting case, knowledge is equal, or at least not intentionally unequal, and the give and take of equal status collaboration is expected. We present research first on two different forms of peer tutoring and then on collaboration. Because empirical as well as theoretical analysis of peer interactions is at such a beginning stage, we include excerpts from interaction protocols, not only as evidence for our interpretations, but to provide material for alternative interpretations as well.

Peer Tutoring
The report of Vygotsky’s pupil, Levina, points to possible cognitive benefits to a tutor from the activity of giving verbal instructions to peers:

Vygotsky said that speech does not include within itself the magical power to create intellectual functioning. It acquires this capacity only through being used in its instrumental capacity (Levina, 1981, p. 296).
To the extent that this is true, then what Levina calls the “intellectualization” as well as the internalization of speech should be promoted by the use of instrumental speech to others. Levina suggests exactly that what is silently perceived as something unitary and whole is immediately broken up into its component elements in any attempt to make a verbal formulation of it. It is easy to be convinced of this as soon as one tries to introduce the clarity of a verbal characterization into an unconscious impression. What are the motivating forces behind this type of verbal formulation? What is it that compels the child to represent his/her perceptions verbally and to formulate and label his/her actions? In answering this question, Vygotsky laid great stress on factors having to do with the social order. He thought that in labeling an ongoing action, the child initially pays tribute to people in the environment by means of verbal representation. He/she makes this representation accessible to them, as if to clarify it. Vygotsky believed that the very act of labeling arose out of the necessity for giving one’s own actions a specialized form comprehensible to others (Levina, 1981, p. 288-289).

Levina’s examples of labeling stimulated by the need to communicate to another, taken from notes and protocols collected under Vygotsky’s supervision, contain only child speech that is directed back to the experimenter. Though the need to communicate to peers is not mentioned, it seems consistent with the Levina–Vygotsky perspective that the need to communicate to a less knowledgeable other—such as a peer—would motivate the identical process at least as strongly. Instruction of peers could, in this respect, be an intermediate step between receptively being directed by the speech of another and productively and covertly directing one’s own mental processes via inner speech.

The first analysis of peer tutoring comes from research in an inner-city multi-grade primary classroom in San Diego. Twelve peer tutoring sequences called instructional changes (ICs) were videotaped for analysis (Carrasco, Vera, & Cazden, 1981; Cazden et al., 1978; Mehan & Riel, 1982). Briefly, in each IC the teacher (T) taught a lesson to one child who then taught the same lesson to one or more peers. Leola, a black third grader, was asked to learn and then teach a language arts task. Here are the first three items on her worksheet in completed form.

1. new
2. no
3. off

You told me

Following is a transcription, minus repetitions, corrections, and so on, of the teacher’s (T) direction as she talked to Leola (L) through the first two items on the task:

Item 1
T: Okay, now number one here says new. What’s the opposite of new?
L: Old.
T: Old. How would you spell old?
L: O-L-D.
T: Okay, in the letters that are on this paper, cross out the letters you just used for spelling old.
L: (L does it.)
T: Good. What word is left?
L: Y-O-U.
T: What does it spell?
L: You.
T: Okay, and down here you’ll write you.

Item 2
T: Okay, now number two there says...
L: No.
T: No. What’s the opposite of no?
L: Yes.
T: Okay, how do you spell yes?
L: Y-E-S
T: All right. Now what are you going...
L: (L crosses out the letters Y-E-S) Told.

Note first that the T’s questions serve to talk Leola through the task until she can do it herself, as Wertsch (1978) has shown for mothers’ help to their preschool children in a puzzle-copying task. That such aid does help Leola work independently is shown by a comparison of T’s instructions for the first and second items. The first three questions are repeated, but then a much vaguer and incomplete question, “Now what are you going…,” is sufficient, and Leola takes off on her own.

The second noteworthy aspect of this IC from the Levina–Vygotsky perspective is the development of increased articulateness and precision in Leola’s verbalizations of the task. If one considers the entire instructional chain as a “discourse imitation test,” the T’s instructions must be reconstructed by the tutor’s cognitive, linguistic, and sociolinguistic system. Whereas T taught with questions, Leola teaches with statements, often “You gotta X.” (Mehan & Riel, 1982, show that his contrast in teaching styles was characteristic of all 12 ICs.)

It was not immediately easy for Leola to put the directions for this task into words. When Leola first tried to explain to T, pretask, what she was going to tell the group, she included explicit reference to only one of the four essential components, the idea of having some letters “left”:

T: Tell me what you are going to tell them to do.
L: Spell these letters, and then put out that letter, and then have another letter left.
T goes over the instructions again, this time asking Leola specifically to say the word “opposite.” Leola then includes that word, but with the vague verb “do”:

T: You want to cross out the opposite of “new.” You better say that, because it’s going to be really important. They are going to read “new,” and then what are they going to do?

L: Do the opposite of it.

Leola achieves the clearest explanation in round 3 (without hesitations and self-repairs):

L: The opposite of off is on, so on number three, you gotta cross on off. O-N. And it is me left, M-E.

