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THE DEVELOPMENT OF FORMAL REASONING IN COLLABORATIVE
PROBLEM-SOLVING SITUATIONS

City University of New York

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by

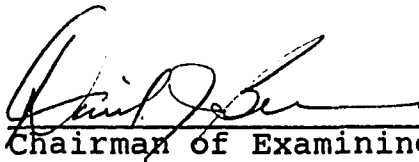
ROSE JEAROLMEN DIMANT

A dissertation submitted to the Graduate Faculty in
Educational Psychology in partial fulfillment of
the requirements for the degree of Doctor of
Philosophy, The City University of New York.

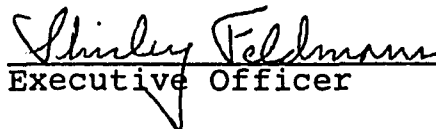
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Abstract

The Development of Formal Reasoning in Collaborative Problem-Solving Situations

by

Rose Jearolmen Dimant

Adviser: Professor David J. Bearison

Piaget has proposed that cognitive development proceeds from individuals' active and reciprocal engagement with their social and physical surroundings. The importance of social interaction results from the potential it creates for cognitive conflict by pressing individuals to recognize other viewpoints, to compare these with their own, and to coordinate different perspectives.

Previous studies have demonstrated that preoperational subjects who worked with peers achieved higher levels of reasoning than children who worked individually. This advantage has been observed during problem-solving sessions and on individually administered posttests. The purpose of this investigation was to assess the relationship between peer interaction and the attainment of formal operational reasoning strategies in college students.

A longitudinal research design employing formal reasoning tasks and a peer interaction measure provided the data for this study. The interaction measure, based on Piaget's equilibration model, consisted of five verbal categories which reflected socio-cognitive conflict.

Conflict was scored by identifying a disturbance speech act produced by one partner in a dyad and a resolution speech act produced by the other partner.

Subjects were 15 same-sex male and female dyads and 15 male and female individual control subjects. There were two dyadic conditions. The same level condition (n=8) consisted of partners, each of whom received a concrete operational score (level 0) on a combinatorial reasoning pretest assessment. The mixed dyadic condition (n=7) consisted of one concrete operational partner (level 0) and one transitional partner (level 2). All control subjects were concrete operational. Analyses of variance and t-tests were used to analyze the data.

The major findings indicated that mixed dyads solved significantly more problems during the longitudinal phase of the study than individual control subjects, but there were no significant differences on pre- to posttest measures. Mixed level dyads solved more problems than same level dyads, but did not achieve higher change scores. Amount of socio-cognitive conflict was positively and significantly related to solving more problems, and to greater pre- to posttest change scores.

Results were discussed in terms of socio-cognitive conflict being a more critical indicator of growth than subject condition alone. Educational implications of peer interaction and cognitive development were also discussed.

To my sons,
Kevin and Elliot

It is with great pleasure that I acknowledge those people who have contributed towards the completion of this doctoral dissertation.

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Jacob, for their years of support...and to Dorothy Strauss for her guidance and unfailing belief in me.

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Chapter I

Introduction

Recent research has demonstrated that young children and college students evidence significant positive change on measures of problem-solving tasks, after participating with peers, compared to control subjects working individually. Studies of conservation acquisition through peer interaction strategies have been reported by Silverman and Stone (1972), Silverman and Geiringer (1973), J. Murray (1974), Botvin and Murray (1975), Miller and Brownell (1975), Perret-Clermont (1980), and Ames (1980). Doise, Mugny, and Perret-Clermont (1975) and Bearison, Magzamen and Filardo (1984) have studied spatial perspective-taking in collaborative situations. Peer debate was found to be associated with higher levels of moral reasoning by Maitland and Goldman (1975) and Berkowitz, Gibbs, and Broughton (1980), with adolescents, and by Damon and Killen (1982) with younger children from kindergarten through third grade. Forman (1981), albeit with a very small sample, has shown that dyads progress faster than individuals in solving a series of formal reasoning level chemical tasks.

In order to study the relationship between social interaction and the acquisition of formal reasoning strategies in college students, the present study investigated the developmental process by identifying patterns of interactive behaviors thought to be associated with successful performance. Two definitions were used to

define success. One involved positive change between pretest and posttest administrations of a combinatorial reasoning task. The second definition of success was suggested by previous research demonstrating the difficulty of inducing formal operational reasoning abilities under single-exposure experimental conditions (e. g. Blasi & Hoeffel, 1974; Niemark, 1975, 1979). Subjects were given progressively more difficult problems to solve during the six week longitudinal phase of this study, and those mastering more advanced problems were considered more successful than subjects not able to show such progress.

The present study was based upon Piaget's cognitive developmental theory, which focused on the interaction between individual and environment. The basic assumption underlying this theory is that cognitive development proceeds from individuals' active and reciprocal engagement with their social and physical surroundings.

Egocentrism is the hallmark of earlier developmental forms, and is manifested by an embeddedness in one's own point of view. Information that is not consistent with expectations is either ignored or assimilated into existing schemes or structures. At the same time the child is highly susceptible to suggestion and imitates without correction. The equilibrations reached between assimilations and accommodations at these levels of development have very unstable boundaries, and new disturbances eventually lead to more advanced cognitive structures. These new structures, in

interaction with the environment, and more particularly the social environment, give rise to perspectivism. (Flavell, 1963; Piaget, 1950, 1977). According to Flavell, "It is social interaction which gives the ultimate coup de grâce to childish egocentrism" (1963, p. 157). Childhood forms of egocentrism eventually give way to different forms of egocentrism as more advanced cognitive levels are attained (Looft, 1972).

With increased abilities in perspective-taking, children become increasingly aware that other individuals have different thoughts, feelings (Shantz, 1976), and spatial perspectives (Piaget & Inhelder, 1956). They become increasingly better communicators as they learn to accommodate their messages to the needs of listeners (Bearison & Cassell, 1975; Piaget, 1959) and become more adept at engaging in transactive dialogues with other individuals, which leads to further cognitive development. According to Bearison, "Much of what we regard as the process of social cognitive development is the formation of mutually intentional relations with others" (in press, p. 3). In transactions, individuals engage in mutual, bi-directional relationships so that the intentions and actions of each will affect those of the other(s) (Berkowitz, 1980). It is through such transactions that disequilibrations and re-equilibrations may be revealed.

Socio-cognitive conflict models suggest that effective

social interactions generate disturbances, or perturbations, leading to disequilibria which can be resolved, or compensated (re-equilibrated), through the coordination of discrepant and unexpected information. This results in further cognitive development, as each new re-equilibration elaborates or improves previous structures (Kuhn, 1972; Piaget, 1977).

The value of social interaction stems from the potential that disturbances create for the occurrence of cognitive conflict by pressing individuals to recognize other viewpoints, to compare their own perspectives to those of others, and to coordinate disparate views. Social interaction is a necessary condition for the transition to more advanced developmental levels by enabling the individual to share other perspectives and to coordinate these with his or her own point of view (Piaget, 1932). According to Piaget, "...it is precisely by a constant interchange of thought with others that we are able to decentralise ourselves in this way, to co-ordinate internally relations deriving from different viewpoints" (1950, p. 164). Thus, the present study hypothesized that members of dyads would be more successful than individual control subjects, both while working together to solve a problem requiring formal operational reasoning strategies, and on individually administered posttests.

The major purpose of the present study was to explore the relationship between socio-cognitive conflict and

progressive change, based on Piaget's equilibration model (1977). Socio-cognitive conflict categories were used to operationally define the equilibration process.

Piaget maintained that the origins of intelligence stem from the individual's self-regulated interactions with objects in the environment, with thought being the interiorized and reversible coordinations of these actions (1971). These coordinations were said to be simultaneously individual and social constructions, so that the effects of one cannot be tested against the other. Accordingly, no statement was advanced regarding a cause and effect relationship between socio-cognitive conflict and cognitive gains.

The most extensive Genevan research on collaborative problem-solving (e.g. Doise et al., 1975; Perret-Clermont, 1980) has been concerned with only one stage in cognitive development, the beginning of concrete operations, although other investigators have focused on adolescents' and young adults' moral judgments (Maitland & Goldman, 1974; Berkowitz et al., 1980). In order to broaden the scope of research concerned with the processes of development, the present study included observations of college students solving problems requiring formal operational reasoning strategies. Based on his work with Genevan children, Piaget (Inhelder & Piaget, 1958) postulated that the development of formal reasoning occurred between the ages of 11 to 12 and 14 to 15.

After reviewing evidence from other cultures and less privileged social classes, he maintained that this development may occur more commonly between 15 and 20 years of age (1972).

The period during which formal operations are acquired appeared to have particular relevance for studying the role of peer interaction in collaborative paradigms. The development of hypothetico-deductive reasoning was said to enable individuals to consider possibilities and to solve problems on a level of abstraction rather than having to empirically work through each step of a problem (Inhelder & Piaget, 1958). Verbal discourse of such subjects provides an appropriate context for observing the conflicts and coordinations thought to occur in the dyadic problem-solving situation. Piaget (in Furth, 1969) remarked on the necessary, although not sufficient, role of language in the formation of operational structures. Regarding propositional operations, he said "It is hard to conceive how they would develop or, rather, how they would reach an advanced stage of development without the use of language" (p. 127). Piaget thought that language could influence the education of thinking and reasoning because of the possibility for the precorrection of errors that can occur between encoding and decoding. Language was seen as extending the equilibration process from the coordinations of actions in general to the coordinations of social actions.

Chapter II

Literature Review

Theoretical Orientation

Social learning theory. Two leading theories have attempted to account for the facilitating effects of social interaction on cognitive development. Social learning theorists accounted for cognitive development by individuals observing and imitating a model demonstrating problem solutions. For example, social learning theorists described learning of conservation as a form of rule acquisition. While recognizing that external and internal conflicts frequently occur during social learning encounters, conflict is not considered to be sufficient nor necessary for cognitive growth. More important, are clarity and consistency of modeled information (Zimmerman and Blom, (1983)).

The modeling effect appeared to be corroborated by Rosenthal and Zimmerman (1972), Zimmerman and Rosenthal (1972, 1974), Botvin and Murray (1975), J. P. Murray (1974), and Zimmerman and Lanaro (1974). However, several findings cannot be accounted for by social learning theory. First, Rosenthal and Zimmerman (1972) and Kuhn (1972) found that observing a model at a lower developmental level produced only weak effects. Social learning theories make no claims regarding the direction of cognitive change except that it is always in the direction consistent with the model's behavior.

This makes it difficult to explain these weak effects according to social learning accounts. Piaget, however, makes strong claims about the direction of cognitive change. Change is always towards more developed states of cognition. Second, previously nonconserving subjects studied by Doise, et al. (1975), Perret-Clermont (1980), and Weinstein and Bearison (in press) offered novel conservation explanations after working with conservers. Third, problem-solving with peers at either the same or lower levels of development has also been found to be beneficial (Perret-Clermont, 1980; Ames, 1980; Mugny and Doise, 1978). In Ames' (1980) report, having two nonconservers work together, each with opposing centrations, resulted in more cognitive gains than nonconserving subjects who were exposed to a child "model" offering nonconserving responses opposite to the subject's centration.

Piaget's equilibration theory. In The development of thought (1977) Piaget proposed an equilibration model that seems better able to account for those factors that cannot be explained by social learning theory, namely gains produced by being exposed to partners on the same or lower developmental levels, and for novel explanations. Piaget's model allows for cognitive change by a process that leads to reorganizing existing schemes or structures when the person is confronted with information that is discrepant with what he or she

expected. In order to create a perturbation in an equilibrated state, the information need not furnish solutions. The important factor for equilibration is the filling of a gap in an existing equilibrated structure. A gap is expressed by an awareness of an insufficiency in a scheme or structure that leaves requirements unfulfilled. Gaps are not always disturbing, but may become so. For example, an individual becomes aware that indispensable knowledge is lacking for solving a problem that he or she feels a need to solve. External perturbations (disturbances) do not create the form for reorganization, but rather set up conditions for self-regulation through experienced conflict created by awareness that information is not in accordance with expectations. After the system is reorganized, new gaps and disturbances appear as a result of coordinating new evidence into the system, and the cycle starts again.

Piaget described three types of behaviors or compensating reactions that result from disturbances: Alpha, beta, and gamma reactions. Alpha reactions either cancel disturbances by neglect or distort them to be assimilated into existing schemes. Beta behaviors consist of integrating the disturbance into the system (accommodation). Gamma behaviors consist of anticipating possible variations. When this occurs, disturbing characteristics are lost, and the variations become established in the potential transformation within the system. In The development of thought, Piaget

assumed each of these behaviors could occur during any period of development. It is difficult to conceive of gamma behavior during the sensori-motor period, since the child has not yet developed the permanent object. Additionally, alpha behaviors were said to reach very unstable forms of equilibrium, and these are found at the lowest levels of development. Prior to his 1977 discussion of compensating behaviors, Piaget's statements about these behaviors posited a developmental pattern for their occurrence (Moessinger, 1978).

It is important to note that cognitive equilibrations do not just return to balance, but they achieve momentary equilibria in more advanced forms. Cognitive equilibration never reaches an end point. Each sequence of equilibration contains gaps that lead to "nonbalance" of the system, followed by re-equilibrations that either elaborate or improve previous structures. Even the most stable forms of equilibration, that found at the level of formal operativity, is open to "increasing equilibrations." At this level, re-equilibration would result in further conceptual elaborations within the existing structure rather than leading to new operational structures.

Damon (1983) has criticized Piaget's most recent description of the equilibration model (1977) for its emphasis on the child's active manipulation of the physical world. He contends this resulted from findings and

conclusions about cognitive development being "...overwhelmingly derived from observations of children in solitary reflection, wrestling with intellectual problems as presented in psychologist-structured testing conditions" (pp. 14-15). Noting that Piaget's earlier writing (1932/1965) cited social cooperation and conflict as prime instigators of development, Damon suggested it was time to adopt a social-cognitive paradigm in order to connect what appears to be different visions of human development. Bearison (1982) found increasing signs that research paradigms have begun to shift focus from the study of intraindividual coordinations to interindividual coordinations in order to investigate the social development of knowledge.

Although Piaget's empirical studies of children engaged in social reasoning has been limited to the development of autonomous moral concepts (1932/1965) and the coordination of listener-speaker perspectives (1926/1974), he has consistently written about the importance of individuals interacting with others as an explanaton for cognitive growth. In The psychology of intelligence (1950/1976) he provided a model of peer interaction based on the reciprocal influences of social cooperation and operational thought. He noted that "without interchange of thought and co-operation with others" the child would never come to group operations into a structured whole. He remarked that on the one hand,

...operational grouping presupposes social life.
But, on the other hand actual exchanges of thought

obey a law of equilibrium which again could only be an operational grouping, since to cooperate is also to co-ordinate operations. The grouping is therefore a form of equilibrium of interindividual actions as well as of individual actions, and it thus retains its autonomy at the very core of social life (1950, pp. 136-164).

Piaget was interested in peer interaction because it could lead to social and cognitive conflict. Conflict is crucial for Piaget because it creates a disequilibrium or discrepancy between the individual's expectations of environmental events and the occurrence of these events. This is capable of producing structural changes (accommodation) in order to assimilate new information. Thus, disequilibrium and internal adjustments result in cognitive development.

