DOCUMENT RESUME

ED 390 709 SE 057 574

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TITLE Assistance in Science-Related Parent-Child Interactions: Problem Solving in the Zone of Proximal Development (ZPD).
PUB DATE Apr 94
NOTE 40p.; Paper presented at the Annual Meeting of the American Educational Research Association (New Orleans, LA, April 4-8, 1994).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS *Academic Achievement; Classroom Environment; *Cognitive Development; Cultural Background; *Parent Child Relationship; Parent Participation; *Problem Solving; *Science Activities; Science Experiments
IDENTIFIERS *Zone of Proximal Development

ABSTRACT

This study sought to connect the science activity educational approach to the higher cognitive development of students using a relatively new learning model, the Cultural Historical theory, based upon the work of Vygotsky. The theory advances the concept that children's intellectual development occurs in interactions with an adult or more capable peer in a zone of proximal development. The activity setting serves as the unit of analysis and is composed of five features which are both objective and subjective: personnel, scripts, task demands, goals, and values and beliefs of the participants. One such setting, a parent-child interaction during science problem solving, was examined for cognitive development. Parent child interaction analysis evaluated dyadic interaction variables that supported child conceptual development during the performance of three science experiments. A cooperative problem solving style was isolated which reflected interaction characteristics that could predict child's intellectual performance in both science tasks and science school achievement. (Author)

Assistance in Science-Related Parent-Child Interactions:
Problem Solving in the Zone of Proximal Development (ZPD)

by

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Paper presented at the
1994 Annual Meeting of the
American Educational Research Association
New Orleans, Louisiana
April 4-8

Abstract

The study sought to connect the science activity educational approach to the higher cognitve development of students. this effort involved a relatively new learning medol, cuttural historical (CH) theory, based upon the work of Vygotsky (1934/1986). The tehory advances the concept that children's intellectual development occurs in interaction with ana audlt or more capable peer in a zone of proximal development (ZDP). The activity setting (Tharp & Gallimore, 1988) serves as the unit fo analysis for CH theory. The setting is composed of five features which are both objective and subjective: personnel, scripts, task demands, goals, values and beliefs of the participants.

One such setting, i.e., parent-chjild interaction during science problem solfving was examined for cognitive development. Parent child interaction analysis (PCI) evaluated dyadic interaction variables that supported child conceptual development during the performance of three science experiments. A cooperative problem solving (CPS) style was isolated which reflected interaction characteristics that could predict child's intellectual performance in both science tasks and science school achievement.

Introduction

The performance of activities in science classrooms has been shown to be beneficial for student achievement (Breddarman, 1983; Shymansky, Kyle & Alport, 1983, Shymansky, Hedges & Woodworth, 1990; Weinstein, Boulanger & Walberg, 1982; Wise & Okey, 1983). In an effort to link science activities in the classroom and the higher level cognitive functions of students, more needs to be known about how aptitude in science or other subject matter is formed. A relatively new model has emerged which may be helpful in understanding science learning, ie.e., cultural historical theory or the sociocultural theory.

In the cultural historical (CH) model, intellectual performance that is assisted often by more expert others is considered important in defining the zone of proximal development which Vygotsky (1978) described as involving (mental)

> functions that have not yet matured but are in the process of maturation, functions that will mature tomorrow but are currently in an embryonic state. These functions could be termed the 'buds' or 'flowers' of development rather than the fruits of development. The actual developmental level characterizes mental development retrospectively, while the zone of proximal development characterizes mental development prospectively (pp. 86-87).

To achieve their full-valued meaning as represented in the culturre, word meanings and sciencd concepts first mut be developed or negotiatied in adult-child interaction and activity in a zone of proximal development (ZPD). Vygotsky (1978) offered the following operational description of the ZPD:

> The zone of proximal development is the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers (p. 86).

Each new concept that the child encouters represents an aooprtunity to create a ne zone. The distance between the child's point of understanding and the adult's point of understanding can be bridged theorugh adult-child interaction in an acitvity (tharp & Gallimore, 1988). In this way, the zone is made to expand

Gallimore and Tharp (1990), operating int he CH framework, also emphasized that it was through "joint activity" (p. 71) that the adult and child establish a state of intersubjectivity in which there is agreement upon "the signs and symbols developed through language," and there is "the development of common understanding of the purposes and meanings of the activity" (Tharp & Gallimore, 1988, p. 89). The intent fo the instruction in this paradigm is to give students enough support in theZPD that they eventually will be able to attain the ghier levels of the conceptual hierarchy on their own (Moll, 1990; Newman, Griffin & Cole, 1989).

There is a need to study ZPD interaction "both in and out of school" (Mehan, 1979, p. 6). Sepcifically there is a neet to examimine the antecedents of the adult-child interactions found in school. The child's interaction with his first teacher, ie.,e his parent, should be investigated (Gallimore & Tharp, 1988).

Parent-child dyadic interaction studies are a topic of increasing interest for research (Farran & Haskins, 1980; Portes, 1988; Radziszewska & Rogoff, 1988, 1991; Rogoff, Malkin & Gilbride, 1984; Tudge, 1985; Wertsch, McNamee, McLane & Budwig, 1980; Wertsch, Minick & Arns, 1989). Much analysis of the support structures in the ZPD has been conducted through the observations of adult-child dyads engaged in problem solving tasks (Rogoff, Malkin & Gilbride, 1984; Brown & Ferrara, 1985). Such support structures have been designated as scaffolding (Griffin & Cole, 1984).

Perhaps Tharp and Gallimore's (1988) most significant contribution to the study of the ZPD is the concept of <u>activity setting</u> (AS) which serves as the unit of analysis for CH theory.

> For a ZPD to be created, there must be a joint activity that creates a context for teacher and student interaction (p.71)....Contexts in which collaborative interaction, intersubjectivity, and assisted performance occur--in which teaching occurs--are referred to as activity settings (p.72).

The activity setting, in which learning takes palce, is defined by five variables: 1) the personnel present, 2) the motivations and purposes of the actors, 3) the scripts used, 4) the task demands or operations of the activity, and 5) the goals, beliefs and values involved (Tharp & Gallimore, 1988; Gallimore, Goldenberg & Weisner, 1992; Weisner, Gallimore & Jordan, 1988).