Overall, one is tempted to argue that the changes in Leola’s instructions constitute an example of what Wertsch and Stone (1978), following the Soviet psychologists, call microgenesis—that is, development within an observable time period, and it is a kind of development that Leola seemed to need. In the nine lessons analyzed by Mehan (1979), some 3 hours of talk in all, she spoke four times, and only twice more than one word. This is not to say she was in any way nonverbal, but is to suggest that she could benefit from challenges to formulate academic content in words, and that the demands of tutoring, including the need for repeated formulation and for corrections of others, provide that challenge well. If there is any validity to the internalization hypothesis, practice in explicit overt formulation should ultimately aid inner speech as well. Vague, inexplicit speech—or a unitary and unformulated perception, in Levina’s words—is not the same as predication and “sense” in inner speech.

Finally, there is an interesting reduction of information in Leola’s instructions after round 3. With two exceptions, in all the rounds after 3 Leola is talking out loud, head down, while she does her own work. In the reduced rounds 4–5 and 7–10, the reduction in information is more by alternative formulations of the components than by deletion of them altogether. For example, the critical word “opposite” is spoken only in rounds 1–3, and then when the first item has to be repeated (IR) and round 6. In the other rounds, Leola says only “out is in” (presupposing that is means is the opposite of) or, even more briefly, simply places the two words in juxtaposition: “west east.” In the two exceptions, IR and 6, explicitness returns as Leola corrects her tutees and she notices that they have made a mistake.

Two alternative explanations are possible for the decreased explicitness in the reduced rounds. It may be due either to Leola’s understanding that the concept of “opposites” can now be assumed or to the decreased explicitness that characterizes speech to oneself. As Wertsch (1979) points out, the decay of old or “given” information is functionally equivalent in dialogue and private speech.

The second analysis of peer tutoring comes from observations by Kamberl (1980) in a second-grade classroom in New Hampshire in which Donald Graves’s research team was observing the teaching of writing. The teacher, Egan, held
regular conferences with individual children. In addition, she encouraged the children to hold “peer conferences” about their writing with each other. Here is one observer’s account of the conferences between two children, Jill and Debbie:

On March 11, Jill was one of six children scheduled for a writing conference....At Egan’s direction, Jill and the other conferees went to the language table. Egan had requested that Jill first spend time with 7-year-old Debbie going over the book to be sure it was ready for a conference....

Jill began by reading each page aloud to Debbie....As Jill listened to her own words, she made changes on pages 1, 2, and 3 without any prompting or comment from Debbie, and on pages 4, 5, and 8 in direct response to questions Debbie asked....

At the conclusion of this half-hour conference, Jill had made six content changes which affected the overall meaning of the piece. She had deleted information which made no sense or which she could not support; she added information to clarify or explain. Debbie’s presence was crucial to the content revisions of the draft. Her physical presence forced Jill to reread the book for the first time since composing; Debbie seemed to make the concept of audience visible for Jill. Jill also needed an active reader to ask questions....

[Later] Debbie claimed her time: “O.K., Jill, you help me now!” They reversed roles, returned to the language table to work on Debbie’s book Ice Follies, until Egan was ready to see Jill 20 minutes later. (Kamler, 1980, pp. 683–685)

Note first that this is a more reciprocal model of peer assistance. The roles of writer and helpful questioner are interchangeable among the children. All the children can learn what to do and say in the questioner role from the teacher’s model in the conferences with her, a consistent model of how to ask helpful questions that are focused on the content of writing, not form. The teacher believes that questions focused on content are more helpful than questions about form; they are also the kind of questions that children can understandingly ask of each other. The teacher’s model thus makes it possible for the children to take turns performing the teacher’s role for each other—to the benefit of each child as author, who can have so many more experiences with a responsive audience; and to the benefit of each child as critic, who can internalize such questions through the process of not only answering them to the teacher, but of asking them of peers as well.

For these benefits to occur, the teacher’s model must be learnable by the children. Graves reports (personal communication) that the conference structure of another teacher in the same school was not as learnable by the children, and so there was less of a multiplier effect via peer conferences in his classroom. This comparison suggests that the intellectual value of peer interactions in a classroom will be enhanced when the teacher consistently models a kind of interaction in which the children can learn to speak to each other.

As Kamler points out, the child writer benefits in two different ways from the peer’s presence. Most obviously, the peer asks questions, following the adult model but with content appropriate to the writing at hand; some of Jill’s changes (pages 4, 5, and 8) were in direct response to Debbie’s questions. Less obviously,
the peer silently but no less effectively represents the needs of an audience and makes “the concept of audience visible.”

We can locate the effect of such a silent audience in the otherwise empty cell created by Wertsch and Stone’s (personal communication) separation of the interpsychological/intrapsychological and external/internal dimensions in Vygotsky’s analysis. Wertsch and Stone separated the two dimensions in order to make a place for egocentric speech. In Vygotsky’s words, “Egocentric speech is internal speech in its psychological function and external speech physiologically” (1956, p. 87)—that is, intrapsychological in function but external in form. We suggest that the changes Jill made in response to Debbie’s silent presence are exactly the opposite: internal in form (though recorded in writing) and interpsychological in function, to make the writing more informative to another.

**Peer Collaboration**

In comparison with peer tutoring, even less is understood about the intellectual value of peer collaboration. This may be partly due to the fact that collaboration requires a work environment that is even further from traditional classroom organization. Peer tutoring tasks tend to resemble common classroom activities: filling in workbooks, reading aloud, editing written assignments, and so forth. In these activities the tutor helps inform, guide, and/or correct the tutee’s work. Collaboration requires a mutual task in which the partners work together to produce something that neither could have produced alone. Given the focus on individual achievement in most Western industrial societies, curricula that promote collaboration are rarely found in schools or studied by educators or psychologists.