Inhelder and Piaget (1958) continued to write about the importance of the social context. They discussed the tendency of adolescents to congregate in peer groups. The relevance of these social relations was considered not merely to exert pressures towards conformity, but to create a source of intellectual decentering. They claimed that in discussions between friends it was common for an individual to discover the fragility of his or her own reasoning when it had to be tested against the reasoning of others.

During the 1960's Piaget (1967; Piaget & Inhelder, 1969) continued to assert the necessity of social exchanges in affecting social perspective-taking, self-awareness, and logical development.

In a gathering of interpretations based on forty-five years of engaging in psychological experimentation, Piaget (1971) reiterated his belief in the isomorphism of the operations of intelligence and the operations making for cooperative exchanges between individuals. The "general coordination of actions" that he continually referred to can be both an interindividual and an intraindividual coordination. The question concerning whether logic and mathematics are individually or socially attained loses all meaning for Piaget. He claimed "The epistemological subject constructing them is both an individual, though decentered in relation to his private ego, and the sector of the social group decentered in relation to the constraining idols of the tribe" (1971, p. 306).

The following review of the literature will report empirical evidence of intraindividual conflict, interindividual conflict, and experiments that have included descriptive categories of interactive behavior as a means of providing information about the social context. Several researchers tried to understand more about the social context in which development occurs and have analyzed behaviors produced during social collaboration. Although the present investigation is concerned with the attainment of formal operational reasoning, only one report could be found in the literature detailing the development of formal reasoning within a peer interaction context (Forman, 1981). However,

studies of other developmental stages are relevant because we are primarily interested in the functional aspects of development. According to Piaget, functional aspects are invariant across all stages of development.

Individual Conflicts of Centration

Several researchers interested in demonstrating how disequilibrium could induce positive change were influenced by the predominant Geneva experimental paradigm of studying cognitive development by observing a child working alone in a laboratory setting. The methods involved creating intraindividual conflicts of centration by having two of the child's observations or measurements yield inconsistent results. Conflict induction was operationalized in various ways to demonstrate that preoperational children would be able to conserve after treatment exposure.

Smedslund (1961) induced conflict by showing preoperational subjects two equal objects and then simultaneously deforming one object and adding to, or subtracting from, the other object. For example, subjects who thought one ball was lighter after it was transformed into a sausage also observed that a piece was removed from the other ball. Subjects had to reach a decision regarding the relative size of the changes, and it was believed that conflict and uncertainty preceded the decision. Murray (1968) used a Muller-Lyer configuration to create conflict. Nonconserving experimental subjects were allowed to remove

two equal sticks from the distorting configuration, in order to reconfirm their equality, and then to replace them. They were then directed to switch the sticks in the configuration so that the stick which originally appeared shorter would appear longer, and vice versa. Bearison (1969) created conflict by inducing nonconservers to use a measurement technique that yielded quantitative information about liquid quantities that contradicted subjects' perceptually based information, and Murray, Ames and Botvin (1977) aroused conflict by having subjects temporarily adopt a position contrary to their own previous conservation or nonconservation statements. Nonconservers and transitional subjects made large and significant gains, compared to controls and between their own pre- and posttest scores. Two types of cognitive conflict were described by Inhelder, Sinclair, and Bovet (1974). Different subsystems, each developing at its own rate, can create conflicts since one subsystem may be more advanced than another. Reasoning may be at a level where the child is aware that experimental findings do not conform to expectations, and this may also lead to conflict.

Conflict Through Peer Interaction

There is evidence that intraindividual conflicts of centration can account for cognitive development in children. However, Doise has argued that "conflicts of cognitive centrations embedded in a social situation are a

more powerful factor in cognitive development than a conflict of individual centrations alone" (Doise and Mugny, 1979 p. 105, emphasis added). While many researchers have continued to adhere to the traditional Genevan experimental paradigm of testing children individually, there has been an increase in the number of studies where children have been observed in collective interactions. Perhaps, this interest in understanding the social development of knowledge was stimulated by the work of social learning theorists (Bandura, 1977; Rosenthal and Zimmerman, 1978), the contributions of Vygotsky and his followers (Vygotsky, 1962, 1978; Luria, 1976; Wertsch, 1979), dialectical methods (Riegel, 1976), and life-span developmental approaches (Baltes and Schaie, 1973; Neugarten, 1968; Riegel, 1973).

The most comprehensive empirical support for the efficacy of collaborative problem-solving has come from Doise and his associates in Geneva. In comparing the performance of individual children to those working in pairs, Doise et al. (1975) observed that children who worked together could successfully perform spatial coordination tasks, whereas children of the same age working alone were unable to so. On individually administered posttests, children in the collective condition had significantly higher posttest scores than subjects in the individual condition, thereby demonstrating that the skills acquired during social interaction were internalized. In another study (Perret-

Clermont, 1980) children who scored at nonconservation or intermediate levels on a conservation of quantity pretest, and who collaborated with conserving peers, were able to give conserving responses when posttested individually. Also, the majority of previously nonconserving or intermediate level children who advanced were able to offer conservation explanations which were different from those used in the pretest, and to which they were not exposed during the course of collective problem-solving. These results advance the case for cognitive restructuring to have occurred, instead of imitating arguments they heard from their conserving partners. This finding, regarding the use of novel explanations on posttests, was replicated by Weinstein and Bearison (in press).

Additional research by Doise and his colleagues further refutes the notion that progress is the result of imitating peers with superior knowledge, or that subjects paired with less advanced partners would regress. Collective performance of children working with a partner who was either more or less advanced was "structurally superior to those of the group members taken individually" (Mugny and Doise, 1978, p. 190). Progress was shown by both the less and more advanced subjects. The fact that more advanced partners also gained from the interaction with less advanced partners supports the hypothesis that progress is the result of coordinating different perspectives, rather than learning from a model.

Perret-Clermont (1980) demonstrated that social interaction is associated with gains as long as the concentrations of subject and others are different. It is not necessary for one partner to be at a more advanced developmental level in order for conflict to occur. Partners at the same level may have different perspectives capable of inducing new coordinations. Indeed, it is not even necessary for either child's initial strategy to be correct in order for progress to occur. Significant differences between experimental and control groups also illustrate that gains made between pre- and posttests were not due to maturation.

Social interaction was found to be related to constructive activity only when the subject had already attained a certain level of competence (Perret-Clermont, 1980). Thus, the gains produced by subjects exposed to collaborative conditions are not due solely to the social context. In a conservation of number experiment Perret-Clermont distinguished four levels of nonconservation responses and found that subjects most likely to progress were those who performed on a pretest at the two highest levels of non-conservation.

The research reported by Doise and his collaborators has generated important questions regarding the social processes associated with cognitive development. These studies have been instrumental in demonstrating the efficacy of peer problem-solving, but they have not fully addressed what is

occurring during social interaction to account for the development. Differences in strategies between partners and prior levels of competence appear to be necessary conditions, but they are not sufficient to explain why only some children progress given these conditions. It is necessary to observe and measure the processes by which peers interact, in order to determine the kinds of interpersonal strategies that are related to development, and to understand why gains are sustained by some groups of collaborators more than others.

The Nature of Peer Interactions

Bearison (1982) argued that using pretest scores to compare the effectiveness of particular dyadic combinations emphasizes organismic "readiness" without recognizing the dynamic aspects occurring in the interactive context:

Cognitive conflict does not occur as a singular perturbation that suddenly disrupts the cognitive equilibrium of the thinker in solitary reflection. Instead, it is a process which unfolds in tandem with a coordinated system of actions and representations that arise from different approaches (centrations) to a problem...it is simply more likely that the coordination of contrary centrations will occur in an interactive context than in a context of solitary reflections (p. 25).

The individual's developmental level (state of "readiness") is important for determining the kinds of social contexts that are apt to induce conflict and how the resultant coordinations will be structured. However, it is within the interactive context that ideas can be "represented, exchanged, confirmed, and contradicted" (Bearison, 1982, p. 9).

Developmental level and social context are equally important for establishing conflict and promoting cognitive growth.

Several investigators studied the social context in which development occurs by observing and measuring interactive strategies used by partners during peer problem-solving encounters. Based on Piaget's equilibration model (1967, 1971), which suggested that structures become more stable with development, Silverman and Geiringer (1973) and Miller and Brownell (1975) predicted that conservers would be more persuasive in convincing nonconservers to yield to their judgments when instructed to reach consensus in solving conservation problems. Interaction categories were developed in order to determine whether conservers and nonconservers, as well as "yielders" and "nonyielders" of the collaborative conservation judgments, differed in their usage of categories. These studies were not designed to assess the relationship between particular patterns of interaction and development. However, they did suggest discourse categories such as disagreements, explanations, and questions that could have developmental significance.

Silverman and Geiringer (1973) found no significant differences between conservers' and nonconservers', nor yielders' and nonyielders', use of interaction categories. Miller and Brownell (1975) did obtain differences for several interaction categories. More conservers than nonconservers repeated their pretest answers, offered explanations,

countered the other's explanation, and moved or suggested moving stimuli.

The results of both studies supported the equilibration model to the extent that significantly more conservers prevailed over nonconservers during the interaction. Silverman and Gieringer (1973) reported that fewer conservers yielded during the interaction and those who did so reverted to conservation responses at posttest one month later.

Miller and Brownell (1975) demonstrated that the superiority of conservers over nonconservers was not due to superior persuasive skills in general, but rather to their more stable conservation beliefs. They achieved this with the addition of two control questions to be resolved between partners: "What is the very best T. V. show?" and "What is the most dangerous animal in the world?" No differences were found between conservers and nonconservers yielding to these control questions.

Perrot-Clermont (1980) suggested that gains made by the nonconservers could be better explained by nonconservers' confrontation with different viewpoints, rather than by persuasion. She cited her own study to indicate that when conserving partners were dominant to the extent of being verbally aggressive, nonconservers did not benefit from the interaction.

In order to demonstrate that cognitive gains were due to conflict, and not exposure to correct conservation solutions,

Ames (1980) paired nonconservers with other nonconservers who maintained contrary preoperatory centrations. Subjects in this peer interaction condition achieved higher posttest conservation scores than subjects exposed to conflicting preoperatory information in role-playing, imitation, and control conditions. Spontaneous generation of conservation assertions occurred in the peer interaction condition, which was related to significantly higher posttest scores. Peer interaction categories, adapted from Miller and Brownell (1975), were analyzed. Ames found very few children disagreed with their partner's assertions or asked them to agree with their own assertions, although there was a tendency to agree with the other, sometimes accompanied by a reason.

In attempting to learn which interaction behaviors were critical in facilitating cognitive growth, Berkowitz, et al. (1980), Damon and Killen (1982), and Bearison, et al. (1984) looked for relationships between particular interaction patterns and posttest gains.

Berkowitz (1980) reported an initial study where undergraduates were instructed to reach consensus on solutions to several hypothetical moral reasoning problems. Disequilibrium, operationalized as the occurrence of confusions, contradictions, and inconsistencies in an interaction between partners, accounted for only four percent of all dialogic behaviors. Following this, Berkowitz, Gibbs

and Broughton (1980) identified behaviors that might predictably lead to disequilibrium instead of the direct expression of disequilibrium. Departing from earlier studies (e.g. Miller & Brownell, 1975) which focused on consecutive assertions between partners, they found that moral stage development was mediated by subjects' use of their own reasoning to confront "...the other's antithetical reasoning in an ongoing dialogic dynamic" (Berkowitz & Gibbs, 1983, p. 402). This facilitating discourse was termed transactive discussion.

Damon and Killen (1982) engaged five to nine year olds in actual social encounters which involved issues of distributive justice. Pre- to posttest change scores established that experimental peer debate subjects were more likely to advance in their moral reasoning than either control subjects who discussed similar justice problems with an adult, or who received only the pretest and posttest interviews.

Peer debates among triads were coded according to two systems. One focused on particular discourse features of distributive justice debates, and included requests for distributional solutions, agreements or disagreements, information, predictions, and explanations. The other system involved interactional qualities theoretically linked to developmental change in reasoning and included agreements, disagreements, compromises, and transforming partners'

statements.

Damon and Killen concluded that analysis of peer debate categories did not support socio-cognitive conflict as a mechanism for change. Children performing rejecting acts were disproportionately represented among those who did not gain. Lower-level children who advanced both accepted and transformed other's statements by extending, clarifying or compromising, and were also the recipients of such acts. Higher-level children who advanced were interacting in a different manner, but the findings did not indicate exactly what they were doing.

Bearison, et al. (1984) suggested that some prior studies might not have found significant relationships between socio-cognitive conflict and cognitive growth because linear relationships between variables were assumed. In their own study, they obtained a significant curvilinear relationship. Five to seven year old children were observed working on spatial perspective problems. Critical aspects of peer interaction were identified which distinguished between dyadic subjects who made significant cognitive gains and those who did not, as well as between dyadic subjects and individual control subjects. Measuring only disagreements, Bearison et al. found that only verbal disagreements which were accompanied by explanations predicted cognitive change. Disagreements without explanations did not result in change. Additionally, change was obtained only if disagreements with

explanations occurred within a medium frequency range. Dyads generating too many or too few conflicts did not do significantly better than control subjects.

Forman's (1981) study has particular relevance to the present study because of its longitudinal design and use of formal reasoning tasks. Socio-cognitive conflict was not measured directly, but qualitative reports of interactions were discussed in terms of socio-cognitive conflict and its relationship to the development of formal reasoning strategies. A model for the development of collaborative relationships based on Parten's (1932) and Sullivan's (1953) theories was proposed. From this model three different kinds of interactions were coded. The lowest level, parallel interactions, involved both subjects working on a problem independently with little or no monitoring of the partner's actions. The next level was associative interactions, during which some monitoring occurred, but subjects still worked independently. At the highest level Forman scored, cooperative interactions, subjects worked together in setting up the experiments. There was some planning of their joint activity, as well as constant monitoring and role differentiation. Both shared a conception of the planning process and task-focused goals.

Eight fourth graders who demonstrated predominantly concrete ability on pretest measures of combinatorial reasoning and isolation of variables worked in pairs once a

week, for 11 weeks, on a series of seven progressively more complex chemical combination problems. The initial problems in the sequence required an isolation of variables strategy for solution, and the more advanced problems required a combinatorial strategy. Four videotapes from each of three dyads were selected for interaction analysis. Two of the three dyads demonstrated the sequence of predicted behaviors: From parallel to associative to cooperative levels. The third pair remained at the parallel level. All three dyads were able to adopt an isolation of variables strategy necessary for the simple problems, but only the cooperative dyads were able to use the combinatorial strategy necessary for the more advanced problems. Pairs of Forman's subjects were compared to subjects in a study reported by Kuhn and Phelps (1982) who worked independently on the same problem series. Pairs mastered problems in the series at a faster rate than individuals, and also obtained higher pre- to posttest change scores in combinatorial reasoning, but not in the ability to isolate variables.