> This includes both objective and subjective features in a united definition of "settings." Uniting the objective features of personnel and task with the subjective features of values, motivations and purposes is a new experience for many social scientists and practitioners. Because these

> features have been typically separated. "The activity setting concept requires some practice before its use is comfortable" [O'Donnell & Tharp, 1990, p. 253]....Objective and subjective features are never sharply separated in AS. Beliefs and values contribute to the "reality" that is perceived (Gallimore, Goldenberg & Weisner, 1992).

Being both subjective and objective in scope the activity setting serves to describe the environment of the ZPD, as well as to explain a child's developmental traits including science aptitude.

In this study, both the actual and proximal levels of developmeent in parent-child activity settings are examined very briefly, in microgenesis, one of three avenues for psychological study described by Vygotsky (Wertsch, 1985b). Maternal assistance patterns are explored in tracing how a given function appears in the inter-psychological plane before being adapted individually as suggested by the first law of cultural development (Vygotsky, 1978). However, without a longitudinal study, only snapshots are provided of the development of higher level psychological functions.

The Problem

One assumption in this investigation is that certain aspects of social interactions inherent in learning situations promote better conditions for conceptual development than others. In paarticular, strategies and assistance, which target the ZOD, need to be explored in relation to student science performance. Another assumption is that the antecedents of school achievement may be found largely in adult-child interaction patterns. the central research questions in the study are: What are some usefulways to characterize (ZPD related) mediational activities in social interactions? what are the characteristics of parent-child interactions and how do they relate to student achievement in science.

Method

A pool of student volunteers from seven schools in a metropolitan area was recruited. After their seventh-grade science teachers distributed the permission requests, the forms were completed by the students and their parents. The permission requests called for volunteers to participate in the PCI study. The form requested permission to obtain the most recent CTBS (California Test for Basic Skills) science scores for the student volunteers. Thirty-two students were chosen for the study. Sixteen students ranked low in science achievement (Normal Curve Equivalent Score NCES =/<50 and mean = 36.4), and sixteen students ranked high in science achievement (Normal Curve Equivalent Score NCES >70 and mean = 83.6). Demographic data was also collected for the thirty-two student volunteers and their families.

The reason for choice of seventh grade is important. It has been documented that students around this age either choose to like or not to like science (Connor, 1990; NSF, 1987). In an effort to gauge the extent of this problem, a science attitude questionnaire was used.

Procedure

Parent Child Interaction (PCI), draws from the work of Portes (1988, 1990,. 1991) in identifying parent-child interaction variables related to intellectual achievement. In this study, thirty-two parent and child pairs from the above volunteer pool were invited for a joint one-hour videotaped interview. A five minute warm-up period, during which the experimenter asked the parent and child questions concerning science, began the PCI. After this warm up, the child was asked to perform three science activities (see Appendix). After the tasks were assigned and written instructions were given to the pair, and the mother was told that she could help at any time.

The tasks were arranged in order of increasing difficulty. The first task consisted of a floating or sinking block experiment which involved prediction. The second task required the dyad to make all possible combinations of five household chemicals (combinatorial logic). The third task involved the testing of acids and bases. The dyad was to construct an algorithm from initial information and to use the algorithm to determine if four other household solutions were acids, bases or neither. The tasks were scored by awarding points for those portions which the dyad successfully completed. The maximum possible score for each task was 100. The maximum score for all three tasks was 300. The outcome measures for the tasks were: Task total score from 1 to 300, Task , Task2, and Task 3 each scored from 1 to 100. These scores were ranked for some analyses: Task total score rank (TSKTRK) where 1 =/< 264 (low group) and 2 >265 (high group).

Coding Method

One trained judge transcribed and coded the thirty-two transcripts into twenty-six interaction categories which have been described in an earlier report (Portes and Cuentas, 1991; Portes 1988). These categories or variables were designed to reflect metacognitive guidance, modeling, feedback, reinforcement, questions (Tharp & Gallimore, 1988), and other task-oriented mother-child interaction characteristics. The variables are listed below.

INTERACTION CATEGORIES

PC1 C responds to M's question, comments, stimuli
PC2 M/C initiates and ends task operations
PC3 M asks open-ended questions
PC4 M ask close-ended ques (Yes/no answers)
PC5 C asks question or for feedback or help
PC7 C agrees with M
PC8 C interrupts M
PC9 C refuses M's help or ignores M's stimulus
PC10 M/C rejects C/M's answer; demands more information; disagree
PC12 M/C finds tasks difficult; lack confidence
PC13 M/C expresses confidence in self, capable
PC14 M/C egocentrric speech
PC15 M/C general comments
PC16 M/C asks E for clarification/instruction/respond to cue
PC17 E cues
PC1' M/C imperatives or directives (Let's) (verb)
PC19 M directs attention verbally, cues, prompts
PC20 M directs attention physically (points, manipulates)
PC21 M directs attention physically and verbally
PC22 M uses positive reinforcement/encouragement/agreement
PC23 M interrupts with chorus response or adds information
PC25 M/C task irrelvant responses
PC26 M/C truncated
PC27 M/C humor
PC28 M/C shift or responsibility
PC29 M/C requests repetition

A coding manual was developed and used extensively in the coding and in the training of raters. Two trained raters examined independently each of the thirty-two transcripts along with videotapes, and scored behaviors along the defined response categories (interaction variables).

After independent scoring was performed, disagreements were resolved by the raters and a judge. The average reliability for the present measures was estimated at .84 and ranged from .81 to .89. These improved substantially (Mean = .97) after resolution of disagreements was reached and subcategories were combined.

The videotapes were also analuzed for qualitative features which served to distinguish parent-child discourse that supported or enhanced student achievement. The PCI study characterized adult-student interactions and how these related to student achievement in science. The characteristics of adult-child inteactions that support student achievement in science and intellectual development in general are presented next.

Results

Statistical Analyses

Correlations between PCI interaction task scores and school achievement were examined to determine if a relationship existed. Significant findings are represented in table 1.