Research on peer collaboration has thus been sparse. The major exception to this generalization is a body of research conducted by a group of Genevan psychologists (Doise, Mugny, & Perret-Clermont, 1975, 1976; Mugny & Doise, 1978; Perret-Clermont, 1980). They have conducted a series of experiments to examine the effect of peer collaboration on logical reasoning skills associated with the Piagetian stage of concrete operations: perspective taking, conversation, and so on.

Most of the Genevan research employs a training study design in which subjects are randomly assigned to treatment or control groups in which they are exposed to different social contexts. For example, the subjects in the treatment group may be asked to solve a conservation task in a small peer group composed of conservers and nonconservers, while subjects in the control group are asked to solve the same problem alone. All subjects are individually pretested and posttested on some standard measure of concrete-operational reasoning, and the effect of exposure to peer collaboration is assessed by comparing the pretest-to-posttest gains in concrete-operational reasoning found in each group. The Genevans have employed this same training study design across a number of studies in which the particular reasoning task chosen, the social groups assembled, and the criteria used to evaluate cognitive growth are systematically varied. After reviewing this entire body of research, Perret-Clermont (1980) concludes that peer interaction
enhances the development of logical reasoning through a process of active cognitive reorganization induced by cognitive conflict. She claims also that cognitive conflict is most likely to occur in situations where children with moderately discrepant perspectives (e.g., conservers and transitional subjects) are asked to reach a consensus.

Two Russian researchers, Lomov (1978) and Kol’tsova (1978), and two Japanese investigators, Inagaki and Hatano (Inagaki, 1981; Inagaki & Hatano, 1968, 1977), have reached similar conclusions—that peer interaction helps individuals acknowledge and integrate a variety of perspectives on a problem, and that this process of coordination, in turn, produces superior intellectual results. For Kol’tsova, the results are precise, rich, and logically rigorous definitions of a social science concept. For Inagaki and Hatano, the results are generalizable and stable conservation concepts. For Perret-Clermont, the results are increased ability to use concrete operational logic.

In none of these studies were subjects’ interactions during collaborative problem solving systematically observed. The studies provide only anecdotal evidence to support the hypothesis that peer interaction is capable of enhancing intellectual performance because it forces individuals to recognize and coordinate conflicting perspectives on a problem. To test this hypothesis, one would need to examine the process of social coordination that occurs during problem solving in order to isolate the social conditions that are the most responsible for cognitive growth. For example, one could observe the interactions that occur while the group is working in order to differentiate those groups in which members work closely together and frequently attempt to coordinate their differing perspectives from those in which members work largely on their own. Then one could examine how these different group interactional patterns affect the problem-solving strategies used. Just this approach is advocated by Perret-Clermont:

We have also shown that, for the task to have educational value, it is not sufficient for it merely to engage children in joint activity; there must also be confrontation between different points of view. Are all the activities described as “cooperation” by research workers such as to induce real interindividual coordinations which are the source of cognitive conflict? This question can only be answered by the systematic observation which remains to be done. (1980, p. 196)

In further studies of the psychology of intelligence, we should envisage not solely the effect of interindividual coordination on judgment behavior, or on performance as an index of development...but also the impact of different types of social interaction, and in particular of partner’s strategies, on the strategy which the subject adopts in order to carry out the task. (1980, p. 192)

We will describe a recent study (Forman, 1981) in which videotapes of collaborative problem-solving sessions were analyzed for the social interactional patterns used and the problem-solving strategies employed. In addition, individual measures of logical reasoning were collected on this sample of collaborative problem solvers that were compared with similar measures collected on a previous sample of solitary problem solvers.
The research design used by Forman is a modification of the training study design utilized by Perret-Clermont and her colleagues. Instead of providing only one opportunity for children to solve a problem in a collaborative fashion, Forman exposed her subjects to a total of 11 problem-solving sessions. There are several reasons for using a longitudinal design to assess children’s problem-solving skills. One can observe the process of cognitive growth directly, rather than having to infer it from pretest-posttest performance; and children can develop stable working relationships. In addition, a longitudinal design was chosen for this study so that the data collected on collaborative problem solving could be compared with similar longitudinal data collected by Kuhn and Ho (1980) on solitary problem solving. [See Kuhn and Phelps (1979) and Forman (1981) for a more detailed explanation of the strengths of this kind of longitudinal design.]

Forman’s study thus provides two kinds of information about collaboration: how the reasoning strategies of collaborative problem solvers differ from those of solitary problem solvers and how some collaborative partnerships differ from others in both social interactional patterns and cognitive strategy usage. In the following discussion, we will focus on these two kinds of data: comparisons of collaborators with solitary problem solvers and comparisons among different collaborative partnerships. We will then discuss the findings of Forman’s study in light of Perret-Clermont’s hypothesis and what seems to us the essential and complementary theory of Vygotsky.

**Forman’s Study**

Like Perret-Clermont, Forman asked children to cooperate in the solution of a logical reasoning task. Unlike Perret-Clermont, Forman selected a chemical reaction task that has been used to assess the ability to isolate variables in a multivariate context (Kuhn & Phelps, 1982). In addition, her subjects were older (approximately 9 years of age) than those selected by Perret-Clermont (4–7 years).