One pair mastered more problems in the series than the other two, and also adopted a combinatorial reasoning strategy three sessions earlier than the next pair to adopt this strategy. In examining the problem-solving performance of this dyad, Forman concluded that they appeared to use their ability to interact cooperatively as a tool in the development of deductive combinatorial strategies. She

suggested that the success of a collaborative relationship depended upon three factors. First, the personality of the partners appeared to be important. A shared sense of self-confidence and an appreciation for the partner's ability appeared to be related to successful interacting. These characteristics allowed partners to engage in heated debates without capitulating too prematurely while defending their own points of view. Because of their mutual respect, each was able to concede when faced with clear disconfirming evidence. The second factor for success seemed to be the ability of each partner to regulate the actions of the other; to assume complementary roles. Kuhn and Phelps (1982) hypothesized two skills necessary for task mastery: The ability to plan and the ability to reflect upon one's actions. As Forman pointed out, the collaborative situation could encourage planning because cooperative interactions do not take place without recognition of role and procedural assignments. By assuming complementary roles, each subject could reflect upon, guide, and modify the partner's actions. The third factor associated with successful performance was conflicts of opinion. Each subject developed an awareness of the partner's need to be provided with clear evidence of his own position in order for inferences to be accepted. Forman hypothesized that social conflict situations provide children with the necessary experience to abandon more quickly the two invalid strategies described by Kuhn and Phelps as being

impediments to mastery: False inclusion and ignoring disconfirming evidence. Piaget (1977) discussed the difficulties of abandoning disconfirming evidence:

...the mind spontaneously concentrates on the affirmations and positive characteristics of the objects, actions, or even operations, the negations are neglected or are constructed only secondarily and laboriously. Since they are required for every form of equilibrium...they are achieved only after multiple difficulties and their elaboration requires long periods of time (p. 15).

In sum, Forman's exploratory study demonstrated the feasibility of observing the development of formal reasoning strategies within a developing peer relationship. She also provided anecdotal data linking successful performance with particular aspects of the social context.

Conclusions

A review of the literature provided evidence that intraindividual conflicts of centration were related to cognitive development. It was also demonstrated that peer problem-solving was associated with development in both social and impersonal cognitive domains, and across various stages of development. In assessing empirical evidence seeking to identify actual behaviors during collaboration, an examination of interaction categories found that researchers have been seeking instances of agreement, disagreement, explanation, and the coordination of viewpoints. By extending Piaget's (1977) intraindividual equilibration model into the social context, these categories may serve as

operational definitions for socio-cognitive equilibration. Awareness of another individual's point of view, when it differs from one's own, is a disturbance that could lead to compensation within the system. This could take the form of either accepting the discrepant information, or trying to change the partner's view by disagreeing or explaining. Coordination of different points of view theoretically leads to higher levels of equilibrium.

When socio-cognitive conflict has been defined as a rejecting or disagreeing style, inconsistent results have been obtained between socio-cognitive conflict and progressive change. Damon and Killen (1982) reported that conflicting styles were inversely associated with growth, while Forman (1981) noted the ability to offer and receive disconfirming (conflicting) evidence is important for the development of formal reasoning strategies. Bearison et al. (1984) obtained a curvilinear relationship between disagreements accompanied by explanations and gains.

In the present study socio-cognitive conflict was reconceptualized in order to explore these inconsistencies. The most obvious difference between intraindividual conflict and socio-cognitive conflict is the presence of at least two individuals. Thus, socio-cognitive conflict was conceptualized as part of a re-equilibration process requiring a disturbance produced by one individual and a resolution produced by the other. Interindividual

disturbances can lead to socio-cognitive conflict, which in turn leads to resolutions. Resolutions during peer interactions are similar to intraindividual compensations. Compensations reduce obstacles created by disturbances for reaching a goal (Piaget, 1977, p. 81). Resolutions were defined as either agreeing with, or ignoring disturbances. Consecutive disturbances, without a resolution, would only serve to maintain the disequilibrium caused by the first disturbance. Development occurs with re-equilibration (resolution).

Disturbances were operationalized to include more than disagreements, or a combative stance. Piaget maintained that reorganization of existing structures can begin when an individual is confronted with discrepant or unexpected knowledge, or other points of view (1977). He emphasized that this took place within a cooperative context (1932/1965). Categories of questions and explanations were included as disturbances because they embody the recognition that collaboration raises the possibility of differing perspectives. Through questioning, partners are able to monitor whether or not the other person agrees or disagrees with them. Explanations may serve to make one's own reasoning, or point of view, understandable to another in an effort to negate or forestall a disagreement. Explanations were categorized as disturbances, rather than resolutions, because it remained to be demonstrated whether the recipient

of the explanation agreed or disagreed with it.

The bipartite coding system of the present study eliminated the opposition between agreements and disagreements that some other studies (e.g. Damon & Killen, 1982) have maintained. Socio-cognitive conflict was conceptualized as a dynamic re-equilibration process that incorporated both agreements and disagreements.

A Method for Studying Formal Reasoning in a Social Context

The present study employed tasks that required formal operational reasoning strategies for problem solution. A brief review of this developmental stage, and a method for studying it, is presented below.

In The growth of logical thinking from childhood to adolescence (1958), Inhelder and Piaget proposed that the fourth, and final, stage of cognitive development involved formal as well as concrete operations. A fundamental difference between concrete and formal reasoning is the subordination of the real to the possible. Reasoning about reality consists of grouping operations, which are internalized actions. Formal thought, however, consists of operating on these operations, with implications arising from propositions. Related to this, is the ability to generate and test hypotheses. Two strategies were considered to be manifestations of formal structure. The first involved the ability to focus on a single variable while holding all other variables constant, thus allowing one to identify the

causative factor in a multivariate context. Experimental isolation of variables by a subject toward the end of the concrete operational period was said to lead to combinatorial reasoning. The ability to reason in terms of all possible combinations of the proposition if p then q , which characterizes the "structured whole," constituted the second strategy found at this stage. Attainment of this ability to logically construct all possible combinations frees the child from the constraints imposed by the concrete here-and-now.

Inhelder and Piaget presented protocols from children's attempts to solve 15 problems said to demonstrate various aspects of formal structure. Other researchers reported different populations demonstrating very low levels, or the complete absence, of the ability to perform tasks theoretically requiring formal structure. These groups include members of other cultures (Dasen, 1972; Luria 1976), the less educated (Goodnow, 1962; Goodnow & Bethon, 1966), the aged (Hooper & Sheehan, 1977, Clayton & Overton, 1973; Sinnott, 1975), as well as a large proportion of normal adolescents and adults in Western populations (Jackson, 1963, Kuhn et al., 1977). However, Kuhn and Phelps (1979, 1982) described a longitudinal method for observing the development of formal reasoning strategies. They found that repeated exposure to problems requiring isolation of variables and combinatorial reasoning for solution enabled subjects to develop formal operational reasoning skills.

They designed a series of problems that required subjects to experiment with various chemicals in order to see what chemical, or combination of chemicals, was responsible for turning a colorless liquid red. Each succeeding problem in the series was more complex than the preceding problem. When one problem type was mastered, a more complex problem was presented at the next session. While initial problems required only an isolation of variables strategy, later problems required combinatorial reasoning for solution.

The methodology described above had clear implications for the present study, which placed it within a peer interaction context. The task, involving isolation of variables and combinatorial reasoning, was suitable for college subjects. The longitudinal design allowed time for development to occur. Bearison (1982) remarked that cognitive conflict is a process, and not something that occurs as a single disturbance. Forman (1981) demonstrated that attainment of formal reasoning strategies was associated with the development of social relationships. Thus, subjects need time and experience working together to develop interactions that are most advantageous for successful problem solution.

Chapter III

Statement of the Problem

The major purpose of the present study was to observe social interactions that are theoretically linked to cognitive development, in order to understand how knowledge is acquired within a social context. Previous empirical evidence has not consistently linked development to specific interaction patterns that could be used to operationally define the theoretical construct of equilibration. There has been evidence of conflict associated with cognitive gains in some studies (e.g. Bearison et al., 1984), while others have found "coordination of partners' centrations" and "agreement" to be associated with growth (e.g. Damon & Killen, 1982). In order for equilibrations to progress, it is necessary to have conflict, as well as agreement and coordinations. Disturbances have the potential to create conflicts, and conflicts need to be compensated (resolved) for development to proceed (Piaget, 1977). Agreements and coordinations may serve to resolve conflicts. The present study included a peer interaction coding system that defined socio-cognitive conflict as a process which included both a disturbance and a resolution. Social interaction categories were derived from previous studies, a pilot study with three dyads, and Piaget's equilibration model (1932, 1977).

The second purpose of the present study was to determine whether social interaction facilitated the performance of

dyads, and whether such gains can be demonstrated on individually administered posttests. Pretests which assessed isolation of variables and combinatorial reasoning strategies were readministered after all subjects encountered a series of problems requiring formal reasoning strategies for effective solution.

A third purpose of the present study was to determine whether pairs of subjects who attained different cognitive level scores on a combinatorial reasoning pretest (mixed-level dyads), or pairs of subjects at the same developmental level (concrete dyads), were more successful.

Prior studies concerned with social interaction and cognitive development generally focused on preoperational children. Only one study was concerned with social interaction and formal reasoning (Forman, 1981). In that study, Forman observed eight preadolescents ranging in age from 8.10 to 9.8. The present investigation was conducted with freshmen and sophomore college students. Subjects who collaborated on problem-solving tasks, calling for formal operational reasoning, were compared to subjects who worked alone. Tasks were presented to all subjects once a week for six weeks. This longitudinal design maximized the likelihood of identifying patterns of interaction that are theoretically linked to cognitive growth because experimental subjects had the opportunity to interact on six separate occasions.

In order to test the hypotheses described below, three

conditions were formed. There were two experimental conditions where subjects worked with partners, and one control condition where subjects worked individually. Subjects were randomly assigned to conditions based on scoring criteria obtained with the combinatorial reasoning pretest screening task described below. One dyadic condition consisted of eight pairs of concrete operational subjects (level 0), and the other dyadic condition consisted of eight mixed-level pairs of one concrete operational subject and one transitional (level 2) subject. The control condition consisted of 15 concrete operational subjects who worked individually.

The following hypotheses were tested:

1. Experimental subjects (i.e. subjects working collectively) will have greater pre- to posttest change scores than control subjects (individuals).
2. Experimental subjects in mixed-level dyads (i.e. concrete level subjects with pretest scores of 0 paired with transitional level subjects with pretest scores of 2) will have greater pre-to posttest change scores than experimental subjects in concrete level dyads (i.e. concrete level subjects with pretest scores of 0 paired with other concrete level subjects).
3. Subjects in dyads who master more advanced problems from the task sequence will have greater pre-to

posttest change scores than subjects in dyads who master less advanced problems.

4. Concrete operational subjects (level 0) in dyads generating higher levels of socio-cognitive conflict will have greater pre-to posttest change scores than concrete operational subjects in dyads generating lower levels of conflict.
5. Experimental subjects working in dyads will master significantly more advanced problems in the task sequence than individual subjects (controls).
6. Within the experimental conditions, subjects working in mixed-level dyads will master more advanced problems in the task sequence than subjects in same-level dyads.
7. Dyads mastering more advanced chemical problems from the five task problem sequence will evidence significantly more socio-cognitive conflict than dyads who do not show as much progress through the task sequence.

The above hypotheses will be tested using analyses of variance.

Different combinations of conflict types were identified to operationally define socio-cognitive conflict. Although no hypotheses were advanced regarding the expected prevalence of particular types of conflicts, exploratory analyses sought to determine if some types were more indicative of success.

In addition, other exploratory analyses determined whether the amount of socio-cognitive conflict changed over the six week experimental phase.

Chapter IV

Method

General Procedure

Subjects were screened for possible inclusion in the study by administration of the candy combinations problem, described below. Those selected for the study received an additional pretest. These two problems were used to determine subjects' cognitive strategies. Subjects who obtained concrete operational scores (level 0) on the candy combinations problem were randomly placed within experimental and control conditions. Transitional subjects (level 2) were assigned to the mixed level dyadic condition. Subjects who scored at levels other than concrete operational or transitional were excused from the study. The two experimental conditions included eight dyads whose members both received scores defined as concrete operational (level 0) on the candy combinations problem, and eight mixed level dyads containing one concrete operational partner (level 0) and one transitional partner (level 2). The control condition included 15 subjects who worked individually on the chemicals task sequence. They each received scores at the concrete operational level.

One week after receiving the two pretests, all subjects selected for the study were presented with the first problem from a series of five chemical problem-solving tasks. Each type of problem required subjects to identify the chemical or

chemicals responsible for a colorless, odorless liquid to turn red or orange. Each problem in the series was increasingly more difficult than the previous one. Subjects continued to receive the same type of problem each week until they mastered that problem type, and then they received the next problem in the series. They continued to receive one problem per week for a total of six problem-solving sessions. The two pretests were readministered one week after the last chemical problem-solving session, and were used as the posttest measures.

Subjects

Students in several English classes at a community college in New York City volunteered to participate in this study. The candy combinations problem, described below, was administered to 91 students. Forty-seven subjects who attained scores at the concrete or transitional levels were included in the study and took an additional pretest, described below. The final sample consisted of 17 male and 30 female freshmen and sophomores. Concrete level subjects were randomly assigned to either experimental or control conditions. Transitional subjects were assigned to the mixed-level dyadic experimental condition. There were two experimental conditions. One contained eight dyads whose members both scored at the concrete operational level. The other experimental condition consisted of eight dyads, where

one partner scored at the concrete operational level and the other scored at the transitional level. The control condition consisted of 15 concrete operational subjects who worked alone during the six week chemicals task phase of the study.

Pretest Measures

Candy combinations problem. This measure was selected to assess combinatorial reasoning ability, and was adapted from Kuhn and Ho (1980) and originally formulated by Barratt (1975). The problem tested the same concept that Inhelder and Piaget (1958) identified as an index of children's ability to engage in formal operational reasoning. The problem was to discover all possible combinations of five elements without replication.

Subjects were shown five jars of different types of candy and a stack of paper plates. They were told the following:

At a party there were five jars, each containing a different type of candy. The first contained lifesavers; the second, hard candy mints; the third, licorice pieces; the fourth, jelly beans; and the fifth, lollipops. Each person at the party took a plate of candy. Nobody took more than one type of candy, and each plate looked different. I would like you to arrange as many plates as you wish, in order to show what each guest ate. Remember, nobody had more than one of the same type of candy, and nobody's plate looked exactly the same as anybody else's plate.

Scoring The following levels were operationally defined according to procedures obtained from Forman (1981).

Level 0 - late concrete operational: The subject produces a series of combinations, where there is no discernible order or systematization in the series.

Level 1 - emergent formal operational: The subject exhibits some systematic combination, but procedures are predomently unsystematic. The minimum criterion for "systematic" combination is operationally defined as the consecutive combination of one element with all possible others, for example $1 + 2$, $1 + 3$, $1 + 4$, $1 + 5$. Subjects producing more than one such "two-way chain," for example the above series and in addition the series $2 + 1$, $2 + 3$, $2 + 4$, $2 + 5$, are scored at a higher stage.

Level 2 - transitional: The subject produces more than one two-way chain but falls short of generating all of the 10 possible two-way combinations, or produces at least one two-way chain and in addition produces at least one three-way chain. A three-way chain consists of all possible combinations of three candy types where two of the three are held constant, for example $1 + 2 + 5$, $1 + 3 + 5$, $1 + 4 + 5$.

Level 3 - early formal operational: The subject systematically produces all 10 combinations of two candy types. Systematic versus chance production of the 10 combinations is differentiated by employing the following criterion: to be scored as systematic, the 10 critical combinations must occur within a sequence consisting of no more than 12 combinations in total. The subject at this

stage may or may not produce any three-way combinations or chains.

