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ABSTRACT

Given the current state of science education Cultural Historical theory appears promising in clarifying how students' social context advances the understanding of science concepts and shapes their attitude toward science. The purpose of the study was to focus on how children's development in science is assisted by both home and school interactions and to understand the learning environment characteristics of children with high and low aptitude in science. The subjects for the study were 32 parent-child dyads who were observed in their seventh-grade science classrooms. Results suggest that high achievers participate in more student-to-student interaction concerning instruction and interact more with the teacher than low achievers. Another conclusion was 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. On the other hand, in the dyad composed of mother and low-achieving child, exchanges were less participatory and the child was more passive. Contains 124 references. (JRH)

Do Schools Account for Aptitude in Science?: A Closer Look at the Construction Zone

by

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Introduction

The difficulties associated with science education in America today have been well documented through the National Assessments of Educational Progress (NAEP) reports from the Educational Testing Service (Mullis & Jenkins, 1988), as well as by other groups interested in science education (Kahle & McInerney, 1989; Linn & Dunbar, 1990; Rotberg, 1990; Rutherford & Ahlgren, 1989; Stedman, 1994). The situation is exacerbated in the case of females and minorities (Kahle, 1982 & 1990; Linn, deBenedictus, Delucchi, Harris, & Stage, 1987; Mullis & Jenkins, 1988; Norland, Lawson, & Kahle, 1974). More needs to be learned about the development of science aptitude in children, particularly in research that focuses on learning environments related to science.

A relatively new model has emerged, which may be helpful in understanding science learning. Cultural historical theory (CH) finds it roots in the work of Vygotsky (1934/1986) and focuses upon the social construction of the intellect. Vygotsky focused on the mediational processes that help to develop intellectual functions in particular with regard to the acquisition of scientific concepts (1986, p. 193).

Vygotsky also emphasized the importance of social interaction with language as a semiotic tool for learning and development. In particular, speech in didactic interactions contains certain semiotic functions (as would other signs or science tools) for the development of concepts and word meanings. To achieve their full-valued meaning as represented in the culture, these word meanings or concepts first must be developed or negotiated 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 <u>adult guidance</u> or in collaboration <u>with more capable peers</u> [emphasis added] (p. 86).

Each new concept that the child encounters represents an opportunity to create a new zone. The distance between the child's point of understanding and the adult's point of understanding can be bridged through adult-chid interaction in an <u>activity</u> (Tharp & Gallimore, 1988). In this way, the zone is made to expand.

Through empirical studies, Vygotsky (1934/1986) established four mental stages for word meaning and concept development. (This developmental aspect of CH is often overlooked. See Cobb, 1994.) These stages are: a) syncretic stage in which images are fleeting in their meanings and not communicated; b) complex stage in which objects are grouped, but the feature used to index the groupings changes from object to object; and c) pseudoconcept stage in which meaning is derived tentatively from everyday encounters and is not referenced to the commonly held cultural understanding. These three stages lead to the development of spontaneous concepts in the mind of the learner. In the fourth, stage, more elaborate scientific concepts emerge that match more closely an expert level.

Vygotsky stressed that to get to formal operations or to develop scientific concepts, the child must interface with and interact with the definitions, meanings and interpretations which come from the culture, and it is the explicit or implicit <u>negotiation</u> concerning word meanings that serves to drive the development of concepts in the mind of the learner. Through adult interaction and feedback, the child actively discovers the full-valued meaning of words and develops higher conceptual thinking. Subsequent to and as a direct result of these experiences, the child then forms his own conceptual creations and generalizes his conceptual knowledge. However, such a learning process does not occur in isolation. Even as the former activity takes place, the child participates in constructing new ZPD's around other concepts which come from the culture. Cultural Historical theory suggests the central position of the cultural knowledge base (socio or macrogenesis) and the history or the development of the "idea" in the mind of the child (microgenesis) (van der Veer & Valciner, 1991). Like constructivist learning theorists, CH advocates do not limit the mental creations of the child to simple replications of those held by a static scientific community or culture. Rather knowledge is seen to evolve and to expand with each new generation of "knowers."

