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ABSTRACT

This paper presents research on a theoretical approach to Logo as a programming language that creates a context for learning in which the process by which children learn and develop, using computers, is of greater interest than the products, or outcomes, of learning. Concerned with the cultural context of Logo learning and principles upon which it is based, the first section reviews the developmental and cognitive theories of Papert, Donaldson, Cole, and Sternberg and Suben. Section two offers the theoretical premise of a reference model for learning Logo based on research in anthropology, psychology, and sociolinguistics. Section three discusses the components of this model in relation to empirical data from a research project on the relationship between Logo programming and young children's self-monitoring and comprehension skills. Finally, the fourth section briefly summarizes the discussion and suggests areas for further research, including the questions of what cognitive prerequisites are needed to program successfully at different age levels, and the policy implications of providing children with such training. Eight reference notes, thirty-two references, two tables, and five figures complete the document. (JB)

Learning Logo: The Social Context of Cognition

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Learning Logo: The Social Context of Cognition

When Mindstorms first appeared in 1980, Papert's ideas on learning Logo captured our imagination. Children would effortlessly learn deep mathematical concepts by using the "turtle;" by exploring "microworlds" they experience the full power of their minds in ways that current educational practices could not, and would not match. A visionary, of course, will always attract detractors; both educational researchers and humanists rushed to do battle with Papert's claims. The researchers claimed Logo did not change children's thinking in substantive ways (Clements & Gullo, 1984; Pea & Kurland, in press), and some even went so far as to suggest there be a moratorium placed on Logo instruction in the schools. (Tetenbaum & Mulkeen, 1984)

The humanists read Papert's ideas as suggesting computers should become the primary medium for interacting with the world; drawing flowers on a screen does not substitute for picking them in an open field under a blue sky, they huffed. (Davy, 1984; Zajong, 1984)

In this paper, we suggest there is a grain of truth on both sides' position. Logo cannot accomplish everything Papert claimed it would, nor should it replace other learning experiences (although our reading of Papert never led us to that interpretation). But we also suggest that Logo has been maligned unfairly, and that the attacks are rooted in a misunderstanding of what Logo is, and how it should be evaluated. Logo is not just another programming language, or a method of instruction like CAI; it creates a context for learning. And in that context the process by which children learn and develop using computers is of greater interest than the products, or outcomes, of learning in a computer environment. Researchers oriented to the product approach are perhaps driven by fear of the "research window" closing too soon, as it did for research on television in the 1950's (Lepper, 1985). It is quick and easy to set up a conventional experimental study to compare a Logo group and a control group on pre-designated outcomes, and then when no significant differences materialize, conclude Logo does not work. But we concur with Papert's attitude expressed in a recent interview: So what? (Green, 1985). By limiting the comparison between groups to arbitrary outcome measures, and not examining the process by which it is taught, we learn nothing about how it may affect the way children think. The shift from a product to a process approach was suggested by Vygotsky over fifty years ago; we will argue in this paper that unless this perspective is adopted in educational and psychological research on learning and instruction, the real and necessary changes in education will never be accomplished.

The paper will be divided into four sections. The first section will deal with concepts of Logo in relation to current thinking about the relationship between culture and cognition. The second section will present the theoretical premises of a reference model developed from research in anthropology, psychology, and sociolinguistics. In the third section, the components of this model will be discussed in relation to empirical data from a research project on the relationship between Logo programming and young children's comprehension monitoring. Finally, in the fourth section, we will attempt to summarize the discussion by suggesting areas for further research.

1. The cultural context of Logo learning

One unusual feature which distinguishes Logo from other programming languages is that it is grounded in principles of learning and development, with two main principles predominating. One principle relevant to this section is Papert's notion of "powerful ideas" which is his shorthand rubric for saying the power of learning is increased tenfold when a child sees the connection between her life and the subject to be mastered. According to Papert (1980), children learning Logo are learning a new process for thinking about the world, not just another programming method. Logo is based upon a philosophy of learning which encourages children to connect mathematical and scientific concepts to their sense of how life itself unfolds.