In both the study conducted by Forman (1981) and that conducted by Kuhn and Ho (1980) the subjects were fourth- to fifth-grade, middle-class children—15 singletons (Kuhn and Ho) and 4 pairs (Forman)—who showed no ability to isolate variables in a multivariate task known as the “simple plant problem.” In addition to the pretest used for subject selection, all subjects were given an additional pretest: a combinations problem in which subjects were asked to arrange five kinds of snacks in all possible combinations. The singletons and pairs participated in 11 problem-solving sessions, approximately once a week over a 3-month period. The two pretest measures were readministered as posttests within a week after the final problem-solving session. All pretests and posttests were administered individually.

The chemical reaction problem consisted of a series of seven chemical problems that were ordered in terms of logical complexity. Problem 1, the simplest, requires that subjects identify the one chemical from a set of five odorless, colorless chemicals that is necessary and sufficient for producing a specified color change when mixed with a reagent. In problems 2 and 3, two or three of the five
chemicals are capable of producing the color change, either separately or together. In problem 4, two chemicals are capable of producing the change, but only when both of them are present; and so forth.

Problem 1, with a different operative chemical each time, was presented for the first four sessions. This procedure ensured that the children were repeatedly exposed to the simplest problem in the series before more difficult problems were introduced. After the fourth session, a new problem in the series was presented whenever the previous problem had been solved once. Thus, progress through the problem series is one measure of the effectiveness of the subjects’ problem-solving strategies.

Each of the 11 problem-solving sessions in both studies followed the same format. First, two demonstration experiments were performed by the experimenter. Then, the children were asked a standard set of questions about the demonstration, for example, “What do you think makes a difference in whether it turns purple or not?” Next, the children were invited to set up the experiments they wanted to try in order to determine what chemicals were responsible for the change. No mixing of chemicals was permitted during this setting-up phase of the task. After the experiments were set up and some additional questions about them were posed, the children were permitted to mix together the combinations they had selected. In Forman’s study, the dyads were encouraged to work together on setting up and mixing the chemical experiments. Finally, after the results from the experiments had been observed, the experimenter repeated the original set of questions in order to assess whether the correct chemicals had been identified.

Forman analyzed only the part of the sessions devoted to planning and setting up the experiments. Four sessions for each of three subject pairs (George and Bruce: sessions 3, 5, 8, 11; Lisa and Linda: sessions 3, 5, 9, 11; Matt and Mitch: sessions 3, 5, 8, 10)—12 tapes in all—were coded. (The fourth pair had been included only as insurance against illness, etc.) The two coding systems used in the analysis consisted of one set of social interactional categories and one set of experimentation categories. In this chapter, we will discuss only one type of social behavior code (procedural interactions) and three types of experimentation strategies (random, variable isolation, and combinatorial).

Procedural interactions occurred during most of the problem-solving sessions coded (a range of 71 percent to 100 percent of the available time). They were defined as all activities carried out by one or both children that focus on getting the task accomplished. Examples of procedural interactions were distributing and arranging task materials, choosing chemical experiments, and recording experiments. Three levels of procedural interactions were identified: parallel, associative, and cooperative (adapted from Parten’s 1932 study of social interaction). These three levels represent three qualitatively different approaches to the sharing of ideas and the division of labor. During parallel procedural interactions, children share materials and exchange comments about the task. However, they make few if any attempts to monitor the work of the other or to inform the other of their own thoughts and actions. Associative procedural interactions occur when
children try to exchange information about some of the combinations each one has selected. However, at the associative level, no attempt is made to coordinate the roles of the two partners. Cooperative interactions require that both children constantly monitor each other's work and play coordinated roles in performing task procedures.

The experimentation strategy codes were adapted from Kuhn and Phelps (1982). Three basic types of experimentation strategies were observed: a random or trial-and-error strategy; an isolation-of-variables strategy; and a combinatorial strategy. The random experiments strategy represents a relatively ineffective, unsystematic approach to experimentation. The variable-isolation strategy is effective for solving the first three problems only. The more advanced problems, 4 through 7, require both experimental isolation and combinatorial strategies. Thus, this experimentation coding system was devised to identify when or if this strategy shift (from only variable isolation to both variable isolation and combinatorial) occurred.

Experimental strategy codes were assigned to a dyad based solely on the type of chemical experiments set up. Neither the type of social organization used to select these experiments nor the kinds of conversations that occurred during the setting-up process affected the assignment of an experimentation code. Thus, the coding of experimentation strategies constituted an assessment of each dyad's behavior that was independent of that obtained by coding their social interactions.

For the comparisons of the problem-solving achievements of collaborators versus singletons, two kinds of data are available: the number of chemical problems solved during the 11 sessions and pretest-to-posttest change scores. The first comparison produced striking differences between collaboration and solitary problem solving. While Kuhn and Ho found that only 4 of the 15 singletons solved problems 1 through 3 in the 11 sessions, all 4 of Forman's dyads solved problems 1 through 4 in the same amount of time. In addition, one dyad (George and Bruce) solved problems 1 through 6 during this three-month period, an achievement approached by none of Kuhn and Ho's subjects.