Table 1 Correlations Among Achievement Variables

	Task1	Task2	Task3	Task Total
Task1				.38*
Task2			.56**	.80**
Task3				.90**
Task Total	.38*	.80**	.90**	
NCES		.53**	.68**	.69**

*p </= .05 **p </= .01 NCES = Normal Curve Equivalent Science

As expected, task performance success in the PCI study was directly related to science achievement.

In order to determine which interaction characteristics in the performance of the above tasks were related to children's scientific aptitude, achievement variables for the tasks and NCES were correlated with the parent-child interaction meausres. Sigr ficant findings are presented in table 2.

Table 2

Correlation of Interaction Variables and Achievement

Variable	Description	NCES	TskTotal
PC4	M closed questions	.37*	.34
PC7	C agrees	.55**	.48**
PC8	C interrupts	.40*	.41*
PC15	M/C general comments	.30	.48**
PC20	M physical cues	.30	.36*
PC22	M encouragement	.31	.45**
PC23	M interrupts	.41*	.44*

*p </= .05 **p </= .01

Discriminant function analyses were employed to explore if a similar set of interaction variables were related to student performance in science (see Appendix, tables i, ii, and iii). Six parent-child interaction variables were found to be of statistical and theoretical significance.

A principal components analysis (PCA) was employed in the next part of the study to uncover meaningful patterns of interaction. This exploratory factor analysis serves to uncover interaction styles that may reflect, to some degree, a regularity in the cognitive environment of the home. The PCI interaction variables were found to be defined by one general factor. The latter was selected on the basis of a Cattell's Scree Test and had an eigenvalue of 4.57 which captured 76% of the variance of the interaction measures (see Appendix Table iv and Table 3 below).

TABLE 3
Factor Matrix and Communalities

Var.	Description	Loadings Factor 1
PC22	M encourages	.90584
PC23	M interrupts	.90319
PC8	C interrupts	.89070
PC7	C agrees	.84995
MVP1	M v/p cues	.84561
PC4	M close ques.	.84070

Var.	Description	Communality
PC23	M interrupts	.81575
PC22	M encourages	.82055
PC8	C interrupts	.79335
MVP1	M v/p cues	.71505
PC4	M close ques.	.70677
PC7	C agrees	.72242

The above factor represents a style of interaction in which the mother uses positive reinforcement, encouragement and agreement (.90). She freely interrupts as well as injects additional information (.90). The child feels free to interrupt with addition information (.89) and agrees with mother (.85).

Mother provides scaffolding in this interaction through closed questions (.84) and through verbal and physical cues (.84). The style of interaction suggests a vigorous information exchange that is reciprocal, yet largely mother-guided. This overall pattern will be referred to as the Cooperative Problem Solving (CPS) factor.

Factor scores were generated for each subject and correlated with NCES scores and task total scores. The relation between the CPS pattern of interaction and students' intellectual performance was found to be significant (see Table 4) in terms of both task and school scores in science.

Table 4

Correlation Between CPS Factor Score and Achievement

	CPS SCORE
NCES	.4389*
Task Total Score	.4827**

*p </= .05 **p </= .01

In order to determine the extent to which high and low (NCES) achievers differed in the CPS interaction factor, mean differences were tested and found to be statistically different. Group 1 (low achievement) factor score mean was -0.46, and group 2 (high) mean was +0.46 ($F[1,30] = 8.28$; $p < .01$). The same pattern held when task performance was examined ($F[1,30] = 3.76$; $p. = .06$). Group 1 (low achievement) factor score mean was -0.33, and group 2 (high) factor score mean was + 0.33. The factor score reflects the extent to which a particular dyad's interaction is like or not like the CPS style. In sum, the CPS factor was found to be predictive of intellectual performance in both science tasks and science school achievement.

Further Analysis of the CPS Factor: Relationship with NCES Scores

Given the finding that the CPS interaction style was predictive of student aptitude in science, a more in-depth analysis of this factor was conducted. The interactions of high and low (NCES) achievers were contrasted for tasks two and three. In the Appendix, the first vignette shows the way a high achiever and his mother (dyad 019) set about the task of making all the possible pairs with five solutions. The dyad's discourse in this task was characterized mainly by maternal positive reinforcement, interruptions, verbal and physical cues and closed questions, while the child interrupted and agreed. This dyad made all possible combinations and achieved a perfect score of 100 for the task. The dyad's factor score (FS) was 0.22.

Vignette two (see Appendix) represents the conversation of low achieving child and mother (dyad 029) during the resolution of task two. Infrequent occurrences of CPS interaction variables characterized the discourse. The student demonstrated less agreement with and interruption of mother during the task performance. Mother gave less encouragement/positive reinforcement. She also did not interrupt and did not issue verbal or physical cues or closed questions as often as mothers of high achieving children. Their final score for the task was 30, and the factor score for this dyad was -1.34.

In contrast, as seen in vignette 3 (Appendix), the interaction pattern of another high CPS factor dyad (013) in the performance of task three was characterized by high frequencies of maternal encouragement, verbal and physical cues, child agreement and interruptions. The dyad's FS was 0.89, and the pair achieved a perfect score of 100 on the task.

Further Analysis of the CPS Factor: Relationship with Task Performance

In examining the relationship between achievement on science tasks and CPS factor scores, it became apparent that an analysis of the pattern of maternal regulation related to task difficulty could prove consequential. The success rate that high and low science achievers had in solving the three tasks in the PCI interview is demonstrated in Figure 1 and Table 5 below. The table also indicates whether the child solved the task alone, whether mother solved alone, whether there was no solution, or whether mother regulated the solution, e.g., by using actions contained in some of the CPS variables.