Level 4 - consolidated formal operational: The subject systematically produces all 10 two-way and all 10 three-way combinations. In addition, production of the five possible four-way combinations and the one possible five-way combination may occur.

Forman (1981) reported interrater reliability to be .88 for the candy combinations task.

Simple plant problem. This measure was selected to assess subjects' isolation-of-variables strategy, and was adopted from Kuhn and Brannock (1977). The subject had to isolate the single effective variable from a multifactor situation in order to determine whether the experimenter's new plant would be sick or healthy. The problem assessed the same concept, isolation-of-variables strategy, described by Inhelder and Piaget (1958) as being necessary to solve their pendulum task. This ability was necessary for mastering the first two problems of the chemical problem-solving series.

Subjects were shown a table containing four artificial plants, two of which looked quite healthy and two in obviously poor condition. A large or small glass of water and a dish containing either dark or light-colored plant food was adjacent to each plant. A bottle marked "leaf lotion" was next to two of the plants. The following instructions were read:

I've been raising some plants. I would like to show them to you and ask what you think. Let's look at this plant first. It seems quite healthy, doesn't it? Every week I gave this plant a large glass of water (experimenter points to glass) and some of this light colored plant food (indicates). Now look at this plant. It doesn't look so healthy, does it? Every week I gave this plant a large glass of water (indicates), some of this dark-colored plant food (indicates), and a little of the leaf lotion in this bottle. (Plants 3 and 4 are similarly described. Plant 3, healthy - small glass of water, light food, and leaf lotion. Plant 4, poor condition - small glass of water and dark food). Now I have another plant like this at home that I've just started working on. I'm giving my plant at home a small glass of water each week (points to another small glass of water on an adjacent table), some of the light-colored plant food (indicates dish adjacent to water), and I'm not giving it any leaf lotion.

Subjects were asked:

1. How do you think my plant at home is going to turn out?
2. How do you know?
3. Does the leaf lotion have anything to do with how the plant turns out?
4. How do you know?

The problem is constructed so that one variable (plant food) is operative in influencing the plant's health and the other two variables are not effective.

Scoring. The following levels were distinguished by Kuhn and Brannock (1977):

Level 0 - concrete operational: No concept of variable isolation. Type A - no relevant answers to questions. Type B - reasoning on arbitrary or irrelevant grounds. Type C -

reasoning from personal knowledge or intuition. Type D - reasoning on the basis of multiple variables.

Level 1 - emergent formal operational: Some concept of isolation of variables although correct variable is not isolated. Type A - elimination of one variable (through assertion only), but failure to unconfound other two. Type B - assertion of one single incorrect variable as operative variable.

Level 2 - transitional: Isolation of operative variable. Failure to logically exclude alternative variables. Type A - reaffirmation of the operative variable. Type B - appeal to personal knowledge or intuition. Type C - exclusion on irrelevant or arbitrary grounds. Type D - teleological conception of all variables as operative. Inability to conceive of any variable as inoperative. Type E - false inclusion. Type F - utilization of a set of nonconclusive instances as proof.

Level 3 - transitional: Failure to isolate the operative variable (in response to first question), combined with logical exclusion of an inoperative variable (see Level 4).

Level 4 - formal operational: Isolation of operative variable and logical exclusion of inoperative variables. Type A - observation that a single level of the inoperative variable yields different outcomes. Type B - observation that different levels of the inoperative variable yield the

same outcome. Type C - the combination of Type A and Type B reasoning.

Kuhn and Brannock reported interrater reliability to be .93 for the simple plant problem.

Experimental Conditions

The present study included two experimental conditions. One consisted of eight dyads who were at the level of concrete operational reasoning (level 0) on the candy combinations pretest. The other condition consisted of eight dyads where one subject was concrete operational (level 0) and the other was transitional (level 2). Each dyad participated in a total of six problem-solving sessions, one per week. Problems were selected from a series adapted by Kuhn and Ho (1980) based on the Inhelder and Piaget (1958) chemicals problem. There were five different problems in the series, each becoming increasingly more difficult. Table 1 lists the effective combination for solving each problem, and the experimenter's demonstration. When one problem was mastered, the next one in the series was presented the following week. Sessions were conducted at the college. Each pair worked in a separate room, and all sessions were videotaped.

Materials. The workroom contained a large table. Materials on the table included: A large supply of small clear plastic containers with covers labelled B, C, D, E, or

Table 1

Chemical Problem Series

| <u>Effective combination</u> | <u>Experimenter's Demonstration</u> |
|------------------------------|-------------------------------------|
| Problem 1: B alone | B + C + D.....reaction |
| | D + E + F.....no reaction |
| Problem 2: B or C or D | B + D + E + F.....reaction |
| | C + F.....reaction |
| Problem 3: B + C + D | B + C + D + E.....reaction |
| | E + F.....no reaction |
| Problem 4: B or C without D | B + E.....reaction |
| | B + C + D + F.....no reaction |
| Problem 5: B + C without E | B + C + D.....reaction |
| | B + E + F.....no reaction |

Note. Adapted from "Self-Directed Activity and Cognitive Development" by D. Kuhn and V. Ho, Journal of Applied Developmental Psychology, 1980, 1 (2).

F, and each containing one of five colorless, odorless liquids; a large number of clear plastic cups; containers of mixing liquids labelled A; and aluminum trays. Each experiment set up by the subjects was placed in a separate tray. After setting-up, each tray contained one to five small plastic labelled chemical containers and the plastic cup where the chemicals were combined with the "mixing liquid." A blackboard and chalk were in the room, but not brought to the subjects' attention. However, they were permitted to use them for recording experiments, if requested.

Procedure. Subjects were seated side-by-side in front of the table containing the chemicals and other materials. The experimenter performed a demonstration of the chemical reaction. In the initial problem, one liquid combined with the "mixing liquid" is sufficient to cause a color change. The experimenter selected three small chemical containers labelled B, C, D, and emptied their contents into a small plastic cup. Three other containers labelled D, E, F were poured into another cup. "Mixing liquid" was then added to both cups, and subjects observed that one mixture turned red and the other remained clear. After ascertaining that the results were observed, subjects were asked:

1. What do you think makes a difference in whether it turns red or not?
2. How do you know?

3. Can you be sure what makes a difference? Why? Why not?
4. If subjects mentioned that only some chemicals were operative, they were asked: Do the other chemicals have anything to do with it? Which ones? How do you know?

The experimenter then invited subjects to set up their own experiments by stating the following:

As you see on the table in front of you, there are many narrow covered containers labelled B, C, D, E, and F. Each one labelled B contains the same liquid, each one labelled C contains the same liquid, and so on. You also have containers of "mixing liquids" labelled A. You observed that by adding the "mixing liquid" we could get a colorless liquid to turn red. Are there any other ways of doing it that you would like to try in order to be sure what makes the liquid turn red? For each experiment you try, the "mixing liquid" must be added last. I would like you to work together on setting-up as many experiments as you would like to try. Let me know when you are finished setting-up. Don't do any mixing at this time. I will ask you some questions, and then you may proceed to mix at that time. It is important to remember to add the "mixing liquid" only after the other chemicals have been poured into the cup.

The experimenter then moved away from the table where subjects were working, but remained in the room while occupied with some work of her own. She answered questions briefly, but not those that pertained to problem solution or strategy. After subjects had set up as many experiments as they wished, they were asked:

5. What do you think you will find out trying it these ways?

6. How do you think it's going to turn out? Why?

After answering these questions, subjects were informed that they may begin mixing the chemicals of the experiments they set up. They were reminded to add the "mixing liquid" only after the other chemicals had been poured into the cup. They were also asked to keep the empty chemical containers on each individual tray containing the cup where the chemicals were mixed for each experiment they tried. The experimenter returned to another part of the room as the subjects began mixing. When they completed all experiments, they were asked:

7. What do you think about how its turned out?

8. What did you find out?

Questions one through four were repeated.

Both partners had to agree on their answers to questions one through four. If they did not, the experimenter said: "Since you are both working on this problem together, I would like you to agree on one answer. Please see if you can agree on one answer for the two of you." If both members of the pair continued to be unable to state the operative or inoperative chemicals, or if there was no agreement and one member was unable to state the operative or inoperative variables, the same problem type was repeated at the next session.

When subjects were able to isolate the effective chemical or combination of chemicals and could agree that the

others did not play a part in the reaction, they were given the next problem in the series at the following session.

At the beginning of subsequent sessions, subjects were informed that the liquids within the containers were not necessarily the same as in the previous session and, therefore, the results may not be the same. Subjects' performance was the only determining factor affecting rate of progress through the problem sequence. The effective chemical or chemicals were varied if repeated presentations of the same problem type was required.

Posttests. The two pretest measures were readministered to each subject one week after the last chemical problem session.

Control Condition

There were 15 subjects in the control condition who scored at the concrete level of the candy combinations pretest. All procedures, materials, and posttests were the same as those described in the experimental condition, except that subjects worked individually in the control condition.

Coding of Videotaped Peer Interactive Behaviors

Each dyad met for six sessions, one per week, for six consecutive weeks. Sessions two through six of the experimental conditions were videotaped, and typewritten transcripts were made of discussions between dyadic partners.

Transcriptions were coded beginning with the conclusion of the experimenter's instructions and terminating with subject's responses to the four questions at the end of the session. Speech acts (see peer interaction codes, I) were coded as either conflict or nonconflict. Conflict speech acts were defined according to criteria defined below (peer interaction codes, II). Nonconflict referred to any two contiguous speech acts that were not identified as conflict. Nonconflict speech acts were coded in order to determine whether more talk in general was associated with performance gains, or whether only the discourse style identified as conflict was associated with gains.

Speech acts directed to one's partner were coded, while those directed to, or by, the experimenter were not.

Peer Interaction Codes

I. Speech acts. The codable unit began with a speech act that one member of the dyad directed towards his or her partner, and ended when the partner responded with another speech act or ignored what was said. If there was no overt response, or if the response did not relate to the partner's speech act, this was coded as "ignore." Speech acts varied from one word to many sentences, but conveyed only one informational component, such as a disagreement, question, suggestion, etc. Codable units were identified as conflict, described below, or nonconflict.

II. Conflict. Conflict referred only to task-relevant

speech acts between two members of a dyad. Each conflict was composed of a disturbance and a resolution, one made by each member of a dyad. There were three types of initial disturbances and two types of final resolutions. Following an initial disturbance, peer interaction often resulted in several contiguous speech acts between individuals before reaching a final resolution. These intervening speech acts were termed "chains of disturbing resolutions." They occurred between an initial disturbance and a final resolution. For scoring purposes, each of these intervening speech acts was considered both a resolution for the preceding speech act and a disturbance for the speech act which followed it. Within a chain, two contiguous speech acts were scored as one conflict. The three initial disturbances, two final resolutions, and the intervening chains created a potential combination of 42 different types of conflict. However, two of the 42 combinations were untenable in practice, thus yielding 40 types of conflict. Examples of conflict codes are included with the code definitions which follow, and in Appendix A. Speech acts may sometimes require difficult interpretive coding judgments. Appendix B includes some samples of transcripts containing speech acts which were difficult to code, and a discussion of how coding judgments were made.

A. Initial Disturbances. Initial disturbances were speech acts that either opened the conversation between

partners, speech acts that followed the resolution of a previous disturbance, or speech acts that followed nonconflicts. Disturbances expressed differences between the opinions or strategies of two dyad members. There were three kinds of initial disturbances that were operationally defined in the following manner:

1. Initial Disagreement. A speech act, without an explanation, which indicated that one partner did not agree with the other's preceding comment. This may take the form of a negative criticism, identified as a disparaging remark, which indicated one partner disagreed with the other.

Example:

"Now, you mix all the twos."

"You have to do some also."
(Initial disagreement)

2. Initial Explanation. A speech act which expressed one's reasoning, or attempted to make something understandable, but not a response to a disturbance. Initial explanations could include a disagreement, or might not include a disagreement. Initial explanations were viewed as efforts to seek agreement and forestall disagreements.

Example:

"We should try each alone because if we just do like twos, we can't be sure it's not just one alone that turns."
(Initial explanation)

3. Initial Question. An inquiry in which one partner determined whether the other partner was in agreement about an opinion or strategy. This category was not identified as a disturbance if one partner was merely seeking an idea (e.g. "What should we do next?").

Example:

"I'm thinking we need combinations,
too. You think so?"
(Initial question)

B. Final Resolutions. Final resolutions were speech acts which expressed a response to an initial or chained (see below) disturbance, and immediately followed it. There were two kinds of final resolutions:

1. Ignore. No overt response to a partner's initial or chained disturbance, or a response that did not relate to the partner's initial or chained disturbance.

Example:

"Should we try three together?"
(Initial question)

"Last night I went to
Captain Walters with my
boyfriend."
(Ignore: Unrelated)

2. Agreement. A speech act which indicated a subject accepted the partner's initial or chained disagreement, agreed with the partner's explanation, or agreed with the partner's inquiry. This code included any restatement of the partner's statement, or an integration of

the partner's statement with one's own statement, with or without elaboration.

Example:

"Forget it, we did enough."
(Initial disagreement)

"Okay. You're right."
(Agreement)

If an explanation was included with an agreement, and it was not immediately preceded by an explanation, this was scored as an explanation type of chained disturbance rather than an agreement resolution. An explanation could not follow a partner's speech act that was coded as an initial or chained explanation. This was because the second explanation either agreed or disagreed with the first and was, therefore, coded as either an agreement or disagreement.

C. Chains of disturbing resolutions. These were speech acts which came after an initial disturbance and before a final resolution, and also required two speech acts to be scored as one conflict. For scoring purposes, each of these speech acts was considered both a resolution to the previous speech act and a disturbance to the forthcoming speech act. Conceptually, however, the following disagreements, questions, and explanations were disturbances. There were four types of chained speech acts:

1. Disagreement. A speech act, without an explanation, which indicated one partner did not agree with the other's preceding initial or chained disturbance. This may take the form of a negative criticism, identified as a

disparaging remark, indicating one partner disagreed with the other.

Example:

"Let's mix them now ,huh?"
(Initial question)

"No, not yet."
(Disagreement)

"Okay, we'll do more."
(Agreement)

2. Explanation. A speech act which followed any disturbance other than an explanation, and expressed one's reasoning, or attempted to make something understandable. Explanations could include a disagreement, or might not include a disagreement.

Example:

"Nope. Wrong. D has nothing
to do with the change."
(Initial disagreement)

"It does, 'cause like
it stops the B and C
when it's with them.
Alone they work, but
not when D is there."
(Explanation)

"Oh. Right, right."
(Agreement)

3. Question. An inquiry that followed any disturbance which indicated one partner determined whether both members were in agreement about an opinion or strategy.

Example:

"No. It can't be B."
(Initial disagreement)

"Why not?"
(Question)

"Because it never worked
alone. It worked here because
It was with the C, and C is
the one that turns it red."
(Explanation)

"Oh, right. Right."
(Agreement)

4. Chained response. A response following either an initial or chained disturbance, which did not fit any other disturbance or resolution code. It was empirically necessary to refer to this code because the response was not a final resolution, and all disturbances must be resolved. Chained responses almost always occurred within discussion chains as answers to questions, but were not agreements or disagreements because the questioner's opinion was not clear.