Operating in the CH framework, Gallimore and Tharp (1990) 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 of the instruction in this paradigm is to give students enough support in the ZPD that they eventually will be able to attain the higher levels of the conceptual hierarchy on their own (Newman, Griffin & Cole, 1989).

Much analysis of the support structures in these interactions has been conducted through observations of dyads interacting during problem solving events (Rogoff, Malkin & Gilbride, 1984; Brown & Ferrara, 1985; Radziszewska & Rogoff, 1988 & 1991; Tudge, 1990; Portes, 1988 & 1991). Such support structures have been designated as scaffolding (Griffin & Cole, 1984). While the process through which the scaffolding takes place has been studied by some and specified as a "cognitive apprenticeship" (Collins, Brown & Newman, 1989), a "guided participation" (Radziszewska & Rogoff, 1988 & 1991) or a "reciprocal teaching" set (Palincsar & Brown, 1989). Tharp and Gallimore (1988) described the teachers's role in scaffolding as assisting performance.

Tharp and Gallimore's (1988) most significant contribution, however, is the <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 place, 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 list 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, an analytical unit of CH theory, serves to describe the environment of the ZPD, as well as to explain a child's developmental traits including science aptitude.

Because CH theory addresses some of the central problems of science education, the model is receiving increased attention in science education literature (Eylon & Linn, 1988; Hedegaard, 1990; Martin, 1990; Connor, 1990; Glasson & Lalik, 1993; Cobb, 1994; Lumpe & Staver, 1995; Shayer, 1993). Others have emphasized some of the tenets of the model without citing any particular theory (Woods, 1989; Rowe & Holland, 1990; Wildy &

Wallace, 1995).

A recurring theme which appears in the science education literature delineates strategies to overcome naive concepts or pseudoconcepts (Lawson, 1988; Strike & Posner, 1985; Wandersee, 1983). Most of these attempts are based upon a constructivist learning theory approach (Piaget, 1972; von Glaserfeld, 1987 & 1989), and propose the use of a type of conceptual change or conceptual clarification technique which emphasizes the internal mental workings of the student's mind while she constructs her own learning. Interestingly, many constructivists point to the importance of classroom interaction and activity for learning (Yager, 1991; Lawson, 1988 & 1993), thus to some degree acknowledging the social aspects of the construction process. Indeed, some go so far as to describe CH as social constructivist learning (Good, 1993; Cobb 1994). However, these investigators do not focus on the link between such social interaction and the making of mind. While the internal mental activity and creations of the learner are of prime importance, according to CH theory, conceptual clarification begins in the activity setting of the ZPD, and the interactions invoked in this clarification process require study.

Given the current state of science education, Cultural Historical theory appears promising in clarifying how students' social context advances the understanding of science concepts and shapes their attitude toward science. The goal of this research is to focus on how children's development in science is assisted by both home and school interactions. Differences in assistance are predicted to be associated with science achievement. By focusing on interactions across settings (home and school), a better understanding of how science aptitude develops during this period can be gained. The purpose of the current study is to understand the learning environments characteristics of children with high and low aptitude in science. In an earlier study (Portes, Zady & Smith, 1994), the cognitive environments of high and low science achievers were examined via a parent-child interaction study which is summarized later. These same children's learning environments in school science classes are examined in this study.

Method

The students from the thirty-two parent-child dyads who participated in a previous study (Portes, Zady & Smith, 1994) were observed in their seventh-grade science classrooms. These students had been selected from a pool of student volunteers from seven schools in the metropolitan area. Students were ranked as low or high science achievers based upon their most recent take of the science portion of the California Test of Basic Skills (CTBS). Sixteen students ranked low in science achievement (Normal Curve Equivalent Score NCES less than or equal to 50 and mean = 36.4), and sixteen students ranked high in science achievement (Normal Curve Equivalent Score NCES greater than 70 and mean = 83.6). Demographic data were also collected.