The pretest-posttest comparison between singletons and dyads produced more mixed results. These results are displayed in Tables 1 and 2 (ignoring for now the initials in parentheses). On the simple plant problem (Table 1), the singletons showed greater progress than the pairs between the pretest and posttest. In contrast, subjects who had worked in pairs seemed to show greater progress on the combinations problem (Table 2) than did the subjects who had worked alone. Thus, while the pairs seemed able to master the series of chemical problems at a much faster rate than did the singletons, they did not show consistently greater pretest–posttest gains.

One clear difference between these two comparisons (progress through the problems versus posttest performance) is that both partners were able to contribute to the solution of each chemical problem presented, but on the pretest–posttest measures the partners were on their own. The relatively sophisticated problem-solving strategies that collaborators were able to display when they could assist
each other were not as apparent when each partner was asked to work alone on similar problems.

Another reason why collaborators did not always outperform the singletons may lie in difference among the partnerships. Due to the very small number of dyads examined, large differences between dyads may obscure all but massive differences between dyads and singletons. Therefore, we turn to the second set of comparisons: those among dyads. First, we will discuss the types of social interactions that occurred over time in the three collaborative partnerships examined. Second, we will look at the experimentation strategies used by those same dyads. Third, we will reexamine their pretest-posttest data.

The most obvious difference among the social behaviors of the three dyads concerned the development of procedural interactions patterns. All procedural interactions were classified as either parallel, associative, or cooperative. Table 3 shows that all three dyads engaged in predominantly parallel and associative interactions during the first session coded (session 3 for all three dyads). Only Lisa and Linda showed any degree of cooperative behavior during this session. However, by sessions 5, 8, and 11, George and Bruce were entirely cooperative. Lisa and Linda retained some associative interaction patterns in session 5, but by sessions 9 and 11 they too were engaging in cooperative interactions. In contrast, Matt and Mitch never cooperated throughout the 3-month period. The interaction pattern that Matt and Mitch seemed to prefer was either predominantly or entirely parallel in nature.

| Table 1. Pretest and Posttest Category Frequencies on the Simple Plant Problem |
|---------------------------------|-----------------|-----------------|
|                                | Predominantly Concrete | Predominantly Transitional | Predominantly Formal | Total N |
| **Pretest**                    |                  |                  |                  |         |
| Singletons                     | 15               | 0                | 0                | 15      |
| Pairs                          | 8                | 0                | 0                | 8       |
| **Posttest**                   |                  |                  |                  |         |
| Singletons                     | 4                | 5                | 6                | 15      |
| Pairs                          | 6 m1, l2, m2, g, k1, k2 | 1 (b)            | 1 (l1)           | 8       |

| Table 2. Pretest and Posttest Category Frequencies on the Combination Problem |
|---------------------------------|-----------------|-----------------|
|                                | Predominantly Concrete | Predominantly Transitional | Predominantly Formal | Total N |
| **Pretest**                    |                  |                  |                  |         |
| Singletons                     | 15               | 0                | 0                | 15      |
| Pairs                          | 8                | 0                | 0                | 8       |
| **Posttest**                   |                  |                  |                  |         |
| Singletons                     | 12               | 3                | 0                | 15      |
| Pairs                          | 5 k2, l1, m1, k1, g | 3 l2, m2, b       | 0                | 8       |
Table 4 summarizes the differences in experimentation strategies used in each pair’s last two sessions. All three pairs used similar kinds of experimentation strategies during the earlier sessions. George and Bruce, the dyad who solved the greatest number of problems, used both an isolation of variables and a combinatorial strategy in the two later sessions. Lisa and Linda used only the variable-isolation strategy in session 9 but both strategies by session 11. In contrast, Matt and Mitch produced either random experiments or experiments capable of isolating single variables throughout the study, despite the fact that neither of these strategies was sufficient for solving the advanced problems that were presented to them during sessions 8 and 10.

Returning to the pretest-posttest measures, we find that George and Bruce, who worked so well together, did not maintain this high degree of performance when they were tested individually. The initials on Tables 1 and 2 show the posttest status of the six children whose tapes were analyzed: George (G), Bruce (B), Lisa (L1), Linda (L2), Matt (M1), Mitch (M2), plus the remaining unanalyzed fourth pair (K1 and K2). On the simple plant problem (Table 1), the children receiving the highest scores were Bruce and Lisa; on the combinations problem (Table 2), Bruce, Linda, and Mitch exhibited the most advanced/reasoning skills. Thus, the clear differences among dyads that were apparent on the videotapes of collaborative problem-solving sessions were not reflected in the posttest results.

In summary, when pairs were compared with singletons, the pairs solved the chemical combination problems at a much faster rate. However, the pairs did not do better than the singletons on all of the posttest measures. Singletons appeared to outperform the pairs on the simple plant problem, a test of a subject’s ability

<table>
<thead>
<tr>
<th>Subject Pair</th>
<th>Type of Procedural Activity (%)</th>
<th>Parallel</th>
<th>Associate</th>
<th>Cooperative</th>
</tr>
</thead>
<tbody>
<tr>
<td>George and Bruce</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Session 3</td>
<td>61</td>
<td>39</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Session 5</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Session 8</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Session 11</td>
<td>0</td>
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to isolate variables, whereas the pairs seemed to do better on the combinations problem.