Example:

"We should mix now, 'cause we
tried all the combinations. We
have all these with these and
all these threes together."
(Initial explanation)

"Wait. Do all alone."
(Disagreement)

"Hm, you think one alone can
work?"
(Question)

"Sure. Could be."
(Chained response)

"Okay."
(Agreement)

Scoring

Each disturbance and its resolution are scored as one
conflict. Any resolution could be a final resolution or
disturbance, with the exception of an explanation. Any
an initial explanation or chained explanation. Explanations

following these categories were either in agreement or disagreement, and were identified as such.

There were potentially forty different conflict types. Each dyad received a total conflict score, which consisted of all conflicts, regardless of type. In addition, category measures of peer interaction were determined for each dyad. There were five categories. Three categories consisted of every initial or chained disagreement, explanation, or question, regardless of its resolution. Two categories consisted of the two final resolutions (ignore or agreement) regardless of its preceding disturbance.

The forty different conflict types were:

- ID-I. Initial disagreement - Ignore
- ID-A. Initial disagreement - Agreement
- ID-D. Initial disagreement - Disagreement
- ID-Q. Initial disagreement - Question
- ID-E. Initial disagreement - Explanation
- ID-R. Initial disagreement - Chained response
- IQ-I. Initial question - Ignore
- IQ-A. Initial question - Agreement
- IQ-D. Initial question - Disagreement
- IQ-Q. Initial question - Question
- IQ-E. Initial question - Explanation
- IQ-R. Initial question - Chained response
- IE-I. Initial explanation - Ignore
- IE-A. Initial explanation - Agreement

IE-D. Initial explanation - Disagreement
IE-Q. Initial explanation - Question
IE-R. Initial explanation - Chained response
D-I. Disagreement - Ignore
D-A. Disagreement - Agreement
D-D. Disagreement - Disagreement
D-Q. Disagreement - Question
D-E. Disagreement - Explanation
D-R. Disagreement - Chained response
Q-I. Question - Ignore
Q-A. Question - Agreement
Q-D. Question - Disagreement
Q-Q. Question - Question
Q-E. Question - Explanation
Q-R. Question - Chained response
E-I. Explanation - Ignore
E-A. Explanation - Agreement
E-D. Explanation - Disagreement
E-Q. Explanation - Question
E-R. Explanation - Chained response
R-I. Chained response - Ignore
R-A. Chained response - Agreement
R-D. Chained response - Disagreement
R-Q. Chained response - question
R-E. Chained response - Explanation
R-R. Chained response - Chained response

Reliability

Five randomly selected transcripts were independently scored by the experimenter and a colleague trained in the use of the coding system. The second rater did not know the pre- and posttest levels, or whether a particular problem in the chemical problem-solving series was solved correctly.

The frequency of disagreements between raters was divided by the frequency of agreements plus disagreements between both raters. Agreement was based on both raters assigning each disturbance and resolution speech act to the same conflict category. Interrater reliability for all conflict types scored varied from 92% to 100% for each transcript, with an average mean agreement of 94% for 189 conflict types scored on the five transcripts.

Chapter V

Results

The following results are presented in three sections. The first reports the effect of subject condition on conflict scores and the effects of subject condition, problem mastery, and conflict on pre- to posttest change scores on the combinatorial reasoning problem. The second section presents the relationship between subject condition and problem mastery scores, and the relationship between conflict and problem mastery scores. Problem mastery refers to the total number of chemical problems successfully solved during the six session experimental phase. The final section reports changes in the amount of conflict generated during different sessions of the experimental phase.

Pre- to posttest change scores for the simple plant problem were not analyzed because 28.9 per cent of subjects received the maximum score on the pretest and another 26.7 per cent received a score at the next highest level. Given that 55.7 per cent of the pretest scores were at the two highest levels, opportunities for significant change were compromised for this measure, and analyses were not continued.

One dyad was eliminated from all analyses. Discussion between subjects in this dyad had to be curtailed on several occasions as they were running out of time. The number of speech acts scored for this dyad was not only

disproportionately high compared to the rest of the sample, but was not a reflection of the number they might have produced were they able to continue.

All dyadic interactions occurring during problem-solving sessions two through six were videotaped. There were two instances of missing data for verbal interaction. The video equipment did not record session two for one dyad, and another dyad solved all five problems by session five. Three dyads each, whose total conflict scores (minus session two in one case and session six in the other) came closest to the totals of the two dyads where data was missing, were used to supply the missing data for these dyads. The mean conflict score of session two from the three dyads whose total conflict scores were closest to the total for the dyad missing the second session were used for that instance of missing data. The mean conflict score from session six of the other three dyads were used for the dyad missing session six data.

Subject Condition and Conflict Scores

The effect of subject condition on the amount of conflict generated across five sessions was assessed by a t test for the difference between mean conflict scores. The mean number of conflict scores for the eight dyads in the concrete dyadic condition was 121.50 and the mean number of conflict scores for the seven dyads in the mixed dyadic

condition was 199.57. No significant difference was obtained.

Subject Condition and Pre- to posttest Change Scores

The effect of subject condition on pre- to posttest change scores for the candy combinations problem was tested by a one-way analysis of variance with four levels. They were: Individual control condition (level 0 at pretest), concrete dyadic condition (level 0 at pretest), concrete subjects in the mixed dyadic condition (level 0 at pretest), and transitional subjects in the mixed dyadic condition (level 2 at pretest). No significant differences were obtained. Table 2 presents the means and standard deviations.

Problem Mastery and Pre- to posttest Change Scores

The relationship between the number of chemical problems successfully mastered by all of the experimental (dyadic) and control (individual) subjects and the pre- to posttest change scores on the candy combinations problem was tested by a one-way analysis of variance. All subjects mastered the first problem in the chemicals problem-solving series of five problems. Therefore, four levels of task mastery were analyzed: Mastery of two problems, mastery of three problems, mastery of four problems, and mastery of five problems. Significant differences were found between levels of mastery and pre- to posttest change scores, $F(3, 41) = 13.63, p < .01$. Means and standard deviations are presented

Table 2

Means and Standard Deviations of the Combinatorial Reasoning Task Change Scores for Subject Conditions

| Condition | n | Change Scores | |
|---|----|---------------|------|
| | | Mean | SD |
| Control Subjects | 15 | 1.07 | 1.16 |
| Concrete subjects paired with concrete subjects | 16 | 1.37 | 1.02 |
| Concrete subjects paired with transitional subjects | 7 | 1.57 | 1.27 |
| Transitional subjects paired with concrete subjects | 7 | 1.29 | 0.76 |

in Table 3, and the analysis of variance is summarized in Table 4. Newman-Keuls post-hoc comparisons indicated that subjects who mastered two problems had significantly less pre- to posttest change than subjects who mastered three, four, or five problems ($p < .05$). The latter groups did not differ from each other.

Problem Mastery by Subject Condition on Pre- to posttest Change Scores

The relationship between the number of chemical problems mastered and subject condition on pre- to posttest change scores for the candy combinations problem was tested by a 2 X 3 analysis of variance. Chemical problem mastery was collapsed into two levels, two and three problems mastered versus four and five. Chemical problem mastery was collapsed for this analysis, because there would have been too many empty cells due to subject sample size. The subject conditions were individual (control), concrete dyads, and mixed dyads. The mixed dyadic condition was not divided into concrete subjects in the mixed dyadic condition and transitional subjects in the mixed dyadic condition, because problem mastery was a dyadic measure rather than an individual measure. There was a significant main effect for problem mastery, $F(1, 44) = p < .01$. Means and standard deviations of the change scores are presented in Table 5, and the analysis of variance is summarized in Table 6. Newman-Keuls comparisons indicated that subjects who mastered four

Table 3

Means and Standard Deviations of the Combinatorial Reasoning
Task Change Scores for Mastery Levels

| Mastery Level | n | Change Scores | |
|---------------|----|---------------|------|
| | | Mean | SD |
| 2 | 16 | 0.31 | 0.60 |
| 3 | 14 | 1.64 | 0.63 |
| 4 | 7 | 2.00 | 1.29 |
| 5 | 8 | 2.00 | 0.76 |

Table 4

Analysis of Variance of the Combinatorial Reasoning Task
Change Scores for Mastery Levels

| Source of Variation | df | SS | MS | <u>F</u> | <u>p</u> < |
|---------------------|----|-------|------|----------|------------|
| Between Groups | 3 | 24.59 | 8.20 | 13.63 | .001 |
| Within Groups | 41 | 24.65 | 0.60 | | |
| Total | 44 | 49.24 | | | |

Table 5

Means and Standard Deviations of the Combinatorial Reasoning
Task Change Scores for Problem Mastery and Subject Conditions

| Condition | n | Mastery Level | | | | |
|-----------------------------|----|---------------|------|---------|------|------|
| | | 2 and 3 | | 4 and 5 | | |
| | | Mean | SD | n | Mean | SD |
| Individual | 14 | 0.86 | 0.86 | 1 | 4.00 | 0.00 |
| Concrete dyadic subjects | 12 | 1.08 | 1.00 | 4 | 2.25 | 0.50 |
| Mixed dyadic subjects | 4 | 0.75 | 0.96 | 10 | 1.70 | 0.95 |

Table 6

Analysis of Variance of the Combinatorial Reasoning Task
Change Scores for Problem Mastery and Subject Condition

| Source of Variation | df | SS | MS | F | p< |
|---------------------|----|-------|-------|-------|------|
| Mastery | 1 | 12.32 | 12.32 | 14.91 | .01 |
| Condition | 2 | 2.08 | 1.04 | 1.26 | n.s. |
| Interaction | 2 | 3.56 | 1.78 | 2.15 | n.s. |
| Total | 44 | 49.24 | 1.12 | | |

and five problems had significantly greater pre- to posttest change scores than subjects who mastered two and three problems, $p < .05$. No significant main effect was obtained for subject condition, and there were no significant interactions.

Conflict Scores for Session 2 on Pre- to posttest Change

The relationship between the amount of conflict generated, during session 2 of the chemical problem-solving series, and the candy combinations problem pre- to posttest change scores was assessed by a t test for the difference between mean conflict scores. Experimental subjects were assigned to high or low conflict groups based on the dyad they were in and the frequency of all types of conflicts generated by that dyad during session 2. High conflict dyads were operationally defined as having scored above the mean for the number of conflicts generated by all dyads, and low conflict dyads as having scored below the mean. The mean number of conflicts for ten dyads in the low conflict group was 10.10 (range = 3 to 17). The mean number of conflicts for the five dyads in the high conflict group was 30.80 (range = 21 to 42). No significant difference was obtained.

Conflict Scores for all Sessions on Pre- to posttest Change

The relationship between the amount of conflict generated across all chemical problem-solving sessions and pre- to posttest change scores for the candy combinations problem was assessed by a one-way analysis of variance with

three levels. The three levels were control subjects (n=15), experimental subjects, low conflict (n=14), and experimental subjects, high conflict (n=9). Only subjects who were concrete operational (level 0) on the combinatorial reasoning assessment task were included in this analysis. Inclusion of the transitional subjects (level 2) would have produced a ceiling effect, as several transitional subjects received posttest scores at the highest level. Experimental subjects were assigned to high or low conflict groups based on the dyad they were in and the frequency of all types of conflicts generated by that dyad during the course of the problem-solving series. High conflict dyads were operationally defined as having scored above the mean for the number of conflicts generated by all dyads and low conflict dyads as having scored below the mean. The mean number of conflicts for the eight dyads in the low conflict group was 67.5 (range = 33 to 131) The mean number of conflicts for the seven dyads in the high conflict group was 247 (range = 202 to 281). There was a significant difference between conflict conditions, $F(2, 35) = 3.70, p < .05$, and pre- to posttest change scores. Means and standard deviations appear in Table 7, and the analysis of variance is summarized in Table 8. Newman-Keuls comparisons indicated that subjects in the experimental high conflict group had significantly greater pre- to posttest change scores than subjects in either the experimental low conflict group or control condition $p < .05$.

Table 7

Means and Standard Deviations of the Combinatorial Reasoning Task Change Scores for Conflict Condition

| Condition | n | Change Scores | |
|-------------------------------------|----|---------------|------|
| | | Mean | SD |
| Control subjects | 15 | 1.07 | 1.16 |
| Experimental low conflict subjects | 14 | 1.00 | 0.96 |
| Experimental high conflict subjects | 9 | 2.11 | 0.93 |

Table 8

Analysis of Variance of the Combinatorial Reasoning Task
Change Scores for Conflict Condition

| Source of Variation | df | SS | MS | <u>F</u> | <u>p</u> < |
|---------------------|----|-------|------|----------|------------|
| Between Groups | 2 | 8.00 | 4.00 | 3.70 | .05 |
| Within Groups | 35 | 37.82 | 1.08 | | |
| Total | 37 | 45.82 | | | |

The latter two groups did not differ from each other.

In sum, analyses of pre- to posttest change scores of the combinatorial reasoning assessment task and the amount of conflict generated found that group condition was not a significant main effect. However, the amount of conflict generated across all sessions of the chemical problem-solving series, and the number of problems successfully mastered during the chemical problem-solving series, were significantly related to pre- to posttest change scores.

Subject Condition and Problem Mastery

The relationship between subject condition and the number of chemical problems mastered during the six problem-solving sessions was tested by a one-way analysis of variance with three group levels. The three conditions were individual (control), concrete dyads, and mixed dyads. The mixed dyadic condition was not divided into concrete subjects in the mixed dyadic condition and transitional subjects in the mixed dyadic condition, because problem mastery was a dyadic score. There was a significant main effect for subject condition on mastery, $F(2, 27) = 10.61, p < .05$. Means and standard deviations appear in Table 9, and the analysis of variance is summarized in Table 10. Newman-Keuls comparisons indicated that subjects in the mixed dyadic condition mastered significantly more problems than subjects in the concrete dyadic condition or the individual (control) condition, $p < .05$. Levels of problem mastery in the latter

Table 9

Means and Standard Deviations of Chemical Problem Mastery Levels by Subject Condition

| Condition | n | Mastery Level | |
|----------------|----|---------------|------|
| | | Mean | SD |
| Individuals | 15 | 2.40 | .63 |
| Concrete dyads | 8 | 3.00 | .76 |
| Mixed dyads | 7 | 4.14 | 1.21 |

Table 10

Analysis of Variance of Chemical Problem Mastery Levels
by Subject Condition

| Source of Variation | df | SS | MS | <u>F</u> | <u>p</u> < |
|---------------------|----|-------|------|----------|------------|
| Between Conditions | 2 | 14.51 | 7.25 | 10.61 | .01 |
| Within Conditions | 27 | 18.46 | 0.68 | | |
| Total | 29 | 32.97 | | | |

two conditions did not significantly differ from each other. Table 11 summarizes the chemical problems presented to subjects at each session and the final level of mastery achieved. Table 12 presents the percentage of subjects within each group solving each problem. Although subjects in the individual control and concrete dyadic conditions did not differ significantly on the number of problems solved, a higher proportion of subjects in the concrete dyadic condition solved problems three and four. Seventy-five per cent of the concrete dyads solved problem 3 (n=6) compared to thirty-three per cent of the individuals (n=5), and twenty-five per cent of the concrete dyads (n=2) solved problem 4 compared to seven per cent of the individuals (n=1). All subjects solved problem two, and only subjects in the mixed dyadic condition (fifty-seven per cent) solved the fifth problem .

Nonconflict Scores and Problem Mastery

The relationship between nonconflict scores and the number of chemical problems mastered was assessed by a one-way analysis of variance for the total number of nonconflicts generated by dyads (concrete and mixed) across five sessions. There were four levels of problem mastery, two through five. No significant differences were obtained between levels of mastery and mean nonconflict scores. Means and standard deviations are presented in Table 13.