Over a four month period of time, classroom science interactions were observed and videotaped for each of the 32 students, as well as the seven teacher volunteers (Cazden, 1986; Mehan, 1979). Each student was observed on four occasions for five minutes each. At least one occasion included a science laboratory activity.

The actions or measures noted were some of the following derived from the Stanford Research Institute (SRI) (Stallings & Kaskowitz, 1974) with the modifications used in A Study of Schooling (ASOS) (Goodlad, 1984; Giesen & Sirotnik, 1979).

FIVE MINUTE INTERACTION (FMI)

- Adult to Student(s) "Whats"
  - Direct Questions
  - Open Questions
  - Response
  - Imperative (requests/commands)
  - Comments/general action
  - Acknowledgement/praise (specific)
  - Encouragement/praise (general)
  - Instruction/explanation
  - Correction (with/without guidance)
  - No response
  - Refusal (flat/with reason)/rejection
  - Monitor/observe
- Adult to Student(s) "Hows"
  - Nonverbal
  - Touching
  - With movement
- Materials used
  - With humor
  - Life experience examples
  - With guidance
  - Demeaning/threatening
  - Punishing
  - Positive affect
  - Negative affect
- Student(s) "Whats" (Adult Involved)

Directive (student initiated interaction)
Compliant (response)
Refusal
Not responding
Contributing
Assertive
Questioning
Student(s) to Adult "Hows"
Nonverbal
Touching
With movement
Materials used
With humor
Life experience examples
With guidance
Demeaning
Punishing
Positive affect
Negative affect
Total Verbal Interaction
Adult initiated (to one or more students)
Student initiated (with and without adult responding)
Miscellaneous Other Codes
Percent of valid frames "repeated" (type of interaction unchanged)

In the current study, student-to-student interactions were also noted. Field notes were recorded from the observations made of the seven teacher volunteers and their students.

The SRI five minute interaction (FMI) technique offered a practical tool to index teacher and student behavior. Giesen and Sirotnik (1979) emphasized "the universality of its potential utilization" (p. 12), as the technique had been used in several different studies.

The behaviors which transpired on the tape were coded into an SRI frame that consisted of five components:

1. WHO 2. TO WHOM 3. WHAT 4. CONTEXT (I B S R) 5. HOW

(I = instruction, B = behavior, S = social, R = routine)

For example, if the teacher were observed lecturing to the entire class, while walking around the room, the SRI frame would be coded: teacher, to the large group, instruction, in an instructional context, with movement (TL4IX). In another example, an observed student was talking and laughing with another student about something social. The SRI frame would be coded: Student, to another student, commenting, in a social context, with a positi affect (SD6S+). (According to the coding manual, S was student socialization, and B was teacher commenting on student socializations.) In all, fifty frames were coded for each five-minute session (FMI or five minute interaction), resulting in a total of 6400 frames. Videotapes were coded by trained independent raters as to the frequency of these actions or measures occurring during any one class period. Inter-rater reliabilities averaged 97.8% (representing percentage of agreement between two raters) with a range of 90 to 100% for the FMI categories.

After the coding was completed, most classroom discourse was found to be distinguished by twenty frame categories called FMI (five minute interaction) variables. (FMI 18 was a low frequency variable not included in the analysis.)