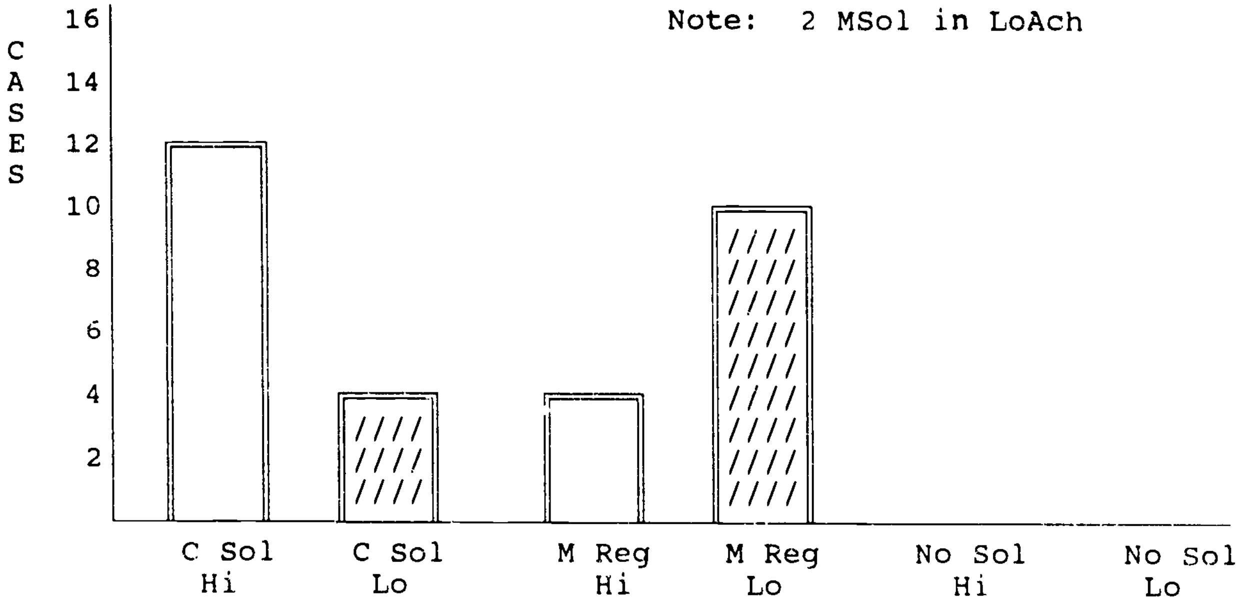
Note For following Figure and Table:

HiAch = High Achievers
LoAch = Low Achievers
NoSol = No Solution
CSol = Child Solves Alone
MSol = Mother Solves Alone
MReg = Mother Regulates Solution
Avg. Score = Average Score