Papert refers to this idea as syntonic learning, learning which is compatible with the learner's sense of life. Other principles upon which Logo is based are: 1) continuity - "mathematics, for example, must be continuous with well-established personal knowledge from which it can inherit a sense of warmth and values as well as 'cognitive' competence"; 2) power - "it must empower the learner to perform personally meaningful tasks which could not be done without it"; and, 3) cultural resonance - "the topic must make sense in terms of a larger social context." (Papert, 1980, p. 54).

Papert's ideas in this regard are strikingly similar to those expressed recently by developmental and cognitive psychologists. Donaldson (1978) noted that when young children (and even adults) are asked to perform disembedded tasks, tasks which appear to have no direct correspondence to the reality of everyday life, they don't perform very well. She suggested children need to have tasks make human sense. The "turtle" in Logo makes this kind of sense to children; it becomes an "object to think with," and allows them to externalize abstract concepts. Children not only see the "turtle," they can "play turtle" by using their bodies to mimic the turtle's actions. Being able to act out physically an abstract idea enhances children's understanding of the task at hand.

Donaldson discusses the need for tasks to make sense; the recent work of several cognitive psychologists and educational ethnographers is directed toward describing how tasks come to make sense through social interaction.

In the cognitive domain, the work of Michael Cole and Robert Sternberg is especially relevant. Cole and his associates (Cole, 1983; Cole, Note 1; Cole & Scribner, 1971) have long stressed the importance of the cultural context in assessing cognitive abilities. Cole (1985) quoted Boas to the effect that:

> In the working of culture, the life of the individual is controlled by culture and the individual effects the culture. The causal conditions of culture lie always in the interaction between the individual and society (Stocking, 1986, p.).

Cole suggested we need an interactional account of cognitive development; since his ideas are critical to the development of our reference model, they will be discussed later in the paper. A newer convert to these ideas is Robert Sternberg, who is now developing a theory of intelligence which takes into account contextual features of the environment. Central to our discussion is a section in a recent paper by Sternberg and Suben (Note 2) on contextual subtheory which relates intelligence to the external world of the individual. The authors noted that:

> Intellectual development in the contextual subtheory occurs via the interplay of adaptation, shaping and selection. When one enters a new environment, one uses the components of intelligence to determine just what balance should be attained between adaptation and shaping and one's decisions regarding what this balance should be may well change as time goes on. It is important to realize that whereas intellectual development from the standpoints of the componential and experimential subtheories does not involve value judgments or points of view, intellectual development from the standpoint of the contextual subtheory does involve such judgments: What one person or culture considers adaptive may be considered maladaptive by other persons or cultures, and the shaping activities that one individual or culture sees as leading to a better fit with the environment may be seen by another individual or culture as leading to a worse fit. In such cases, not only the actions of the individual may be perceived in multiple ways, but the environment itself may be perceived in different ways by different observers. (Sternberg & Suben, Note 2, p. 8-9).

What is interesting about this quote from our point of view is the idea that cultures vary in the value they place on adaptive behaviors; we cannot assume cognitive abilities hold constant across all cultures. To strengthen their argument, Sternberg and Suben drew upon the work of educational ethnographers (Heath, McDermott and Schiefflen) who have identified the contextual features of the environment which lead to differential adaptations of behavior. Using data from these studies, Sternberg and Suben noted that metacomponents of intelligence such as: 1) understanding the nature of tasks one is confronted with; 2) deciding upon steps in accomplishing tasks; 3) putting these steps together to form a strategy; and 4) allocation of resources are all influenced by the sociocultural context in which the child lives.

The connection between Papert and these theorists is that Papert claims learning must be connected to the learner's sense of life; Cole and Sternberg claim learning is mediated through the cultural and social context in which the learner is placed. We interpret this to mean learning Logo should not only be a meaningful task for the child; we must also describe the social context in which the teaching-learning process occurs. Only by considering both these factors can the success or failure of Logo be tested.