When comparisons were made between the pairs, it was found that George and Bruce solved more chemical combination problems than did the other pairs. In addition, George and Bruce were the first pair to switch to an entirely cooperative interaction pattern and to use a combinatorial experimentation strategy. On some of these variables, that is, the degree of cooperation shown and the use of a combinatorial strategy, Lisa and Linda appeared to hold an intermediate position between the two pairs of boys. However, these fairly consistent differences in interactional style and problem-solving strategy use were not reflected in the posttest performance of these children. In general, George and Bruce did not exhibit consistently higher levels of reasoning on their individual posttests than did the other subjects.

**Discussion**

What can these results tell us about the hypothesis proposed by Perret-Clermont that peer interaction can induce cognitive conflict that, in turn, results in cognitive restructuring and growth? Forman did find an association between high levels of social coordination (cooperative procedural interactions) and the use of certain experimentation strategies (combinatorial strategies). However, she did not devise a measure of cognitive conflict for her study, and her findings thus cannot establish that social coordination results in cognitive conflict, which then affects problem-solving skills.

One reason why cognitive conflict was not assessed was that overt indices of conflict, that is, arguments, were relatively rare during the portion of the problem-solving session examined—the setting-up phase of the task during which experimentation strategies were most apparent. In this portion of the session, hypotheses concerning the experiments could be proposed but not tested. During most of the setting-up time, children were busy working, separately or together, on laying out and sharing task materials and on planning and choosing experiments. Among

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### Table 4. Experimentation Strategies Used in Chemical Problems 4–7

<table>
<thead>
<tr>
<th>Subject Pair</th>
<th>Random Combinations</th>
<th>Isolation-of-Variables Strategy</th>
<th>Systematic Combinational Strategy</th>
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the children who interacted at a cooperative level, a great deal of mutual support, encouragement, correction, and guidance was exchanged. For example, one child would select chemical combinations while the other checked for duplicates. Instead of conflicting points of view, one saw two people attempting to construct and implement a joint experimentation plan to be tested later on in the task.

Conflicting points of view were apparent later in the problem-solving session, when most or all of the results of the experiments were visible. At that time, one could observe children forming distinct and sometimes opposing conclusions about the problem solution. Just such a conflict occurred in problem-solving session 3 between George and Bruce: Here is a summary of their interaction taken from a videotape record.

In this session, chemical C alone was the solution to the chemical problem. The two boys set up and mixed the following set of experiments: B, C, BE, CD, CE, DE, BDE, CDF, DEF. In addition, they could examine the results of the two demonstration experiments: BCE, DEF. All the experiments containing chemical C turned purple, the rest remained clear.

After all the experiments were mixed, the experimenter asked both children, “What makes a difference in whether it turns purple?” Bruce initially concluded that the answer was C and E. George expressed his surprise that a single element, for example C, produced the desired color change. In response to the standard prompt from the experimenter, “Can you be sure it's C and E?” Bruce reexamined some experiments and found one that contained E (and not C) that did not change color. Bruce, however, did not conclude at this point that C was the only operative chemical. George then asked Bruce whether all the experiments containing C produced the desired color change. Bruce scanned each experiment containing C and announced that each did change color.

Based on the experimental evidence and some information remembered from previous sessions, George concluded that C was the solution to the problem. Bruce, however, contradicted George by asserting it was F. At this point, they both reexamined the experiments. Afterward, George still concluded it was C and Bruce concluded it was C and F.

The experimenter asked whether they could be sure of their answers. George replied that he was sure of C but not of F. Once again, the evidence was examined. This time, Bruce identified the experiment CDF as indicating that F was an operative chemical. George countered this argument by comparing it with experiment DEF that did not produce the desired reaction. Bruce responded that D and E were more powerful liquids than F and therefore prevented F from working. George then tried another approach by asking Bruce how he could tell it was F and not C that made the mixture CDF turn purple. Bruce replied by asking George how he could tell it wasn't both C and F that made CDF turn purple. George's concluding remark was an assertion that he just knew it was C alone.

This interchange shows the kinds of activities that conflicting solutions to the problem seemed to induce. The children returned repeatedly to the experimental evidence for supporting data. Because their conclusions differed, they were forced to acknowledge information that refuted their own inferences as well as data that
supported them. These data then had to be integrated into a convincing argument in support of their own point of view. Counterarguments to their partner’s position also had to be constructed. Bruce, in particular, was forced to revise his conclusions based on the evidence George brought to his attention. Despite his efforts, George was unable to convince Bruce to accept his conclusion. Unfortunately, they had not provided themselves with enough of the appropriate experimental evidence in session 3 to enable them to reach a consensus about the solution.

Collaboration on the chemical reaction task thus seems to involve two different types of social interactive processes. The first process, which occurs during the setting-up or planning stage of the task, involves either separate (parallel) working patterns or closely coordinated cooperative patterns. Cooperation during the setting-up stage consists of mutual guidance, encouragement, and support. Often during this phase of the task, complementary problem-solving roles are assumed.

Later on in the task, when experimental evidence is being examined, the second kind of interactive process occurs. At this time, each child seems to be reaching independent conclusions about the solution of the task that are based on all or only some of the available experimental evidence. After each child comes to a conclusion, he or she may find that his or her partner does not agree. In this circumstance, overt conflicting perspectives on the experimental evidence are expressed in the form of an argument. Arguments capable of producing a consensus seemed to be those that made use of appropriate supporting evidence.