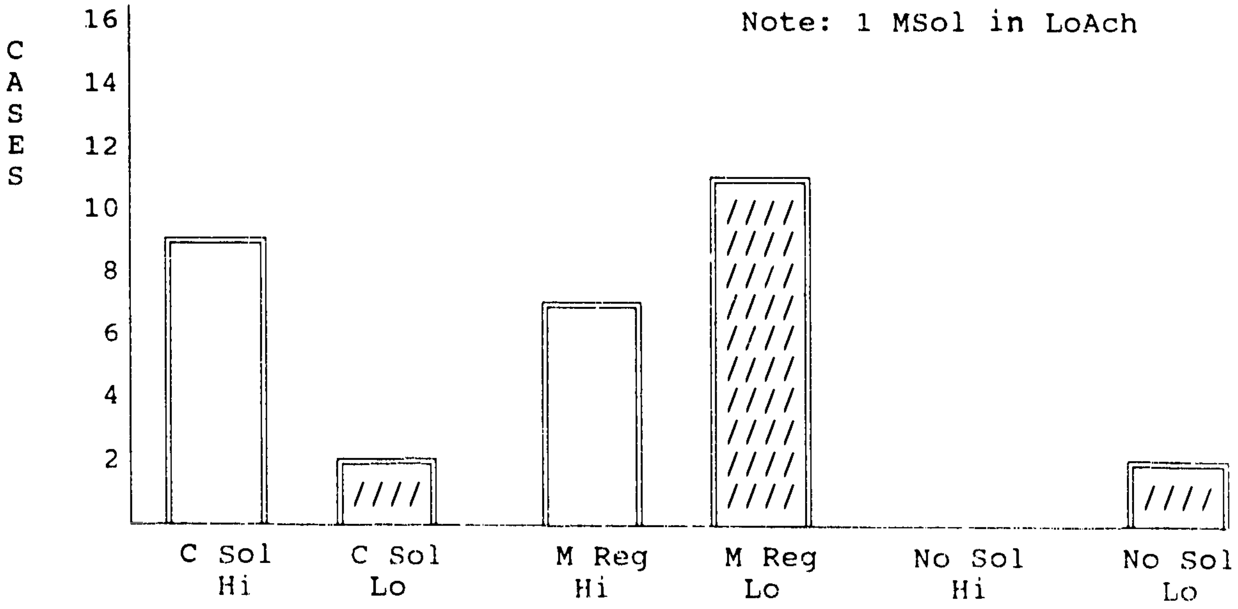
FIGURE 1

Success Rates on Tasks

TASK ONE LOW DIFFICULTY



TASK TWO MEDIUM DIFFICULTY



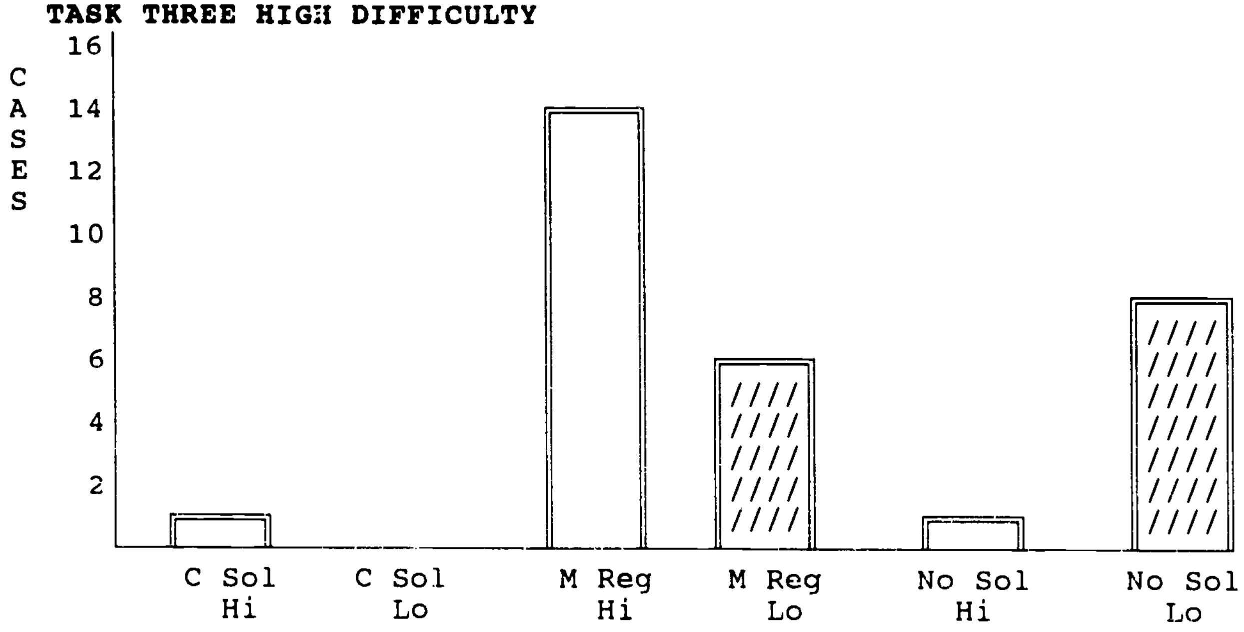


Figure 1. Success Rates on Tasks

TABLE 5
Success Rates on Tasks

Scores on the tasks

Case#	TASK1				TASK2				TASK3			
HiAch	No Sol	C Sol	M Sol	M Req	No Sol	C Sol	M Sol	M Req	No Sol	C Sol	M Sol	M Req
002		100				100						100
003		67				100						100
005		67				100			00			
006		100				100						100
008				100		80						100
009		100						10C				100
011				100				100				75
012				100				100				100
013				100		100						100
016		100						100				100
019		100						100				100
021		100						100				100
022		100				100				25		
025		100				100						75
026		67						100				100
028		67				100						100
Avg. Score		89		100		98		100		25		96
LoAch												
001		100						80				25
004				100				70	00			
007			67					70	00			
010		67						60	00			
014				100				100				50
015				100				60				25
017				67	00				00			
018				100				80				100
020				100		100			00			
023				100	00				00			
024		100						100	00			
027				33				70				50
029			100				30		00			
030				100				100	00			
031				100				90				75
032		100				40			00			
Avg. Score		92		90		70		80				54

From the graph, in Figure one, and Table 5, it can be seen that the simplest task (Task 1) was solved by the child alone most commonly among high achievers, while this task received more maternal regulation among the low achievers. Task two, which examined combinatorial logic, demonstrated much child-solves-alone activity among high achievers (but a typical perfect score when mother regulated). Among low achievers, the child rarely solved task two alone, and mother often regulated (but the dyad only infrequently achieved a perfect score). There was only one child-solved task three, and the score was 25. While mother regulation was commonly associated with perfect scores in the case of high achievers, high scores on task three resulting from mother regulation were rare for low achievers, and the most frequent course of events was problem insolution among this achievement group.

Discussion

These results suggest that CPS and the observed style of mother-child interaction are meaningful and significantly related to the achievement level of the child. The cooperative problem-solving factor (CPS) represents a pattern of interaction comprised of maternal support variables that assist (scaffolding) the child to be an active learner both at home and school. Mother offers support, while the child attempts to take responsibility gradually for the performance of the task. The picture is one of elaboration and positive reinforcement. The mother is so intent upon the scaffolding procedure that she feels free to interrupt at any time with genuine reinforcement or with additional information to help the child to deal with the science task. In turn, the child feels the freedom to interrupt mother, to offer agreement, to interject his own ideas, or to take over the information which the mother has provided to accomplish the task. The child often demonstrates agency, i.e., "individual(s)-operating-with-mediational-means" (Wertsch, 1991), after metacognitive assistance is provided. The level of intersubjectivity, i.e., the joint engagement in the development of understanding (Tharp & Gallimore, 1988), is demonstrated both by the child's feeling of freedom to interrupt and by the child's willingness to agree with mother and with her mediational style. The mother's mediational style is characterized by a series of verbal and physical cues, as well as closed questions.

CPS captures conditions in which task-oriented dyads who interact vigorously are the ones who tend to have children who are successful in school. Mother and child are willing to interact in the intersubject or interpsycholgical plane, an environmental regularity that is supportive of cognitive development. It may be that the child does not initially attain the over arching concept, but the process is one in which the child later on may make deductions based upon the internalization of the actions (semiotic uptake) which took place during the problem-solving event (Wertsch & Stone, 1985; Wertsch, Minick & Arns, 1989).

The CPS interaction variables were readily demonstrated by the discourse between the members of one dyad (019) during the resolution of task two and by another dyad (013) during the performance of task three. The discourse was characterized by the mother giving positive reinforcement/agreement/encouragement and interrupting to provide additional information or cues and closed questions. The child member of the dyads felt freedom to interrupt and demonstrated the intersubjectivity by agreeing with their mothers. Mother and child were vigorously involved in conceptual development. It would appear that maternal regulation characterized by the six variables which make up the CPS factor (see Table 3) serves to promote science achievement. The temporal order, however, must always be questioned. High achieving students may cause this style of interaction to occur more frequently with their parents.

It is interesting to note that when the experimenter told the mother in the dyad 013 that she could help at anytime, the mother replied: "He usually does things by himself. Very independent. Has been since the day he was born." Yet mother and son worked together in a team-like fashion to solve a perplexing problem. In fact, none of the students was able to solve task three independently of mother's regulation, as Table 5 demonstrates.