If Papert has used only the concept of "powerful ideas" in developing Logo, it might have gained even greater acceptance than it now has. More importantly, it might have had the impact on children's cognitive development Papert claimed it would have. At present, the available research does not support Papert's lofty claims. The Bank Street College of Education research is the best known (Pea, Note 3; Pea & Kurland, in press); researchers found that after a year of Logo instruction, eight and nine year old children were unable to transfer their problem solving techniques to other tasks, and that their performance did not differ significantly from that of a control group. Clements and Gullo (1954) did find limited transfer on one problem solving task among first graders, but they concluded that there was no evidence that the programming significantly affected children's cognitive development. While research on Logo is still too limited to conclude it has no effect, these early reports are not encouraging.

Can Logo work the way Papert first envisioned it? And just what effects can we expect it to have on children's cognitive development? To answer the first question, the contradiction between Papert's "powerful ideas" and Piagetian principles of development must first be resolved. Especially problematic is Papert's interpretation that children learn through discovery in the absence of any formal curriculum or direction by a teacher. Leron (1985) noted that when children are left to their own devices in a computer lab, "they fall into a hacking style of programming, which does not seem conducive to learning deep and sophisticated ideas" (p. 27). As a solution to this problem, Leron (1985) outlined a course of action he termed "quasi-Piagetian learning" (QPL), which assumes a more active role for teachers and learning materials, but still preserves the Piagetian spirit of non-judgmental and exploratory learning. We adopt a similar perspective in our reference model, but we will suggest the more appropriate theorist to consider is Vygotsky, not Piaget.

To answer the second question, changes in the way Logo instruction is assessed will need to be accomplished. If Papert is correct in his assertion that Logo influences the process of children's thinking, then assessing its effectiveness by studying the "products" of Logo learning misses the point. Comparison of a Logo group to another (e.g., CAI or control) can still be carried out, but the comparison should not be made only in terms of equivalent performance on some outcome measure. Instead, the comparison should be made with reference to how the process of learning differed within each group. According to Cole and Means (1981), a fundamental weakness of experimental designs (still the best method for demonstrating group differences) is that you can't ensure equivalence of treatment and you can't set equivalent performance as the standard for demonstrating treatment equivalence, because then legitimate differences between groups would never be discovered. One way out of this dilemma is to set up the treatment groups, but treat each setting as a context in its own right, specify features of the interactional context within which learning is achieved, and then compare differences between groups on both this dimension (process outcomes) and performance measures (product outcomes). Assessing Logo instruction requires an approach we call the natural history of an experiment. By using this approach, subtle differences in learning may appear between groups which have long range consequences; such differences may not appear on measures which depend upon an either/or response (either children solve a problem or they don't). We will present empirical data later in the paper to support the contention that Logo does effect changes on learning both across time in the instructional sessions and on an analog transfer task.

The two points advanced in this section are: 1) the teaching and learning of Logo cannot be disassociated from the sociocultural context in which instruction occurs; and 2) assessing the effectiveness of Logo instruction depends upon utilizing a multi-disciplinary, multi-method approach which allows for comparisons between groups in terms of process variables, not just product variables. The topic addressed in the next section is the nature of the reference model developed from a multi-disciplinary perspective which can be used to study the process of learning Logo.

2. Reference model for learning Logo

Before describing the components of the model, we should clarify the term, "reference model", since its meaning may not be commonly shared in the social sciences. We borrow the term from Gearing (1979), who himself borrowed it from Paul Garvin and Madeleine Mathiot. In Gearing's words"

> The recommended that one construct a reference model, gathering data and near-knowledge from existing literature and experience and drawing these into a synthesis. This reference model must frame a methodological stance and in addition it might contain various logically related propositions that make no strong claim as to external reality, but which do clearly admit of empirical examination. Such a reference model operates to shape the framing of research questions and to assist in the pursuit of answers. Second, Garvin and Mathiot suggested that one additionally and simultaneously needs a "theory." This contains whatever may exist of knowledge that is germane and seems certain. Such a theory is at its early stages necessarily a nearly empty receptical, as it were. It will come to hold in logical order new knowledge, gained through empirical research, and guided by the reference model, as it becomes firmly established. (1979, p. 169-170).