FMI01	Teacher asks question of other student(s)
FMI02	Teacher asks question of observed student
FMI03	Other student(s) answers teacher's question
FMI04	Observed student answers teacher's question
FMI05	Teacher acknowledges other student's answer
FMI06	Teacher acknowledges observed student's answer
FMI07	Other student(s) ask teacher a question
FMI08	Observed student asks teacher a question
FMI09	Teacher answers other student's question
FMI10	Teacher answers observed student's question
FMI11	Teacher direct instruction to one or more students
FMI12	Teacher observes or monitors class

FMI13 Students ask each other questions, answer questions, or comment (all relat d to instruction)
FMI14 Any student comments to teacher (conversation)
FMI15 Other students socializing
FMI16 Observed student socializing
FMI17 Teacher gives corrective feedback about behavior to any student(s)
FMI18 Miscellaneous low frequency (not included in analyses)
FMI19 Teacher makes a command or request related to instruction
FMI20 Teacher makes a comment, conversation related to instruction
FMI21 Teacher gives corrective feedback about instruction to any student(s)

In order to identify the FMI categories most related to science achievement, a multivariate analysis of variance (MANOVA) was conducted using those categories with high frequencies and reliabilities. These dependent variables were FMI01 (teacher questions), FMI08 (observed student questions of teacher), FMI11(teacher direct instruction), FMI12 (teacher observes), FMI13 (student-to-student questions), FMI16 (observed student socializing) and FMI17 (teacher corrects behavior). Independent variables were science achievement (low, high) and gender (male, female).

Results

The MANOVA found only a main effect for science achievement level (Wilks F = 4.41, p = .00) and no interaction with gender nor a main effect with gender. Table 1 represents the univariate F tests for the seven dependent variables.

Table 1

Univariate F tests on MANOVA Variables
from Main Effects with Achievement

VARIABLE	MEAN SCORES LOW SCIENCE	HIGH SCIENCE	F	SIG OF F
FMI01	2.52	2.18	.11	.74
FMI08	.10	.48	3.20	.08
FMI11	14.87	15.72	.02	.88
FMI12	19.97	4.23	15.27	.00
FMI13	28.52	47.27	13.49	.00
FMI16	7.81	5.02	2.81	.10
FMI17	1.56	.33	5.16	.03

Three of the variables achieved significance ($p < .05$): FMI12, FMI13 and FMI17. FMI12 represents teacher observing the class, or the student or students engaged with a task but not interacting with another. FMI13 indicates student-to-student interaction involving instruction. FMI17 represents teacher giving corrective feedback based upon students' behavior. While FMI08 and FMI16 only reached marginal significance, they seem to be of practical importance. FMI08 denotes the observed student volunteer asking the teacher a question. FMI16 denotes student-to-student socializing.

The present results were also contrasted with norms based on Goodlad's (1984) and Goodlad, Sirotnik and Overman's (1979) A Study of Schooling (ASOS). The original study showed that 77.4%

of FMI frames were associated with instruction (I), while 18.4%, 2.9% and 1.7% of frames were associated respectively with behavior (B), routines (R), and social activity (S). Tables 2 and 3 illustrate the frame percentages for the four context variables in ASOS, as well as in the current study.

Table 2

Comparison of ASOS Context Frequencies with Current Study

Context	ASOS % of Frames	Current Study % of Frames
Instruction	77.4	87.0
Social	1.7	11.5
Behavior	2.9	1.5 (combined with routines)
Routines	18.4	

Table 3

Context Analysis Current Study

Current Study	% of Frames		Totals
Instruction (using ASOS criteria)	64.7		
Student to student instruction	22.3		
All instruction (including student to student)			87.0
Teacher direct instruction		21.1	
Teacher to student interaction		24.7	
Student to student socializing			11.5
Student to student social and instruction		33.8	
Routines and Behaviors			1.5
			100.0

Marked differences in percentages can be noted between ASOS and the current study. Instruction (which excluded student-to-student interaction in the original ASOS) constituted 64.7% of all frames coded in the current study. However, when student-to-student instruction was included, the instructional total percentage rose to 87%, because student-to-student instruction constituted 22.3% of the frames. Student socializing made up 11.5% of the total frames coded. Actual teacher-to-student interaction made up 24.7% of frames. In the current study, routine and behavior frames were not noted with any great frequency (1.5%).