Low achieving dyads' task interactions were characterized by less CPS. The picture was more passive. From the above transcription, it was obvious that mother and child were not interrupting each other with vigorous interchanges. Mother was not giving much positive reinforcement/encouragement. The child was active in the task, but not that interactive with the mother, and he was not able to demonstrate concept development (combinatorial logic). What is more, the approach the dyad took to the task made it appear as if they had not read the directions adequately. For some interaction measures, such as verbal/physical cuing, there was a fundamental difference in the way the written directions were used. High achievers' mothers were less concrete, i.e., their cues were less based on repeating verbatim or paraphrasing the written instructions. Often, lower achieving dyads seemed to demonstrate an almost purely physical dependence upon the written directions, e.g., pushing directions at the child. Such performance hints at illiteracy, (or possibly the level of attainment of higher order thinking skills or representational thinking, [Sigel, 1979]) and as such brings into question an important variable of the activity setting, i.e., task demands. In order to perform the science tasks, the dyad had to be able to read the directions. The interaction measures were important differentiators of student achievement, but did some of the difference in task performance scores reflect the fact that high achieving dyads were more literate?

Conclusion and Implications

One way to lend meaning to the present results is to understand them using the concept of activity setting (AS) in the analysis of children's development of scientific aptitude. The AS unit provides for the analysis of development of five factors in children's socio-cognitive environments. The activity settings constructs of personnel, scripts, task demands, goals and beliefs, thus serve the ensuing discussion.

The parent-child interactional analysis (PCI) described a pattern of interaction comprised of maternal support variables that assist or "scaffold" the child's development. The mother and high achieving child dyad seemed to possess a set or to demonstrate a prior acquaintance with the type of problem represented by the science tasks. Their approach made the problem appear familiar, and their goal was to win at the game. The mother and high achieving child seemed to have already the prerequisite skills and knowledge to complete the experimental tasks.

The CPS factor revealed that mothers of high achievers offered encouragement and support through questions and cues, while the child attempted to take responsibility for the performance of the task. Mother and child interacted vigorously, frequently interrupting in order to solve the problem at hand. The intersubjectivity, apparent in the dyad's interaction, reflected that shared beliefs and goals were present.

The dyad composed of mother and low achieving child's exchanges were less participatory, and the child was more passive. The mother did not provide the type of scaffolding that supported conceptual development. In fact, the mother did not reinforce or encourage as much, nor were there animated information exchanges characterized by interruptions and agreement. Why this was so can only be conjectured, but may be related to educational and occupational factors that influenced various needs.

It is not certain whether mother a d low achieving child had an established pattern of working together in problem solving events, while high achieving dyads seemed more predisposed to adapt to this situation. The chief obstacle for the lower achieving dyad could have been the script itself. While mother and low achieving child probably had worked together in other settings, the science activity might have required knowledge and scripts quite alien to them. The foreigness of the scripts or operations necessary to do well prevented the dyad from succeeding. The goals which these dyads had in mind were not clearly evident and such a finding supports previous research (Wertsch, Minick, & Arns, 1989).

The task demands perhaps shed the most light on the difficulty the mother and low achieving child encountered. The mothers of low achievers relied on the printed directions to anchor their interactions. As was noted before, some mothers literally pushed the printed directions at their child instead of using verbal cues. In order to perform the science activity, the dyad had to be able to read the directions. Literacy was an important task demand. High achieving dyads did not rely on concrete directions, but rather, seemed to "distance" their discussions toward problem requirements. Thus these mothers "distanced" their assistance strategically (Sigel, 1979).

As may be noted in Table 5, mothers of low achievers were able to assist fairly well during the first task which required prediction based upon sinking or floating blocks. Perhaps this task required less reading ability, or it could have been that the experiment was similar to situations which the dyad had experienced in everyday life. The task may have appeared more meaningful, and the familarity could have led the dyad to believe that they could solve the problem. Tasks two and three required abstract thought and were less applicable to everyday life. Low achieving children required more assistance and were less likely to obtain it from mothers, who frequently failed to see the problem. On the other hand, high achievers and their mothers often seemed impelled by the challenge presented by tasks two and three, and the adults's resources were employed.

In sum, the results of this study seem to indicate that parents who manifest a capacity to guide children's problem-solving activities through the means shown in the CPS factor tend to have children who are more advanced in science achievement in school. These students are also more capable of solving science tasks. As Vygotsky (1986) noted: "Context mediates the acquisition of scientific concepts and the child's development in general." The willingness to interact with intersubjectivity or on the interpsychological plane is an environmental regularity that is supportive of cognitive development. Families with less cooperative problem solving have children who tended to be less involved with the science tasks, less actively invested in the task at hand, and who demonstrated less of a sense of agency. Literacy problems may also play a role in their poor performance.

Limitations

One important limitation for the current study was the recruitment of the low NCES achievement group. Most students who returned the consent form had NCES of 28 or greater.

Teachers explained that very-low-achieving students attended school sporadically, and that their parents were often absent from the home. Some teachers stated that the parents of the lower achievers could not read the consent form.

Future Study

In order to more adequately assess the effects of teaching-learning interactional environment on conceptual development, different achievement indicators could be used. In the implementation of the Kentucky Educational Ref rm Act (KERA), provision has been bade to evaluate student learning through the use of performance events. Perhaps the results of these events could be used to assess conceptual development in relation to teaching-learning interactions.

Another area for future research should involve a closer examination of how students make instrumental use of assistance, relative to the way it is provided on those occasions in which the child manifests "semiotic uptake" during the observation of the performance of science activities.

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Note 2 Concerning Science Tasks

The science tasks were derived in whole or in part from the following works:

Rutherford, F. J. (1989). Project 2061 Science for All Americans, Washington, D.C. : AAAS

1990 Boysen, E.C. KERA (Kentucky Education Reform Act) Six Goals or Learning Outcomes in Science. Frankfort, Ky.: Commonwealth of Kentucky Office of Education.

Inhelder, B. & Piaget, J.(1958). The growth of logical thinking from childhood to adolescence. New York: Basic Books.

Task 1 consisted of a sinking/floating block experiment which involved prediction and inference. It was adapted from The Science Report Card: Elements of Risk and Recovery. National Assessment of Educational Progress (NAEP) (1988). Princeton, New Jersey: The Educational Testing Service.