At the onset of our discussion, we should make it clear that our reference model is presented in an imperfect form, and since our research on Logo instruction is just beginning, our theory is indeed "nearly empty." But we do feel the need to make explicit the theoretical premises of our model, since social science research in general and educational and psychological research in particular has long been characterized by the absence of well-grounded theoretical perspectives. As Sanday (1976) noted:

> The major weakness (of some scientific studies of human behavior, particularly of cultural behavior(... is that what passes as theory "includes remarkably few propositions which meet the basic requirements of science, that is to say, which explicitly state the relationships between phenomena, specify precisely how those changes as relevant variables are altered, and support such statements with adequate validating evidence" (Murdock, 1971, p. 20)

Bloome (Note 4) suggested Sanday seemed to be calling for three things: "1) the need to make one's theoretical perspective explicit (to make it available to scrutiny by others); 2) the need to make one's theoretical perspective responsive to the results of application to data bases (that is, to make it responsive to the results of scientific inquiry); and 3) the need to ground theoretical perspectives in the data bases in which they are concerned (that is, the theoretical perspective needs to be relevant to the data base rather than irrelevant, outside sets of propositions and assumptions." (p. 6-7). By engaging in these activities, we hope to contribute to the long, slow process of developing a comprehensive theory of learning and instruction, and avoid the "mindless empiricism" endemic in educational and psychological research.

A. The psychological perspective

We will begin discussion of the model with reference to the ideas taken from psychology. To provide clarity and coherence to our points, we will treat each of the perspectives separately, even though we recognize that at a higher analytic level they are interrelated. As stated earlier, Papert's work appears closer in spirit to ideas expressed by Vygotsky. The concepts from Vygotsky relevant to our work are: 1) the concept of mediated activity; 2) the concept of internalization; and 3) the concept of the zone of proximal development.

Vygotsky viewed sign and tool use as mutually linked yet separate in the child's development, and saw both subsumed under the more general concept of indirect (mediated) activity. For Vygotsky, tool and sign use represented "two means of adaptation as diverging lines of mediated activity" (Cole, John-Steiner, Scribner & Souberman, 1978, p. 55). He suggested this divergence results from the essential difference between the two in the ways that they orient human behavior:

> The tool's function is to serve as the conductor of human influence on the object of activity; it is externally oriented; it must lead to changes in objects. It is a means by which human external activity is aimed at mastering, and triumphing over, nature. The sign, on the other hand, changes nothing in the object of a psychological operation. It is a means of internal activity aimed at mastering oneself; the sign is internally oriented. These activities are so different from each other that the nature of the means they use cannot be the same in both cases. (Cole, et. al. 1978, p. 55).

The problem before us was the transpose Vygotsky's ideas on tool and sign use into a framework describing Logo instruction. We theorized the use of Logo on a computer fits Vygotsky's concept of a tool. Through the use of the "turtle" children see themselves creating and transforming objects. Children can carry out endless possibilities in mastering nature through the creation of "microworlds" on the computer. This concept is similar to Olson's (1976) idea of cognitive amplication through technology: what the mind can do depends upon the devices provided by the culture.

But learning Logo is a process that involves more than just using a tool. The role of language needs to be considered. When children "speak" to the turtle using the appropriate commands, they are externalizing their thought processes in carrying out a solution to a problem (e.g., make a square). And as they "talk" to the "turtle" with Logo, they talk about their actions, their intentions, and the "turtle's" actions (e.g., "I want to make him go down," "we made him go like this and then go like this"). Vygotsky sees speech as critical in the development of mediated activity. In his words,

> 1) A child's speech is as important as the role of action in attaining the goal. Children not only speak about what they are doing: their speech and action are part of one and the same psychological function. directed toward the solution of the problem at hand.

> 2) The more complex the action demanded by the situation and the less direct its solution, the greater the importance played by speech in the operation as a whole (Vygotsky, 1978, p. 25-26).