Dependent upon whether the FMI variables were observed in regular classrooms or during science activities, there seemed to be a difference in the occurrence of the interaction categories. In order to see if FMI variables' relation to science achievement was dependent upon the classroom context in which they were observed, two different MANOVAs were performed one with FMVs (regular class instruction format) as dependent variables and achievement and gender as the independent variables and the other MANOVA with FAVs (science activity class) as the dependent variables and achievement and gender as the independent variables.

Table 4

MANOVA Contextual Variables by Achievement
Univariate F tests

Variable	F	Sig. of F
FMV11	4.88	.035
FAV11	6.44	.017
FAV13	7.30	.012
FAV16	4.21	.050
DF = 1,28		

From tables 4 and 5, it can be seen that four FMI variables were found to be class context related. For example, while teacher direct instruction was found to be more prevalent with high achievers during regular classroom formats, it was three times more likely to be found with the low achieving groups during science activities. Also, low achievers were found to be socializing during activities three times more often than high achievers.

Table 5

Oneway ANOVA Contextual Variables by Achievement with Numbers of Occurrences Indicated

	F	p	ONEWAY XHI	XLO	OCCURRENCES #HI	#LO
FMV11	4.14	.05	13.5	8.5	219	138
FAV11	3.96	.06	2.2	6.4	35	102
FAV13	3.90	.06	34.9	24.7	558	395
FAV16	3.74	.06	1.6	4.9	25	78
	DF = 1,30					

Note: FAV variables were noted only in classes in which a science activity was in progress.

Interpretive Findings

The prior SRI results suggest that high achievers participate in much student-to-student interaction concerning instruction. High achievers were seen more often to ask questions of the teacher. (Although teachers did not consistently respond to these questions.) Some elements of these practices can be seen in the following extract from the field notes taken in a class of high achievers:

> Observer Comment: Students were to start by drawing the leaf and then taking notes on the drawing as teacher lectured. Lecture lasted 15 minutes. Students then answered questions missed on the worksheet.
> Teacher: "This is the palisade layer. Of course, you know what palisade means."
> Boy Student: "No. What does palisade mean?"
> Teacher: "Well, at Fort Boonesboro, Daniel Boone built a palisade around the fort. Now, what do you conjecture?"
> Students: "A fence or wall of slats!"
> Observer Comment: At the end of the lecture, while filling in worksheets, many students gather around the transparency on the overhead and chat about it. (AND52)

Low achievers appeared more passive. Low achievers were more often present in classes in which the teacher was observing or monitoring, and these students were not interacting with teacher or with others. However, low achievers did misbehave or socialize more with others during classes. And, the teachers did respond with corrective feedback concerning behavior. Some of these aspects are evident from the field notes of a class of low achievers:

> Observer Comment: Teacher assigns the rest of the questions for seatwork, while teacher goes around and talks individually with some students.
> Girl Student: (raises her hand) "Ms.---, how do you pronounce this word?"
> Observer Comment: Teacher goes over and tells girl student. Another girl student acts up again. Teacher goes over and stands behind her. Teacher is constantly monitoring the group during seatwork. Teacher left class for a moment.
> Boy Student: "Where's Ms.---!"
> Observer Comment: Some students start to talk. Teacher walks in on them and looks sternly. Group becomes quiet.

Teacher: "Raise your hand if you have not finished."
Students: Raise hands.
Teacher: "OK. I'll give you a few more minutes." (BRT 26-27)

When classroom context, i.e., format of the lesson, was taken into consideration, the SRI results suggest that high achievers receive more direct instruction from teachers. This is no surprise, since direct instruction and achievement have been often related in the literature. In fact, some researchers have argued that since the association between direct instruction and student achievement is so persistent, this type of teaching should be used in lieu of any educational innovation (See Brophy 1988a and 1988b; and the response by Cuban, 1988). However, the above relationship is not necessarily causal. It may be that this type of instruction is simply more likely to be found in settings in which most students are relatively advanced and well behaved. In the current study, for example, the teacher who had the most direct teaching-style targeted Advanced Program AS. Interestingly, the results also indicate that when activities were being used in the classrooms, teachers tended to use more direct instruction with the low achieving group as compared to the high achieving group. Following is a representation of the field notes from a class of low achievers:

Teacher: "Put 2.5 mls in your small cups. The mark on the cup says five. How do you get half of 5?"
Boy Student: "I don't know."
Another Student: "You divide."
Teacher: "That's right. To get half of 5 you divide by two. I'll come around and check to see that you have the right amount."