Task 2 consisted of making all combinations of five household chemicals and can be found in various forms in the following works:

Skolnick, J, Langbort, C., & Day, L. (1982). How to encourage girls in math and science. pp. 137-138. Prentice Hall.

Vaidya, N. (1970). Some aspects of Piaget's work and science teaching, pg. 131. S. Chand, New Delhi.

Rutherford, F. J. (1993). Benchmarks for science literacy,p.291. New York: AAAS.

Task 3 consisted in constructing an algorithm to test acid and bases and to analyze the acid or base status of several solutions. This task can be found in various forms in the following works:

Fredericks, A. D. & Asimov, I.(1990). Science fair handbook, p. 26. Glenview, Ill.: Good Year Books.

Unesco (1973). New Unesco source book for science teaching, p. 55. The Unesco Press.

Rutherford, F. J. (1993). Benchmarks for science literacy, p.297. New York: AAAS.

APPENDIX

Parent-Child Interaction (PCI) Tasks

TASK 1 FOR PARENT AND CHILD

Instructions: test to see which of these blocks sink or float and see what types of statements of general rules you can come up with. Record your results on this paper.

Block size	Type of block	Check one: Sinks	Floats
1 inch	wooden block		
1 inch	steel block		
3 inch	wooden block		
3 inch	steel block		
5 inch	wooden block		
5 inch	steel block		

Generalization: What is the more important factor for predicting if the block sinks or floats, the size or the type of block? Using the data you just gathered, predict which of the following would sink or float.

Block size	Type of block	Check one: Sinks	Floats
2 inch	wooden block		
2 inch	steel block		
4 inch	wooden block		
4 inch	steel block		

Adapted from: <u>The Science Report Card: Elements of Risk and Recovery.</u> National Assessment of Educational Progress (NAEP) (1988). Princeton, New Jersey: The Educational Testing Service.

TASK 2 FOR PARENT AND CHILD

Instructions: Using the five labeled solutions ABCDE, the large test tubes and the droppers, make all the possible pairs with the solutions. Explain what happens with each mixture on the sheet of paper.

Letter of Solution	+	Name of Solution	Appearance of Mixture

Adapted from: Newman, D., Griffin, P., Cole, M. (1989). The Construction Zone: Working for Cognitive Change in School. Cambridge, Mass.: Cambridge University Press.

TASK3 FOR PARENT AND CHILD

Given: 7 labeled tubes with one of the following solutions in them: color solution (pH indicator), vinegar, soda, solution A, solution B, solution C, solution D. Droppers, large tubes in a rack.

Instructions: Mix a few drops of the color solution with vinegar. Record what happens on the sheet. Vinegar is an acid. Mix a few drops of the color solution with soda. Record what happens. Soda is a base.

In the different tubes, mix the color solution with solutions A, B, C, and D and record what happens.

Solution	Color Change	Acid	Check One Base	Neither
Vinegar		x		
Soda			x	
Solution A				
Solution B				
Solution C				
Solution D				

Generalization: What can you say about solutions A, B, C, and D?

Adapted from: Newman, D., Griffin, P., Cole, M. (1989). The Construction Zone: Working for Cognitive Change in School. Cambridge,Mass." Cambridge University Press.

APPENDIX Parent Child Interaction Vignettes

Vignette One Dyad 019

(A repeated number with "i" indicates an interruption.)

62E And here are your directions.
63C&M (read)
64M All the possible pairs.
65C (looks at wrong tubes in the back of rack) Ah, so these (points) are the ones that we mix?
66E The ones in the back, we're gonna use in the next experiment.
67C Oh. OK
68C Oh, so we're gonna use this (points)
68Mi to E OK. Pairs meaning A+B, A+C, A+D, A+E (points)
68Ei Just whatever you want to do
69M OK. Cause what I was thinkin **(points to Child) you can do A+B, A+C, A+D, A+E (points) Then B+C, B+D, B+E. See what I mean?**

70C (moves head)
71M **And then C+**
72C Oh, there's stuff in these other ones? (picks up tube) **Oh. Ok.**
72Mi **Yeah. I'm gonna write that down.**
72Ci to E I didn't see. I thought it was a clear tube. And, I was wondering how she was gonna mix all that with just A.

73M **A plus B. (writes) A plus C. (writes) A plus E.**
73Ci Magic! (squeezes dropper) Hold on, if you do it A plus B, then B won't be regular.
74M What?
75C I mean just like if you mix ah blue and green. It won't be green no more. So you can't mix blue anymore.
76M **But you're mixin 'em. (points to empty tubes)**
77C I know, but if you go A plus B, then you won't have B anymore.
77Mi (counts empty tubes)
78M **But, you're not gonna (touches dropper) mix them in here (points) then**
78Ci **Oh! Sorry. I thought you had to mix them in here** (points) then
79M No. **(points) You're mixin 'em into the tubes here**
79Ci A plus B (pulls up drops of A) That's it.
80M **(counts tubes) 1,2,3,4,5,6,7,8,9,10. So we got 10 tubes.**
81C (starts to pull up drops)
82M Wait! Wait!
83C (puts dropper down)
84M OK. **Then we gonna do (point to paper and writes) B+C, B+D, B+E, OK? And, then we'll do C, C+D** (writes)
85C C+E
86M **OK.** (writes)

87C then D plus
88M **D would have been with A and B and C (points) D plus**
89C E
90M (writes) **E (counts, points) 1,2,3,4,5,6,7,8,9,**
OK. Got 10 tubes.
91C (turns to E and makes a face) (touches dropper)
92MCE (laugh)
93C (pulls paper toward self. Picks up paper) I thought she .
was
gonna do the writing for me. I don't like writing.
94M **Well (points to paper), you have to figure out what**
you're gonna do before you do it.
OK. That's A.
95C (puts in drops)
96M **Right.** Not too much.
97C (wines)
98M **Plus B.**
99C (puts in drops of B) Neato!
100M **OK. Now wait. (points to Child) (points to paper)**
101C (picks up pencil)
102M It turns red.
103C **Yeah.** (writes) It turned
104M (picks up tube) Magenta! Well! (laughs)
105C to E It's like a new wine. **Magenta** Well. Coming to your store.
106C Turned Ma-gen-ta. (writes) Mom, spell magenta.
107M **You spelled it correctly. Now A plus C. (points)** Don't drip it over there now. **Alright.**
Task discourse is long and continues for 152 more lines and ends on line 259.