Table 11

Chemical Problems Presented at Each Problem-Solving Session

| Name | Session | | | | | | Mastery Level (Problems Solved) |
|-----------------------|---------|---|---|---|---|---|------------------------------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | |
| <u>Individuals</u> | | | | | | | |
| Ingrid | 1 | 1 | 1 | 2 | 2 | 3 | 2 |
| Danny | 1 | 1 | 1 | 2 | 3 | 3 | 2 |
| Joseph | 1 | 1 | 2 | 2 | 3 | 4 | 3 |
| Edy | 1 | 2 | 2 | 2 | 2 | 3 | 2 |
| Diane | 1 | 2 | 2 | 2 | 3 | 3 | 2 |
| Michael | 1 | 2 | 2 | 2 | 3 | 3 | 2 |
| Susan | 1 | 2 | 2 | 2 | 3 | 3 | 2 |
| Josie | 1 | 2 | 2 | 2 | 3 | 3 | 2 |
| Sal | 1 | 2 | 2 | 2 | 3 | 3 | 2 |
| William | 1 | 2 | 2 | 3 | 3 | 3 | 2 |
| Anna | 1 | 2 | 2 | 3 | 3 | 4 | 3 |
| Pam L. | 1 | 2 | 3 | 3 | 3 | 3 | 2 |
| Jose | 1 | 2 | 3 | 3 | 3 | 4 | 4 |
| Lois | 1 | 2 | 3 | 3 | 3 | 4 | 3 |
| Lillian | 1 | 2 | 3 | 4 | 4 | 4 | 3 |
| <u>Concrete Dyads</u> | | | | | | | |
| Lucius & Todd | 1 | 2 | 2 | 3 | 3 | 3 | 3 |
| Pam R. & Janie | 1 | 2 | 2 | 3 | 3 | 3 | 3 |
| Alice & Karen | 1 | 2 | 2 | 3 | 3 | 3 | 2 |
| Kathy & Beth | 1 | 2 | 2 | 3 | 4 | 4 | 3 |
| Evan. & Marie | 1 | 2 | 3 | 3 | 3 | 3 | 2 |
| Ros & Marlene | 1 | 2 | 3 | 3 | 3 | 4 | 3 |
| Sandra & Phyllis | 1 | 2 | 3 | 3 | 3 | 4 | 4 |
| Paula & Louise | 1 | 2 | 3 | 3 | 4 | 5 | 4 |
| <u>Mixed Dyads</u> | | | | | | | |
| Gino & Anthony | 1 | 2 | 2 | 2 | 2 | 3 | 2 |
| Rana & Melayne | 1 | 2 | 2 | 2 | 3 | 3 | 3 |
| Yvette & Janet | 1 | 2 | 3 | 3 | 4 | 5 | 5 |
| Jacques & Robert | 1 | 2 | 3 | 3 | 4 | 5 | 5 |
| Tania & Pam A. | 1 | 2 | 3 | 4 | 4 | 5 | 4 |
| Emma & Carla | 1 | 2 | 3 | 4 | 5 | 5 | 5 |
| C. D. & Rony | 1 | 2 | 3 | 4 | 5 | | 5 |

Table 12

Per Cent of Subjects Within Conditions Solving Each Problem

| Condition | n | Mastery Level | | | |
|---------------------|----|---------------|----|----|----|
| | | 2 | 3 | 4 | 5 |
| Individual subjects | 15 | 100 | 33 | 7 | 0 |
| Concrete Dyads | 8 | 100 | 75 | 25 | 0 |
| Mixed Dyads | 7 | 100 | 86 | 71 | 57 |

Table 13

Means and Standard Deviations of Nonconflict Scores for
Chemical Problem Mastery Levels

| Mastery Level | n | Nonconflict Scores | |
|---------------|---|--------------------|-------|
| | | Mean | SD |
| 2 | 3 | 49.67 | 29.53 |
| 3 | 5 | 79.60 | 56.67 |
| 4 | 3 | 108.33 | 27.65 |
| 5 | 4 | 97.00 | 7.87 |

Conflict Scores on Session 2 and Problem Mastery

The relationship between conflict scores of all types (total) generated during session 2 and the number of chemical problems mastered at the conclusion of the chemical problem-solving series was assessed by a one-way analysis of variance for the total number of conflicts generated by dyads (concrete and mixed) during session 2. There were four levels of problem mastery, two through five. A statistically significant difference was obtained between mean conflict scores of all types and different levels of problem mastery, $F(3, 11) = 9.73, p < .005$. Table 14 presents the means and standard deviations. The analysis of variance is summarized in Table 15. Newman-Keuls comparisons indicated that dyads who mastered four and five problems did not differ from each other, but did have significantly higher conflict scores during session 2 than dyads who mastered two and three problems, $p < .05$. Subjects in the latter two groups did not differ from each other.

Conflict Scores and Problem Mastery

I. Conflicts Scores of all types (total) and problem mastery. The relationship between conflict scores of all types (total) and the number of chemical problems mastered was assessed by a one-way analysis of variance for the total number of conflicts generated by dyads (concrete and mixed) across five sessions. There were four levels of problem mastery, two through five. A statistically significant

Table 14

Means and Standard Deviations of All Types of Conflict Scores
on Session 2 for Chemical Problem Mastery Levels

| Mastery Level | n | Conflict Scores | |
|---------------|---|-----------------|-------|
| | | Mean | SD |
| 2 | 3 | 5.67 | 3.79 |
| 3 | 5 | 10.20 | 5.07 |
| 4 | 3 | 33.00 | 10.82 |
| 5 | 4 | 23.25 | 8.46 |

Table 15 :

Analysis of Variance of All Types Conflict Scores on
Session 2 by Chemical Problem Mastery Levels

| Source of Variation | df | SS | MS | <u>F</u> | <u>p</u> < |
|---------------------|----|---------|--------|----------|------------|
| Between Groups | 3 | 1539.11 | 513.04 | 9.73 | .005 |
| Within Groups | 11 | 580.22 | 52.75 | | |
| Total | 14 | 2119.33 | | | |

difference was obtained between levels of mastery and all types of mean conflict scores, $F(3, 11) = 29.92$, $p < .01$. Table 16 presents the means and standard deviations. The analysis of variance is summarized in Table 17. Newman-Keuls comparisons indicated that dyads who mastered problems four and five did not differ from each other, but did have significantly higher conflict scores than dyads who mastered problems two and three, $p < .05$. Subjects in the latter two conditions did not differ from each other. These results are shown in Figure 1. Table 18 indicates the amount of conflict of all types (total) generated by each dyad during each problem-solving session.

II. Conflict category scores and problem mastery. The forty different types of conflict were collapsed into five categories of three disturbance categories and two resolution categories. The three disturbance categories were (1) disagreements, (2) questions, and (3) explanations, no matter what type of resolution followed them. The two resolution categories were (1) agreements and (2) ignores, no matter what type of disturbance preceded them. Five one-way analyses of variance were done using the different conflict category scores as dependent variables and levels of problem mastery as independent variables.

A. Disagreement category conflict scores and problem mastery. Significant differences were obtained between different levels of problem mastery and the use of

Table 16

Means and Standard Deviations of All Types of Conflict
Scores for Chemical Problem Mastery Levels

| Mastery Level | n | Conflict Scores | |
|---------------|---|-----------------|-------|
| | | Mean | SD |
| 2 | 3 | 71.00 | 54.15 |
| 3 | 5 | 85.40 | 25.09 |
| 4 | 3 | 239.00 | 32.36 |
| 5 | 4 | 253.00 | 28.13 |

Table 17

Analysis of Variance of All Types Conflict Scores by
Chemical Problem Mastery Levels

| Source of Variation | df | SS | MS | <u>F</u> | <u>p</u> < |
|---------------------|----|-----------|----------|----------|------------|
| Between Groups | 3 | 104843.74 | 34947.91 | 29.92 | .01 |
| Within Groups | 11 | 12849.20 | 1168.11 | | |
| Total | 14 | 117692.94 | | | |

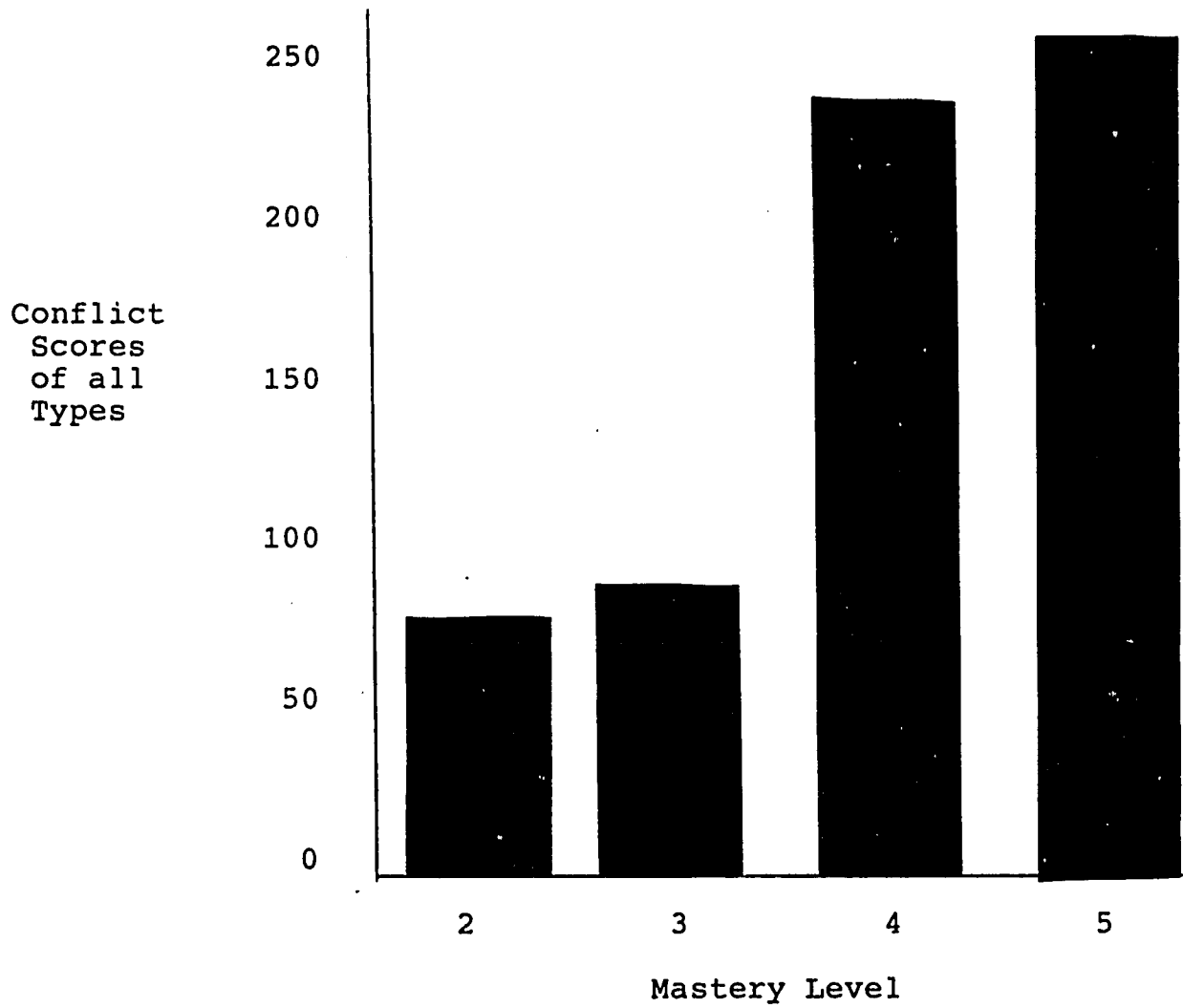


Figure 1. Mean conflict scores as a function of mastery level.

Table 18

Amount of Conflict of all Types (Total) Generated for Each Problem-Solving Session

| Dyad Subjects | Session | | | | |
|------------------|----------------------------|----|----|-----|----|
| | 2 | 3 | 4 | 5 | 6 |
| | <u>Low Conflict Dyads</u> | | | | |
| Lucius & Todd | 6 | 2 | 6 | 37 | 4 |
| Pam R. & Janie | 4 | 10 | 5 | 17 | 43 |
| Alice & Karen | 4 | 2 | 2 | 5 | 20 |
| Kathy & Beth | 11 | 18 | 18 | 25 | 25 |
| Evan. & Marie | 3 | 40 | 31 | 14 | 45 |
| Ros & Marlene | 15 | 27 | 21 | 30 | 28 |
| Gino & Anthony | 10 | 5 | 15 | 8 | 9 |
| Rana & Melayne | 15 | 23 | 10 | 6 | 22 |
| | <u>High Conflict Dyads</u> | | | | |
| Sandra & Phyllis | 42 | 27 | 31 | 31 | 71 |
| Paula & Louise | 36 | 49 | 41 | 68 | 74 |
| Yvette & Janet | 17 | 38 | 53 | 56 | 84 |
| Jacques & Robert | 41 | 24 | 98 | 74 | 44 |
| Tania & Pam A. | 21 | 24 | 36 | 102 | 79 |
| Emma & Carla | 29 | 25 | 56 | 37 | 67 |
| C. D. & Rony | 16 | 64 | 70 | 41 | 76 |

Table 19

Means and Standard Deviations of Disagree Category
Conflict Scores for Chemical Problem Mastery Levels

| Mastery Level | n | Conflict Scores | |
|---------------|---|-----------------|-------|
| | | Mean | SD |
| 2 | 3 | 13.33 | 13.80 |
| 3 | 5 | 10.20 | 2.39 |
| 4 | 3 | 29.67 | 5.13 |
| 5 | 4 | 29.29 | 10.56 |

disagreement type disturbances, $F(3, 11) = 5.73$, $p < .02$. Means and standard deviations appear in Table 19. Newman-Keuls comparisons indicated that subjects who mastered five problems had significantly more disagreement category scores than all other subjects. Subjects who mastered four problems disagreed significantly more than those who mastered two or three problems, $p < .05$. The latter two groups did not differ from each other.

B. Question category conflict scores and problem mastery. There was a significant relationship between different levels of problem mastery and the use of question type disturbances, $F(3, 11) = 38.60$, $p < .01$. Table 20 presents the means and standard deviations. Subjects who mastered four or five problems did not differ from each other but did ask significantly more questions than subjects who solved two or three problems, $p < .05$. There was no difference between the latter two groups.

C. Explanation category conflict scores and problem mastery. A significant relationship was found between different levels of problem mastery and the use of explanation types of disturbances, $F(3, 11) = 19.65$, $p < .01$. Means and standard deviations appear in Table 21. Newman-Keuls comparisons indicated that subjects who solved four or five problems did not differ from each other, but used explanation type disturbances significantly more often than subjects who solved two or three problems, $p < .05$. No

Table 20

Means and Standard Deviations of Question Category
Conflict Scores for Chemical Problem Mastery Levels

| Mastery Level | n | Conflict Scores | |
|---------------|---|-----------------|-------|
| | | Mean | SD |
| 2 | 3 | 34.67 | 17.95 |
| 3 | 5 | 43.20 | 16.57 |
| 4 | 3 | 114.00 | 17.52 |
| 5 | 4 | 136.00 | 11.43 |

Table 21

Means and Standard Deviations of Explanation Category
Conflict Scores for Chemical Problem Mastery Levels

| Mastery Level | n | Conflict Scores | |
|---------------|---|-----------------|------|
| | | Mean | SD |
| 2 | 3 | 5.67 | 3.51 |
| 3 | 5 | 8.60 | 4.39 |
| 4 | 3 | 26.67 | 2.08 |
| 5 | 4 | 24.25 | 6.18 |

significant difference was obtained between the latter two groups.