Teacher: "Put the bead in vial number one. Does it sink or float? Try each bead in each vial and fill out the chart."
Observer Comment: Teacher using loud whistles to get students' attention. Teacher begins to do the "wrap up" for the lab. Class lapses into misbehavior again.
Teacher: (in a loud voice pounding on the table, half-smiling) "Get your papers out and read page 28."
Observer Comment: Teacher assigns homework.
Teacher to Observer: "It was like pulling teeth today."
(DON 15-16)

Another finding, associated with achievement and the use of science activities in the classroom, appeared to index mutual student assistance, which was suggestive of cooperative learning. Apparently higher achievers frequently used interactions with other students during activities for mutual assistance in learning. During laboratory activities, high achievers tended to have more student-to-student discourse over matters of instruction than did low achievers. Activities seemed to increase student interaction over science concepts, a fact which suggests another way concept development is enhanced for advanced students. In contrast, lower achieving students appeared to take the opportunity to socialize or to misbehave during science activities more often than did higher achievers. Thus lower achievers' zone of proximal development in science appears to be minimally activated relative to high achievers. Higher achievers appear to have access to both teacher and peer assistance. However, students' interaction with teachers was found to be infrequent and unrelated to student's achievement level in general (See Note 1). This finding is well in line with Goodlad's (1984) work with respect to the passiveness encountered in classrooms across the nation.

Conclusions and Implications

One way to lend meaning to the present results is to use the concept of activity setting (AS) (Tharp & Gallimore, 1988) in the analysis of children's development of scientific aptitude. Combined with the prior Parent Child Interaction study (PCI)(Portes, Zady & Smith, 1994), the results describe essentially science-related activity in the two most important settings in which children co-construct networks of science and other concepts,i.e., home and school. The study's focus is to examine actions of the participants and other persons that impact the ZPD and support conceptual development. The activity settings constructs of personnel, scripts, task demands, goals and beliefs, thus serve the ensuing discussion.

The prior parent-child interaction 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. The CPS (cooperative problem solving) factor, derived from the PCI study, 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 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.

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. Some mothers literally pushed the printed directions at their child instead of using verbal cues. In crder 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 (Sigel (1979).

In relating these findings to the classrocm portion of the study there was some evidence that high achievers sought vigorous information exchanges with their teachers. They were more prone to ask their teachers questions (FMI08). But, the teachers did not respond more often to these students (FMI10). The chief mode of teaching for high achievers was teacher direct instruction which seemed to fall in line with their ZPD's as compared to low achieving students. However, as was noted in the SRI results, high achievers constantly participated in student-to-student interaction involving instruction even when the teacher was lecturing (FMI13). Classroom use of science activities also demonstrated much student-to-student interaction among high achievers (FAV13). But science activities were not that advantageous for low achievers, as they took the opportunity to socialize (FAV16).

The lack of teacher-student questioning and responses stands in contrast to the vigorous information exchanges demonstrated by the CPS interaction style of high achieving dyads in the PCI study. High achievers and their mothers were continually "talking on each others lines" while they were negotiating the concepts in the ZPD. Students in classrooms, on the other hand, must "wait their turn" before engaging in conversation with teachers. Instructional conversations were found to be few and far between. In fact, all teachers discouraged "call outs" and regarded these as potentially disruptive. It seems that the constraints on classroom teachers limit their assistance at higher levels of conceptual development. As seen in the PCI discourses, the type of assistance appears to be available for some students in the home.