Vignette two Dyad 029

(A repeated number with "i" indicates an interruption.)

34E Now the next one. (E takes caps off tubes hands over rack) And , here are your directions.
35M (takes directions and pencil, points at directions, reads aloud) Instructions: Using the five---
36C (observes)
37M (looks at tubes)
38M Do you think you know how to do it?
39C (shakes head no)
40 M&E (chuckles)
41M (turns paper over to C to read)
42C (reads)
43M (touches tubes and droppers)
44M Know how to do it?
45C (shakes head no)
46M (takes paper)
47C (takes rack of tubes, picks up dropper)
48E You're only going to need about four drops.

49M (squeezes droppers and puts in drops in front of C. Then pulls rack to herself) Hum. (puts ABCDE all in same tube)
50C (observes) That sizzled up.
51M Huh?
52aC I said, that sizzled up. Green gray.
52bM **OK.** (continues to put in drops)----(egocentric speech)
53C (observes)
54M (reads----) (picks up pencil) ----(egocentric speech)
55M **OK.** What happened?
56C It changed colors, and it sizzled.
57M (writes change color sizzle)
58M to E OK. You put each one of these in? (points to rack of tubes)
59E Whatever you want to do
60M OK. (takes rack of tubes, puts drops in a tube)
M to C OK. Mix some more in there. (pushes rack to C)
61C (takes rack, put drops into tube, observes tubes)
62M (writes) Tell me all the letters did you use.
63C C, D and B and A.
64M (writes)
65C And it just changed colors.
66M (writes changed colors) It didn't sizzle?
67C Huh unh. (shakes head no)
68M **OK.** Mix some more.
69C (takes dropper)
70M **Just like A and C. Something like that.**
71C (picks up dropper for B)
72M **You can use B.**
73C (puts in drops)
74M What's that?
75C C and A
75Mi C and A
76M (observes)
77C It's red.
78M (writes reddish color)
79C (takes dropper, puts in drops of B)
80M (observes and writes B)

Vignette Three Dyad 013

(A repeated number with "i" indicates an interruption.)

373C (laughs)
374C&M (laugh)
375C Oh well.
375Mi Oh well.
376M **What generalizations**
376Ci (takes paper from M hands to E)
377MCE (laugh)
378M Wait, Will You

379C Oh.
380M **have to make the generalizations.**

381C (takes paper from E) (reads)
382M (takes rack of tubes)
383C They are either an acid or a base. (puts paper down)
384M **OK. A is definitely an acid. (points to tubes) And, D,** I think, is a base, and the other two I think are neither.
385C (takes paper and pencil and writes) **A is an acid.**
386M Well what are the generalizations that you can make about your mixtures? **I think in what you want they are wanting**
387C **Alright fine.** What is that? (erases paper) We always do this in groups.
388M (laughs)
389M **Well, probably when you mix a solution with an acid, you're gonna have something with pH of that will look red**
390M **and that (points to tubes)**
391M **the pH which is the acid**
391Ci I know. I know.
392M **The color**
392Ci I know
393M **or base level**
394C It indicated whether it is an acid or a base.
395M **Right. (shakes head yes)** By what?
396C Color
397M **Right. (shakes head yes)**
398C So?
399M **So when you if you mix (points to tubes) something, you can generalize whether it is an acid or base by it's color probably.**
400C that (gets ready to write)
401M I may not be right. This is being recorded. (laughs)
402C **When you mix a color** (writes) Well, I can turn that off (indicates tape recorder)
403M No. (laughs) **When you mix something**
403Ci (looks at tape recorder) **When you mix**
404M **When you mix a solution with an acid or a base (points to tubes) you can tell**
405C **When you mix a solution** (writes)
406M **You can tell its pH by its color**
407C (writes When you mix a solution with a pH indicator, you can tell if it is an acid or a base by its color.)
408M **(reachers over and erases on paper)**
409C OK?
410M **Um huh**
411C (hands paper to E)

APPENDIX

TABLE i

Discriminant Function Analysis Interaction Variables
by NCESRK

Eigenval	Connon. Corr	Wilks	Sig	%Correctly Class.
1.49	0.77	0.40	.003	93.8%

Variable	Sig
PC7	.001
PC5	.002
PC16	.002
PC18	.002
PC9	.002
PC17	.001
PC14	.002
PC10	.003

Table ii

Discriminant Function Analysis Interaction Variables
by TSKTRK

Eigenval	Connon. Corr	Wilks	Sig	%Correctly Class.
3.32	0.88	0.23	.005	93.8%

Variable	Sig
PC15	.042
PC29	.020
PC25	.028
PC7	.028
PC27	.032
PC5	.037
PC4	.032
PC9	.023
PC13	.006
PC16	.006
PC1	.006
PC17	.007
PC18	.007
PC21	.009
PC26	.006
PC3	.008

APPENDIX

TABLE iii

Discriminant Function Analysis Interaction Variables

Variable	Description
PC5	C asks questions or for feedback or help
PC7	C agrees with M
PC16	M/C asks E for clarification/responds to cue
PC17	E cues
PC18	M/C imperatives or directives (Let's) verb
PC1	C responds to M's question, comments, stimuli
PC3	M asks open-ended questions
PC4	M asks close-ended questions (Yes/no answers)
PC15	M/C general comments
PC21	M directs attention physically and verbally
PC26	M/C truncated
PC27	M/C humor
PC22	M uses positive reinforcement/encourage/agree
PC23	M interrupts with chorus response or adds info
PC8	C interrupts M
PC9	C refuses M's help or ignores M's stimulus
PC10	M/C rejects C/M's answer; demands more info disagree

TABLE iv

Principal Components Analysis

Factor	Eigenvalue	% Variance Explained
1	4.57388	76.2
2	.43802	7.2
3	.32570	5.4
4	.31347	5.2
5	.21046	3.5
6	.13846	2.3