D. Agreement category conflict scores and problem mastery. A significant relationship was obtained between levels of problem mastery and the use of agreement types of resolutions, $F(3, 11) = 36.77, p < .01$. Means and standard deviations are shown in Table 22. Subjects who mastered five problems agreed significantly more than all other subjects, while those solving four problems agreed significantly more than subjects who mastered only two or three problems, $p < .05$. There was no significant difference between the latter two groups.

E. Ignore category conflict scores and problem mastery. No significant relationship was obtained between levels of problem mastery and the use of ignore types of resolutions. Table 23 presents the means and standard deviations. These types of resolutions were rarely used, accounting for only seven per cent of all responses to disturbances.

In sum, there was a significant relationship between subject condition and the number of problems mastered during the six session chemical problem-solving series. Mixed dyads solved significantly more problems than control subjects or concrete dyads. The number of problems mastered during the series was found to be significantly associated with the expression of all types of conflicts (total), as well as with the expression of disagreement, question, and explanation

Table 22

Means and Standard Deviations of Agree Category
Conflict Scores for Chemical Problem Mastery Levels

| Mastery Level | n | Conflict Scores | |
|---------------|---|-----------------|-------|
| | | Mean | SD |
| 2 | 3 | 22.67 | 4.51 |
| 3 | 5 | 31.80 | 17.11 |
| 4 | 3 | 81.33 | 10.69 |
| 5 | 4 | 102.00 | 8.37 |

Table 23

Means and Standard Deviations of Ignore Category
Conflict Scores for Chemical Problem Mastery Levels

| Mastery Level | n | Conflict Scores | |
|---------------|---|-----------------|------|
| | | Mean | SD |
| 2 | 3 | 7.33 | 6.66 |
| 3 | 5 | 8.80 | 3.42 |
| 4 | 3 | 15.33 | 2.08 |
| 5 | 4 | 17.50 | 7.23 |

categories of disturbances. Greater mastery was associated with the expression of higher levels of all types of conflict and with each disturbance category. Also, dyads who mastered more chemical problems used agreement category resolutions more often than dyads who solved fewer chemical problems.

Amount of Conflict Generated for Each Problem-Solving Session

A one-way analysis of variance with five levels for sessions two through six was computed to test whether the amount of all types of conflict (total), generated by experimental subjects during each session, changed over the course of six problem-solving sessions. There was a statistically significant relationship between conflict means and session number, $F(4, 70) = 8.55, p < .01$. Newman-Keuls post-hoc comparisons indicated that significantly more conflicts were generated on session six than on sessions two, three, or four, $p < .05$. Also, significantly more conflicts were generated during sessions four and five than during the second session, $p < .05$. Means and standard deviations appear in Table 24, and the analysis of variance is summarized in Table 25.

Table 24

Means and Standard Deviations of All Types Conflict Scored
for Each Problem-Solving Session

| Session Number ^a | Conflict Scores | |
|-----------------------------|-----------------|-------|
| | Mean | SD |
| 2 | 18.00 | 16.58 |
| 3 | 25.20 | 17.23 |
| 4 | 32.87 | 27.07 |
| 5 | 36.73 | 27.51 |
| 6 | 46.07 | 27.50 |

^a
n = 15 for each session

Table 25

Analysis of Variance of All Conflict Types Scored for
Each Problem-Solving Session

| Source of Variation | df | SS | MS | <u>F</u> | <u>p</u> |
|---------------------|----|----------|---------|----------|----------|
| Between Groups | 4 | 7099.20 | 1774.80 | 8.55 | .001 |
| Within Groups | 70 | 14535.95 | 207.66 | | |
| Total | 74 | 21635.15 | | | |

Findings by hypotheses

1. It was predicted that experimental subjects (who worked collectively) would have greater pre- to posttest change scores than control subjects (who worked individually). Analyses indicated no significant differences between the control condition and the two experimental conditions on the change scores. Thus, hypothesis one was not supported by the data.

2. It was predicted that experimental subjects in mixed-level dyads would have greater pre- to posttest change scores than experimental subjects in concrete dyads. No significant differences were obtained between subjects in concrete-level dyads and subjects in mixed-level dyads. Thus, hypothesis two was not supported.

3. It was predicted that subjects in dyads who mastered more advanced problems would have greater pre- to posttest change scores than dyad members who mastered less advanced problems. The analyses indicated that the number of problems successfully mastered was significantly related to pre- to posttest change scores, thus supporting hypothesis three.

4. It was predicted that concrete operational subjects in dyads generating higher levels of socio-cognitive conflict, would achieve greater pre- to posttest change scores than subjects in dyads generating lower levels. Subjects in high conflict dyads had significantly greater pre- to posttest change scores than subjects in low conflict

dyads. Thus, hypothesis four was supported by the data.

5. It was predicted that experimental subjects working in dyads would master more advanced problems than control subjects (individuals). Results indicated that experimental subjects in mixed dyads mastered significantly more problems than either control subjects or experimental subjects in concrete level dyads. Thus, hypothesis five was partially supported by the data.

6. It was predicted that within the experimental conditions, subjects in mixed-level dyads would progress to more advanced problems than same-level dyads. Subjects in mixed-level dyads did master significantly more problems than subjects in same-level dyads. Thus, hypothesis six was supported by the data.

7. It was predicted that dyads mastering more advanced problems from the five problem task sequence would evidence significantly more socio-cognitive conflict than dyads who did not show as much progress. The analyses indicated an association between mastery level and frequency of socio-cognitive conflict. Dyads who mastered the two most advanced problems in the sequence, problems four and five, generated significantly more socio-cognitive conflict of all types (total), as well as significantly more of each disturbance category and the agreement resolution category, than dyads who mastered two or three problems. Thus, hypothesis seven was supported by the data.

Chapter VI

Discussion

The present study had three purposes. The major purpose was to determine whether socio-cognitive conflict differentiated between experimental subjects who solved more problems while working together, and achieved higher change scores on individually administered pre- to posttests, than experimental subjects who mastered fewer problems and achieved lower change scores. Based on Piaget's equilibration model, socio-cognitive conflict was operationally defined as a disturbance speech act made by one member of a dyad and a resolution speech act made by the other. Disturbance speech acts included disagreements, questions, and explanations. Resolutions included agreement with the disturbance, or ignoring it. The second purpose of the study was to compare performances between subjects who worked collaboratively during the experimental phase of the study with control subjects who worked individually. A third purpose was to investigate whether there were performance differences between dyads in which both partners were at the same developmental level (concrete dyads) and dyads in which partners were at different levels (mixed dyads).

The major findings of the present study indicated that the amount of socio-cognitive conflict of all types (total) was positively and significantly related to pre- to posttest change scores on a problem requiring formal operational

reasoning strategies. In order to eliminate a ceiling effect, this finding was based on analysis of subjects who scored concrete operational (level 0) on the candy combinations pretest. It did not include subjects who attained transitional (level 2) scores. The number of succeedingly more difficult problems mastered during the experimental phase of the study was also positively and significantly associated with the amount of socio-cognitive conflict of all types, as well as all disturbances and the agreement resolution.

Subject condition was not significantly associated with pre- to posttest change scores, but was associated with the number of chemical problems mastered during the experimental phase. Mixed dyads solved significantly more problems than either concrete dyads or subjects in the individual control condition. Although no significant differences were obtained between concrete dyads and individual control subjects in the number of problems mastered, there were nonsignificant trends indicating that more concrete dyads than individual control subjects mastered specific problems in the series. More specifically, all subjects in all conditions were able to solve problems one and two, and only several mixed dyads solved problem five. However, six concrete dyads (75%) were able to solve problem three compared to five individuals (33%), and two concrete dyads (25%) were able to solve problem four compared to one individual (7%).

Subjects in one dyad were eliminated from all statistical analyses because their discussions did not end by the conclusion of several problem-solving sessions, which made it impossible to accurately measure the frequency of their socio-cognitive conflict. Socio-cognitive conflict was a major variable in this study and its frequency was determined solely by subjects' verbal production, without experimenter intervention. Thus, it was decided that the inability to accurately measure conflict for this dyad outweighed any consideration for including them in the statistical analyses.

Theoretical Framework

The results of the present study are consistent with Piagetian theory which posits a relationship between critical aspects of social interaction and progressive change. In the present study, socio-cognitive conflict was identified as a critical discourse style. All other discourse was defined as nonconflict. There were no significant differences between nonconflict frequency scores and problem mastery for experimental subjects. However, experimental subjects who engaged in higher levels of socio-cognitive conflict mastered more problems from the chemical problem-solving series than experimental subjects who generated lower levels of socio-cognitive conflict. Experimental subjects who generated higher levels of socio-cognitive conflict also had

significantly greater change scores, on individually administered pre- to posttests, than control subjects or experimental subjects who generated lower levels of conflict.

The Relationship of the Present Study to Other Studies

Previous research has demonstrated an association between peer interaction and development through several studies which reported that subjects who were given the opportunity to solve problems with peers achieved significantly higher scores than individual control subjects on individually administered posttests (e.g. Doise et al., 1975; Perret-Clermont, 1980). These findings have advanced the argument that the skills acquired during collaboration can be internalized. However, it was observed that some individuals were more successful than peers working together, and that some subjects who had worked with peers did not do significantly better than individuals. Miller & Brownell (1975) have argued that "...research should focus less exclusively on post-test gain and more on identifying the potentially generalizable aspects of the processes by which change comes about" (p. 997). This resulted in attempts to identify the critical aspects of peer interaction that might be associated with the gains made by some members of peer groups, but not others.

The results of the present study, which found no significant pre- to posttest differences across subject conditions, indicated that subject condition alone was not

sufficient to explain the findings of previous studies (e.g. Doise et al. 1975; Perret-Clermont, 1980) that demonstrated peers generally performed better than individuals. Closer examination of posttest scores, for subjects who were concrete operational (level 0) on the pretest, revealed that experimental subjects in high conflict dyads achieved significantly higher posttest scores than either control subjects or subjects in low conflict dyads. This indicated that experimental subjects in this study demonstrated significantly more progress than individual control subjects only if they generated significant levels of socio-cognitive conflict.

The seven high conflict dyads included two concrete dyads and five mixed dyads. Although the majority of high conflict dyads consisted of mixed level partners, no significant differences were obtained for the amount of conflict generated between concrete and mixed dyads. In other words, partners who were at different cognitive levels on the pretest candy combinations screening problem did not produce significantly more conflict than partners at the same developmental level.

While the results of the present study were consistent with Piaget's equilibration model of development, they did not appear to be in accord with findings reported by other investigators (e.g. Ames, 1980; Damon & Killen, 1982) regarding the role of conflict. In the previous studies

conflict was defined in terms of disagreements or negations, and a significant relationship was not obtained between these categories and progressive change. Ames reported some tendency towards agreement, and few instances of negation. Damon and Killen found that lower-level children who advanced were more likely to both accept and transform their partners' statements, and to be recipients of such acts, than to contradict or disagree with their partners. In their definitions, the authors did not conceptualize conflict to include resolutions as part of a total re-equilibration process. In the present study, conflict was conceptualized as part of a process requiring a disturbance produced by one partner and a resolution produced by the other. Resolutions to disturbances could take the form of agreement with, or ignoring, the disturbance. Thus, an agreement was not in opposition to a disturbance (e.g. disagreement), but was one way of resolving the disturbance. Continuous unresolved disturbances would have maintained the disequilibrium caused by the initial disturbance. According to Piaget (1977), re-equilibration occurs when disturbances are compensated (resolved).

The point was made that higher levels of socio-cognitive conflict was associated with more progressive change in the present study. Bearison et al. (1984) found that conflict and gain were curvilinearly related. In their study, subjects who generated too little or too much conflict did

not advance as much as subjects producing conflict in a middle range. The present investigator did not obtain the same results. Instead, higher levels of conflict were associated with mastering more chemical problems and with greater pre- to posttest change scores.

There is a possibility that the present data was truncated, and that still higher levels of conflict would not be associated with greater gains. The only data suggesting this stems from one dyad dropped from the statistical analyses. They were eliminated from the analyses because their discussions had not ended by the conclusion of several problem-solving sessions. They generated 92 conflicts more than the next highest scoring dyad (193 above the mean for high conflict dyads), but only mastered three chemical problems. All dyadic subjects who generated high conflict levels mastered four or five chemical problems, while low conflict was associated with mastering two or three problems.

In sum, the present study demonstrated that higher levels of socio-cognitive conflict were associated with mastery of more difficult problems requiring formal operational reasoning strategies, and for the internalization of those strategies as measured by individually administered posttests.

The Nature of Peer Relationships

The following observations of subjects working on

chemical problems are presented in order to convey the nature of peer interactions in high and low conflict dyads. No videotaped observations were recorded during the first session. Therefore, these descriptions pertain to sessions two through six.

Most discussions occurred during the setting-up and mixing phases of the experimental sessions. During the setting-up phase, discussions between subjects in high conflict dyads commonly involved planning which chemicals to try, hypotheses about the outcome of experiments, and role assignments. Role assignment allowed each partner to concentrate on particular chemical combinations, while eliminating replications between partners. Discussions during the mixing phase generally involved subjects' reporting experimental outcomes to each other, and their conclusions. This was common for both high and low conflict dyads. In addition, high conflict dyads often tried to explain unexpected findings.

Gino and Anthony were representative of low conflict dyads, and were particularly interesting because they were the only mixed-level dyad unable to solve more than two chemical problems. They did not engage in disagreements or explanations, during setting-up or mixing phases, until session 4, and did not solve the second problem until the fifth session.

During their first attempt to solve problem 2, Gino

(transitional level 2 at pretest) suggested several combinations, and Anthony (concrete level 0 at pretest) agreed. Anthony's only contribution was to suggest one combination in response to Gino's asking whether he wanted to try anything else. Even though they both suggested F alone was the effective chemical, after observing the experimenter's demonstration for problem 2 (B+D+E+F and C+F both caused a reaction), they did not experiment with any of the chemicals individually. It appeared that Anthony thought Gino was suggesting this, but failed to pursue it. Gino had inquired "What do you want to do first, just the F?" Anthony responded "Just the F." Gino then said "Okay, you want to try F with E, and F with D, and F with C, and F with B?" Anthony agreed to this, and they never tested any chemicals individually during this session. The effective chemicals were either B, C, or D, and they set up the following experiments (asterisks denote a color change):

BC*

BF*

DE*

EF

BDF*

Anthony poured the contents of the tubes and Gino added the mixing liquid. There was no discussion as they observed the results. After all experiments were mixed, they noted only one combination did not turn red. From this, Gino concluded

"any of these combinations combined will work, except for F+E," to which Gino responded "yeah."

The second time they attempted to solve problem 2, no discussion occurred during setting-up. During the mixing phase, only a couple of requests were made. These pertained to whether a color change had occurred, such as "E+F turned pink. Did C+F?" The effective chemicals were either B, D, or E, and they mixed:

BC*

BD*

CD*

CF

EF*

They again concluded any combination could work, except for the one combination that had not changed colors.