Teachers are not the only regulators of conceptual development. The above problem in the observed classrooms was partially compensated by cooperative learning activities. Cooperative learning strategies changed the scripts, task demands and somewhat increased the personnel available for conceptual development in the ZPD. From this study, high achievers employed cooperative learning for mutual assistance. If advanced students cannot attain conceptual clarification from their teachers, they can always turn to each other.

However, relying on the regulation which peers provide has important theoretical implications. In Vygotsky's operational description of the ZPD, the regulator is an adult or more capable peer (1978). If the peer who is serving as dyadic regulator does not possess the scientific concept, but rather, a pseudoconcept, the dyad may learn the information improperly. Tudge (1990) has referred to this phenomenon as "regression." Others have also noted the problems in peer regulation (Radziszewska & Rogoff, 1991; Levine & Moreland, 1991; Lumpe & Staver, 1995).

Another problematic issue has to do with low achievers. These students appear to lack the prerequisite skills needed for task demands and the familiarity of the sets. Chief among the deficiencies was the problem of limited literacy. Their lack of mastery of skills and knowledge will prevent these students from developing scientific concepts. Literacy and related deficits in the conceptual tools needed for learning should be addressed directly. Activity settings which are meaningful and contextually rich, possibly in addition to current schooling practices, could help these students to bridge the gap.

Although cooperative learning scripts do somewhat increase the regulators of conceptual development, the opportunity for participation in the instructional conversation with more capable others needs to be increased. Strictly speaking, this increase in opportunity will entail an expansion of the personnel available in the activity settings of school. Increases in the teacher-student ratio could serve to address many of the ZPD-related problems observed in this study. However, since increasing the teacher-student ratio would entail scarce economic resources, schools need to develop other strategies. Such possible strategies include: extended schooling for the low achievers, multi-age classes in which older students could serve as dyadic regulators, and the recruitment of classroom aides. Parents and volunteers from the community could be included in the adult-to-student formula. Interactive computer learning may also serve some of the regulation function.

In sum, current mismatches in the variables of the AS, e.g., personnel and task demands, prevent science classroom learning from resulting in the vigorous information exchanges characteristic of higher achieving mother-child dyads participating in conceptual development while performing experimental tasks. These mismatches require serious attention to restructuring schooling guided by theoretically-derived perspectives. In the past, learning theory (behaviorism) did not succeed in the development of higher cognitive development. CH theory helps to provide for intellectual development and should serve as a theoretical base for school reform. If children are to develop intellectually, schools must provide the personnel necessary and insure that students are in possession of the skills which school tasks demand.

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.

In addition, the method employed in this part of the study does not allow for assessing directly the relation between observed interactions and student learning of scientific concepts. These findings provide little evidence of scaffolding or assistance by teachers. The methodological narrowness of the approach does not permit meaningful interactions between teacher and students to be detected, even where they might exist. The SRI data mainly reflect the amount of certain types of classroom activity which helped to confirm several prior findings.

Future Study

Since this IA (interaction analysis) system does not allow for conceptual understanding of how classroom interactions might support intellectual development, another approach needs to be employed to add depth to classroom study.

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 in those occasions where the child manifests "semiotic uptake" during the observation of the performance of science activities.

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FINAL NOTE

Although they sought other student regulation during activities, did higher achievers have more opportunity to interact with the teacher? In order to answer the question, a new variable was designated during the analysis. This interaction variable was composed of teacher and observed-student questions, responses and acknowledgements, and was found not to be statistically important, reflecting the low base rate for frequency of occurrence. In this study, thirty-two students were observed on four occasions each. Fifty frames were coded for each of these four occasions. Three of these occasions were averaged and the categories were designated FMV variables. (The science activity frames remained distinct in this part of the study and were designated FAV.) Out of the 1600 possible frames coded for the FMV, only eighteen of the interactional type were observed for lower achieving volunteers, and fifteen frames were observed for higher achieving volunteers.