It appears that Perret-Clermont’s notion that cognitive conflict is the mediator between peer interaction and cognitive reorganization can be tested best in contexts where overt manifestations of conflict are likely. These contexts seem to occur when children have access to a wealth of empirical evidence, when this evidence is capable of suggesting at least two distinct solutions to the problem, and when a consensual solution is solicited.

Perret-Clermont’s hypothesis about the importance of cognitive conflict comes from Piaget’s theory concerning the role of social factors in development. Most of the past research on the topic of peer collaboration has been based upon Piaget’s ideas. Piaget placed more importance on peer interaction than upon adult-child interaction, so it is not surprising that the bulk of research on collaboration has shared a Piagetian perspective.

In order to understand the limitations as well as the strengths of this perspective on collaboration, one needs to appreciate the role that peer interaction plays in Piaget’s theory. Piaget (1970) identified four factors that he believed are necessary for a theory of cognitive development: maturation, experience with the physical environment, social experiences, and equilibration or self-regulation. In addition, Piaget claimed that equilibration is the most fundamental of the four factors. Peer interaction, and social experiences in general, derive their importance from the influence they can exert on equilibration through the introduction of cognitive conflict. Perret-Clermont shares this view of development when she writes:
Of course, cognitive conflict of this kind does not create the forms of operations, but it brings about the disequilibriums which make cognitive elaboration necessary, and in this way cognitive conflict confers a special role on the social factor as one among other factors leading to mental growth. Social-cognitive conflict may be figuratively likened to the catalyst in a chemical reaction: it is not present at all in the final product, but it is nevertheless indispensible if the reaction is to take place. (Perret-Clermont, 1980, p. 178)

When Piaget looks at peer interaction, therefore, he looks for evidence of disequilibrium, that is, cognitive conflict. He is not interested in describing or explaining social interactional processes as a whole. Piaget’s theory is most helpful in explaining those situations where cognitive conflict is clearly and overtly expressed in external social behaviours, for example, arguments. However, in situations where overt conflict is not apparent and where mutual guidance and support are evident, his theory provides few clues concerning the role of social factors in development. Fortunately, Vygotsky’s writings on adult-child interaction offer insights into the intellectual value of these kinds of peer interactions.

To illustrate how Vygotsky’s ideas shed light on some of the processes involved in peer collaboration, we will discuss another set of observations of George and Bruce. One of the most puzzling findings from Forman’s study was the discrepancy between how a dyad functions as a unit and how the partners function separately. George and Bruce were clearly the most successful collaborators, yet they did not show the same consistently high level of functioning when they were posttested separately. This discrepancy between dyadic and individual performance levels was also apparent when subjects who collaborated were compared with those who worked alone. On the posttest measures, which were individually administered, collaborative problem solvers did not do better than solitary problem solvers. Nevertheless, collaborative partners were able to solve many more chemical problems than could solitary problem solvers during the same period of time.

Vygotsky acknowledged that a discrepancy might exist between solitary and social problem solving when he developed his notion of the zone of proximal development. He defined this zone as “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” (1978, p. 86). Thus, Vygotsky hypothesized that children would be able to solve problems with assistance from an adult or more capable peer before they could solve them alone. This seemingly obvious observation was then used to reach several original conclusions. One conclusion was that the zone of proximal development could be used to identify those skills most amenable to instruction. Another was that learning consists of the internalization of social interactional processes. According to Vygotsky, development proceeds when interpsychological regulation is transformed into intrapsychological regulation.

Returning to Forman’s data, it appears that a similar process of interpsychological to intrapsychological regulation may also occur in collaborative contexts where neither partner can be seen as objectively “more capable,” but where the
partners may assume separate but complementary social roles. One child may perform an observing, guiding, and correcting role while the other performs the task procedures. This observing partner seems to provide some of the same kinds of assistance that has been called scaffolding by Wood, Bruner, and Ross (1976). Such support from an observing partner seems to enable the two collaborators to solve problems together before they are capable of solving the same problems alone. When collaborators assume complementary roles, they begin to resemble the peer tutors described earlier. For example, the observer/performer roles are functionally similar to the critic/author roles observed in Egan’s New Hampshire classroom.

In addition, one can see in Forman’s data instances where problem-solving strategies first appear as social interactional procedures and are later internalized. Remember that a combinatorial problem was administered to each child individually at three different times (as a pretest, as an immediate posttest, and as a delayed posttest). In addition, these same children were presented with a similar combinatorial problem in each problem-solving session when they were asked to decide jointly which chemical mixtures to set up. Therefore, a comparison can be made between the combinations generated by each child when he or she worked alone or in pairs.

Both George and Bruce used an empirical strategy to generate combinations during their pretest—for example, selecting a combination at random and then basing the next combination on the first by adding, subtracting, or substituting one of its elements. The third combination would then be produced by copying, with another minor revision, the second combination. Pairwise checking of each new combination with each previous combination was the empirical procedure used for guarding against duplications.

In their early collaborative problem-solving sessions, George and Bruce worked in parallel and each used an empirical strategy similar to the one used on the pretest to generate combinations. After about a month of working together, they devised a social procedure for generating combinations empirically by assuming complementary problem-solving roles: one selected chemicals and the other checked their uniqueness.

After two months, they had begun to organize their combinations into groups based on their number of elements. In addition, they had devised a deductive system for generating two-element combinations. This deductive procedure enabled the child who had previously done the checking to prompt, correct, and reinforce the selections of his partner. Higher-order combinations were produced empirically using the familiar social procedure.