Although Gino and Anthony did not solve problem 2 during the next session, they generated their highest conflict level, and disagreements and explanations occurred for the first time. This seemed to enable them to reach conclusions that would prove helpful during the fourth, and finally successful, attempt to solve this problem type. Anthony suggested experimenting with F by itself, and offered the first explanation: "...we think F is the one that changes the color, so...maybe we should just pour F alone." Gino agreed, but neither suggested any other chemical by itself. They mixed:

F

BC*

BE*

BF*

CD*

CE*

CF*

DE*

Upon discovering F did not work alone, Anthony concluded "it could be any combination, but they don't work alone." However, Gino disagreed: "Well, we only tested out F." Several disagreements and explanations followed. Anthony maintained that any combination would work, but "the ones that are alone don't work, because we tried one alone, and it was the only one that didn't work. All the others worked." Gino was not sure that other single chemicals would not work, because "I don't think we have enough data. Maybe if we would have tried one, every one alone, maybe we could have been sure." In the end, Anthony agreed. At the next session, Gino suggested trying each chemical alone, thus finally enabling them to solve the second problem.

Problem 3 was presented during their final session, and they failed to identify the correct combination, B+C+D. This time they isolated each chemical, and set up nine of the ten two-way combinations. After mixing them and observing no color changes, Gino suggested they "didn't do enough

experiments. We should have put E with two other solutions and F with two others, and see if three solutions would change them." Anthony said "Yeah, maybe 'cause every single one we tried never changed." Although they did not identify the correct combination, Gino and Anthony showed progress in their reasoning. Contrary to many other subjects who failed this problem type, they did not assume that the only correct combination was the experimenter's demonstration (B+C+D+E). Instead of using this false inclusion strategy to arrive at an answer (which they had used during their first two attempts to solve problem 2), they reasoned that they could not rule out the possibility of a three-way combination, because they had not tried enough combinations.

The nature of peer interactions in a high conflict dyad was exemplified by Paula and Louise, both of whom were concrete operational (level 0) at pretest. They generated more total conflict during their second session than Gino and Anthony did on the second through fourth sessions combined. While Anthony and Gino did not disagree or offer an explanation until their fourth session, Paula and Louise did so from the second session. Although Gino suggested almost all the experiments he and Anthony set up, Paula and Louise contributed fairly equally. During the mixing phase, Paula and Louise each tested different experiments. However, they continuously checked with each other, and reported their findings to one another, as they proceeded. They also tried

to explain unexpected findings as they occurred.

Since they thought F was the effective chemical in problem 2, they were quite surprised to discover that F did not change color when tested alone. Instead of just observing this result, Paula referred to the experimenter's effective demonstration (C+F) and explained to Louise that "Because F was mixed with C, so it's a chemical that has to be mixed with something." Louise responded "So two of the capsules are the same. So it has to be the B and the C. C makes F work."

They were able to solve problem 2 on their first attempt because they tested each chemical by itself. Paula suggested this immediately: "We could do one of them, too." When Louise did not understand what Paula wanted to do and suggested a combination, "Yeah D+C," Paula disagreed, stating more clearly: "No, we should try just like the F alone, the C alone..."

Paula and Louise were unable to solve problem 3 on the first presentation, and this appeared to become apparent to them during the mixing phase. Instead of just noting they hadn't tried enough combinations, as Gino and Anthony did, Paula and Louise discussed which necessary combinations they failed to set up. After discussing several possibilities, Louise pointed to one of the experimenter's demonstrations, and said: "But see, look what she used. She used BDC+E. One, two, three, four to make the red. We need combinations

of either the first three or all four like she used the first time." Paula replied that "Maybe two work. See you don't know if it's two, because it could be like B+D."

Their discussions of unexpected findings were particularly useful when they tried to solve problem 4. The following interaction enabled them to attend to the negation as they mixed their experiments:

But then how come when I do
The C with the D and E, it
gets yellow?

The E and the D are nothing
either.

I'm getting confused in these
experiments.

Yeah, well I know it's some-
thing with B, like everything
with B turned. All the ones
I have with the B.

Yeah, but then I have one
here and it didn't turn.

C+D+E. Well, and F with
E didn't turn it.

Yeah. All these had at
least B or C?

D+C here is nothing. Uh oh.

Well, I have BF. So B+C+F
are identical solutions, and
they affect whatever they
come in contact with.

Uh oh, I don't know. Maybe
D+E has the same stuff.

Yeah?

Well, as far as I can see, C
and B are the solutions that
makes it pinkish-looking.

Yeah. All mine with B and C.

What did you use it with?

No, so I say B and C then
will turn it.

Yeah, see this is B and C.

Alright, let's put it this
way. Somehow these two
solutions are identical, B
and C, but mix one by itself
with D and it didn't turn.

Yeah, like no reaction to it, because then I have a D with E and F. Nothing. I have a lot of D's. Nothing. The D kills it like. It kind of takes away the C and B.

Yeah, yeah.

Paula and Louise solved problem 4 during their first attempt, but failed the most difficult problem on the last session because they had not set up enough combinations. Their interactions always reflected true collaborative problem-solving. Each partner checked every experiment she wanted to set up with the other partner. They constantly monitored each other during the mixing phase. Unexpected findings were discussed as soon as they occurred, often resulting in disagreements and explanations.

Although Paula and Louise advanced considerably from their individual pretest performances (concrete operational, level 0), they did not fully consolidate the combinatorial reasoning strategy. However, Paula advanced to transitional level 2 and Louise to early formal operational level 3 on individually administered posttests. Gino and Anthony each received the same posttest score as he did on the pretest.

Change in Conflict Scores Over Sessions

Forman (1981) maintained that successful collaborative relationships need time to develop. Findings from the present study indicated that time is also needed for relationships to become established so that socio-cognitive conflict levels increase. Significantly more conflict was

produced during the sixth session than during sessions two, three, or four, and significantly more conflict occurred on the fourth and fifth sessions than on the second session.

The possibility that higher conflict levels observed in later sessions was associated with the need to construct more combinations in order to solve advanced problems, rather than the number of times subjects interacted, was considered but rejected. In order to hold problem level constant for all subjects, only the amount of conflict generated during the second session was analyzed. All experimental subjects received the same problem (problem 2) during the second problem-solving session. There was a significant relationship between socio-cognitive conflict levels generated during this session and the number of problems mastered by the conclusion of the experimental phase. Mastery of four or five problems was associated with higher levels of conflict in the second session, and mastery of two or three problems was associated with lower conflict levels. These results seemed to partially dispel the view that the relationship between conflict level and gain was due to more advanced problems motivating higher conflict levels. However, no significant relationship was found between socio-cognitive conflict levels generated during session 2 and pre- to posttest change scores.

Formal Operational Reasoning Strategies

All subjects mastered at least the first two chemical problems from the series of five, indicating the presence of isolation of variables strategies. Examination of the simple plant pretest scores indicated that 55.7% of all subjects attained scores at the two highest levels. Thus, these subjects, like Kuhn's (1979) late adolescent sample, were capable of some formal reasoning in one context (the simple plant problem for the present sample) before the experimental phase. It is not unexpected then that 68% of all subjects who were concrete operational (level 0) on the combinatorial reasoning pretest advanced, at least, to the emergent formal level (1) on the posttest. Piaget has stated that the experimental isolation of variables leads to combinatorial reasoning strategies (Inhelder & Piaget, 1958). Subjects unable to master more than the two problems that required an isolation-of-variables strategy obtained significantly lower pre- to posttest change scores than subjects who were able to solve these plus at least one of the problems that required a combinatorial reasoning strategy.

One of the findings of this research was that higher levels of conflict were related to mastering four or five problems in the chemical problem-solving series. Lower levels of conflict were associated with mastery of two or three problems. Task analysis clarifies this sharp distinction. Different problems in the series of chemical

problems required different formal operational strategies for mastery. The first two problems in the series can be solved by applying an isolation of variables strategy to disentangle an existing combination. The last three problems required combinatorial reasoning strategies as well, necessitating the construction of combinations. To solve these latter problems, subjects had to first set up sufficient experiments. Then, to infer the operative chemical(s), an isolation of variables strategy was necessary (Forman, 1981). In order to solve the most difficult problems in the series, four and five, it was also necessary to abandon disconfirming evidence. Piaget (1977) noted the difficulty with which negations are constructed. In the present study members of high conflict dyads were able to abandon disconfirming evidence. Subjects in low conflict dyads were not, and falsely included the negation. Kuhn and Ho (1982) have identified false inclusion and ignoring disconfirming evidence as impediments to achieving formal operational reasoning.

One-third of all dyadic subjects advanced to predominantly formal levels of reasoning (levels 3 and 4) on the individually administered combinatorial reasoning posttest. The intervention technique used in this study did not train subjects in any way, or allow for experimenter feedback. Thus, the occurrence of change is considered to be the result of subjects' own construction of new reasoning

strategies and a reflection of formal operational structures. It should be noted, however, that Niemark (1975) and Kuhn and Ho (1980) have cautioned against the use of any single assessment problem as providing adequate evidence of an individual's level of reasoning.

Educational Implications

Current educational policy advocates unequal social interaction situations and, to a lesser extent, independent problem-solving. The social context of education overwhelmingly consists of a teacher transmitting information to less knowledgeable students. Sometimes, students are asked to discover solutions and acquire knowledge through their own problem-solving efforts, most notably through homework or workbook assignments. It is very rare that students are encouraged to collaborate with one another on projects. When this does occur (for example, in laboratory courses) each student is usually responsible for an independent product.

Consistent with Piagetian theory, the findings of this study indicate that peer collaboration can be a viable and facilitating tool to add to existing educational practices. Although no relationship was found for subject condition and progressive change, observations of different dyads demonstrated that a particular quality of interaction was associated with gains. These results suggest that when students work together, they need to be encouraged to raise

questions, ask for and offer explanations, and to disagree with one another. They should be made to understand the importance of mutual respect and the consideration of different ideas, thereby encouraging the participation of each student. In this way, peers who work together can refine, perfect, and develop strategies by monitoring the thoughts and actions of their partners, as well as their own. Social interaction can encourage justification and elaboration of one's own reasoning, and enhance consideration of other perspectives, leading to new cognitive coordinations and constructions.

There is both practical and theoretical merit for students' peer interactions. Practically, one teacher most often interacts with many students and cannot directly engage each one for any length of time. Cognitive developmental processes need time to develop. It is not unusual for students not directly engaged in discussion to lose interest. Theoretically, Piaget (1967) proposed that mutual respect between peers genetically follows unilateral respect, and "leads to a new organization...that is comparable to logic itself" (pp. 57-58). Bearison et al. (1984) observed that mutual balance in the expression of conflict between partners resulted in significantly greater gains than when one partner was dominant. They concluded that equal contribution to the social dialectic "structures the coordination of interindividual perspectives" (p. 25).

APPENDICES

APPENDIX A

Examples of Peer Interaction Codes

The following speech acts are examples of each disturbance and resolution defined in the methodology section, peer interaction codes. A speech act for each partner is set in a separate block, and each line connecting any two blocks was scored as one conflict. The code assigned is in parentheses.

A. Initial Disturbances

1. Initial Disagreement.

You do all of them alone.

No, you do that.
(Initial disagreement)

Oh, okay.
~~(Agreement)~~

2. Initial Explanation.

I think it's C to turn red.

I think it's B, because it
turned red with BC, but not
with C, D and E.
(Initial explanation)

(Ignore)

3. Initial Question.

How about trying each one
alone?
(Initial question)

That's sounds good.
(Agreement)

B. Final Resolutions

1. Ignore.

I think it's B, do you?
(Initial question)

I am trying combinations of
twos, then three together,
then some more.
(Ignore - unrelated answer)

2. Agreement.

It's gotta be B, 'cause it
was in the two that worked
there, and it's the only
one in both...so it's gotta
be that.
(Initial explanation)

Yeah, I was thinking the same.
(Agreement)

I think we should start
with all alone, what do
you say?
(Initial question)

All alone and also two's then.
(Agreement by integrating
partner's speech act with
own).

C. Chains of disturbing resolutions

1. Disagreement.

What you said can't be.
It's no sense.
(Initial disagreement)

I'm right. I know it.
(disagreement)

Look here, see B didn't
work with D and E, so
it can't be B.
(explanation)

Oh, you're right.
(Agreement)

2. Explanation.

So, you think it's C?
I'm thinking it has to be.
(Initial question)

Yeah, 'cause look. It works
every time we used it, and
none of the others
work...alone or with more.
(explanation)

Okay, so let's tell her
we think it's C.
(Agreement)

3. Question.

What you said is wrong.
(Initial disagreement)

Yeah, why?
(question)

(Ignore)

4. Chained response.

Alright, it's got...has to
be a combination. The C
works with everything, and
the B doesn't.

No, no, look the B does.
(Initial disagreement)

Look here. The B didn't
work when I used B+D+E.
It works alone, and it
works with B+F. So, some-
thing sometimes stops the
B from working.
(explanation)

Well, so you think D+E stop
it?
(question)

D+E, I don't know.
(Chained response)

We should have tried just like
B+D and B+E, because now we
don't know if D+E stops it, or
if just one of them stops it.
It be that only the D, or only
the E stops it.
(explanation)

Right, right. Why didn't
we think of that when we
put them together?
(Agreement)

APPENDIX B

Examples of Difficult-to-Code Speech Acts

The following are examples of speech acts that were difficult to code. They did not seem to clearly fit the definitions of any category code.

The following final resolution was coded by eliminating other possibilities. This speech act obviously did not fit any of the chained codes. It also did not fit the ignore code, since there was a response which appeared to be related to the disturbance. Having eliminated all other possibilities, the agree code was assigned.

Anything involving F or E
with any solution, but not
together.

No, it doesn't mean to say it
has to be with F and E,
because this has C and B over
here and that works.
(Initial explanation)

Oh.
(Agree)

A disturbance beginning with "let's" was coded as a question. "Let us" seemed to imply something that both partners should be doing. Thus, the recipient of this speech act needed to agree or disagree.

Let's do each alone.
(Initial Question)

Okay.
(Agreement)

The overwhelming majority of discussions between partners fell into clusters of one speech act followed by another. However, there were several instances where one partner produced two disturbances before the other replied. Although it did not appear the second partner ignored the first disturbance, the ignore code was assigned by empirical necessity since all disturbing speech acts must be resolved. The ignore code was the only code that could accommodate no overt response.

No, no. We have to have C alone. Let's try threes. We never did like threes. You know like D with E and F.
 (Initial Disagreement)
 (Initial Question)

(Ignore)

Yeah, threes.
 (Agreement)

Lengthy speech acts sometimes created a problem in code assignment. This occurred when one partner interjected while the other was generating one disturbance. It was decided to code these cases as one disturbance and one resolution.

Oh no. Look, B+D+E didn't work.

It could still be B, because we have two maybe negative chemicals and the C is also like a positive,

Yeah

so the C like gets under to override the negatives

Yeah, oh yeah

and the B can do the same
thing like. So the B and
C will work, but not if
they're alone with these
two

Right, good.

Yeah

because then like the two
negatives overtake the one
positive.

(Initial Explanation)

Yeah, they overcome the
solution that makes it red.
(Agreement)

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