At the last session, the boys continued to assume complementary roles but now used the blackboard as a recording device. They produced combinations in a highly organized fashion—singles, two-element combinations, three-element combinations, and so on—and were able to generate almost all of the 31 possible combinations. They used a deductive procedure for generating the two-element combinations but still relied on their empirical procedure for the higher order combinations.

At the first posttest one week after the last collaborative session, the degree to which each boy had internalized a deductive combinatorial system was assessed by asking
them to generate combinations independently. Bruce was able to generate all 10 two-element combinations deductively on his own, but George was not. George used an empirical system to generate combinations. On the second posttest 4 months later, however, both boys had internalized a deductive procedure for producing two-element combinations.

It appears that these two boys were able to apply a preexisting intrapsychological rule, an empirical combinatorial procedure, to a collaborative context by dividing the procedure into complementary problem-solving roles. With repeated exposure to the problem, these boys were able to progress to a deductive procedure for generating simple, two-element combinations. At first, deductive reasoning was clearly a social activity for George and Bruce. Each time one partner selected a series of combinations, the other guided, prompted, and corrected his selections. Later, one partner was able to demonstrate that he had internalized this deductive procedure by using it to generate all possible two-element combinations on his own. Four months later, both partners were able to generate all possible pairs of five objects deductively by themselves. Thus, for these two boys, deductive combinatorial reasoning first appeared in a collaborative context. Only one of the two boys was initially able to show that he had internalized this procedure when he generated combinations alone. Months later, however, both boys had internalized this deductive process.

In summary, a Piagetian perspective on the role of social factors in development can be useful in understanding situations where overt indices of cognitive conflict are present. However, if one wants to understand the cognitive consequences of other social interactional contexts, Vygotsky’s ideas may be more helpful. In tasks where experimental evidence was being generated and where managerial skills were required, by assuming complementary problem-solving roles, peers could perform tasks together before they could perform them alone. The peer observer seemed to provide some of the same kinds of “scaffolding” assistance that others have attributed to the adult in teaching contexts.

Thus, the Vygotskian perspective enables us to see that collaborative tasks requiring data generation, planning, and management can provide another set of valuable experiences for children. In these tasks, a common set of assumptions, procedures, and information needs to be constructed. These tasks require children to integrate their conflicting task conceptions into a mutual plan. One way to achieve a shared task perspective is to assume complementary problem-solving roles. Then each child learns to use speech to guide the actions of her or his partner and, in turn, to be guided by the partner’s speech. Exposure to this form of social regulation can enable children to master difficult problems together before they are capable of solving them alone. More importantly, experience with social forms of regulation can provide children with just the tools they need to master problems on their own. It enables them to observe and reflect on the problem-solving process as a whole and to select those procedures that are the most effective. When they can apply this social understanding to themselves, they can then solve, independently, those tasks that they had previously been able to solve only with assistance.
Thus, collaborative problem solving seems to offer some of the same experiences for children that peer tutoring provides: the need to give verbal instructions to peers, the impetus for self-reflection encouraged by a visible audience, and the need to respond to peer questions and challenges. The reciprocal model of peer assistance that characterized the children in Egan’s classroom is even more apparent in collaborative problem-solving contexts, similar to those observed by Forman.

Conclusion

In conclusion, in these analyses we are not talking about a children’s culture separate from adults. What Leont’ev and Luria discuss as the “most important specifically human form of mental development”—namely, “the assimilation of general human experience in the teaching process”—must ultimately be grounded in adult–child interactions. But peer (and cross-age) relationships can function as intermediate transforming contexts between social and external adult–child interactions and the individual child’s inner speech.

Although such peer interactions take place in home and community as well as at school, they may be especially important in school because of limitations and rigidities characteristic of adult–child interactions in that institutional setting. Cazden (1983) argues for the value to child development of a category of parent–child interactions of which the peek-a-boo game and picture book reading are familiar examples. In interactions such as these, there is a predictable structure in which the mother initially enacts the entire script herself and then the child takes an increasingly active role, eventually speaking all the parts initially spoken by the mother. The contrast between such learning environments and the classroom is striking. In school lessons, teachers give directions and children nonverbally carry them out; teachers ask questions and children answer them, frequently with only a word or a phrase. Most importantly, these roles are not reversible, at least not within the context of teacher–child interactions. Children never give directions to teachers, and questions addressed to teachers are rare except for asking permission. The only context in which children can reverse interactional roles with the same intellectual content, giving directions as well as following them, and asking questions as well as answering them, is with their peers.

**QUESTIONS FOR REFLECTION**

1. Why does it make sense that Vygotsky’s perspectives for education would apply to a student peer group and not solely to one-on-one adult–child interactions?
2. What factors influence a student’s learning in the zone of proximal development?
3. How is a Vygotskian perspective useful in understanding the value of peer collaboration?
NOTES
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1 Other social interactional codes were used to identify conversations that served to plan, reflect upon, or organize these procedural activities (metaprocedural interactions), task-focused jokes (playful interactions), task-focused observations (shared observations), and off-task behavior.

2 A second set of posttests was administered to both samples 4 months after the first posttest. The pairs constantly outperformed the singletons on both second posttest measures. However, the interpretation of these findings is problematic due to the fact that this 4-month period occurred during the school year for the pairs but during the summer for the singletons.

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