As a child develops, mediated activity begins to occur as an internal process. Vygotsky labeled this the process of internal reconstruction of an external operation "internalization," and described the process as a series of transformations:

> a) an operation that initially represents an external activity is reconstructed and begins to occur internally...
>
> b) an interpersonal process is transformed into an intrapersonal one. Every function in the child's cultural development appear twice: first, on the social level, and later, on the individual level; first, between people (interpsychological), and then inside the child (intrapsychological)...
>
> c) the transformations of an interpersonal process into an intrapersonal one is the result of a long series of developmental events.

Turning aside from Vygotsky for a moment, and looking at research in cognitive-developmental psychology, we find great attention being paid to a new area of inquiry, metacognition. Flavell (1979) noted that metacognition occurs through the actions of and interactions among four classes of phenomena: a) metacognitive knowledge, b) metacognitive experiences, c) goals (or tasks), and d) actions (or strategies) (p. 906).

Germane to this discussion is Flavell's assertion that the quantity and quality of children's metacognitive knowledge and monitoring skills may be increased through systematic training. We share this view, and suggest that Vygotsky's work specifies the process by which the development of metacognitive knowledge and monitoring skills is accomplished. By providing children with experience in mediated activities which allow them to externalize their thinking processes, these skills are gradually internalized to guide actions in other areas.

However, we have not yet accounted for the role of social interaction in development. Vygotsky dealt with this role with his concept of the zone of proximal development:

> It 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 (Cole et. al., 1978, p. 86).

If we substitute "programming" for "problem-solving," we can say that what children accomplish with Logo in collaboration with others is a precursor to what they will accomplish independently later in development. The key is "collaboration with others"; Cole (1983) noted the concept allows us to understand that children (or more generally novices) can be participants in events that they do not fully understand and which they are incapable of accomplishing as individual activities." (p.). THis view implies learning is a mutually constructed activity in which the child carries cut those actions he/she is capable of performing while becoming coordinated with new aspects of the interaction that can later be used in new situations (Cole, 1983).

To summarize the points we have made this far, Logo operates as a tool which children can use to transform objects. Embedded within the learning process is language as a sign: children engage in symbolic activities through their speech. This mediated activity is first externalized and later internalized; the metacognitive aspects of children's thought can be externally represented through the turtle's actions. Learning precedes development; the teacher and learner jointly construct the learning process; the child's actions are mediated not only through tool and sign use, but through the actions of the teacher. What we need to describe next is the mechanism for the transfer of knowledge between teacher and learner; how does a child come (or not come, depending on the situation) to acquire knowledge from another?

B. The sociolinguistic perspective

Vygotsky emphasized the critical role of speech in the development of higher psychological functions; Cole (1983) noted that an interactional model of development would need to consider "the role of language as the primary medium of interaction and a major resource for inducting children into the meaning systems that constitute human cultures." (p.). We suggest in this section that by adapting the framework developed to study teaching as a linguistic process to an experimental (not naturally occurring) teaching session, we can specify the means by which metacognitive knowledge is transmitted to, and internalized by, the learner. The aspect of metacognitive knowledge germane to our discussion is the strategy factor - knowledge of what strategies are likely to be effective in achieving what subgoals and goals in what sorts of cognitive undertakings (Flavell, 1979).

Green (1983) has provided an invaluable synthesis of research on teaching as a linguistic process, and she summarized the constructs from this research under three broad themes: 1) face to face interaction is rule-governed; 2) meaning is constructed and signalled during interaction and 3) classrooms are communicative environments. We will discuss each of these constructs in relation to behavior within an experimental context.

Regarding the first construct, we find that language within an experimental teaching session is indeed rule-governed. However, it appears that the teacher exerts more control over discourse rules simply because her intentions regarding the nature of the treatment are more fully explicated. For example, we created a set of metacognitive teaching strategies (Figure 1) where the teacher would look for specific responses from the children. Creating an experimental context is similar in one sense to writing a script; you have certain expectations as to what the other person should say. These expectations do become frames of reference (Green 1983) but unlike the ones occurring in natural settings, these frames are not determined by the culture, but by the experimenter's goals in the treatment. By having the teacher model the use specific strategies to solve problems with the "turtle," she was providing the "scaffolding" to support children's thinking unitl thay began to practice these techniques on their own (Wood, Bruner & Ross, 1976). Our perspective in this case is similar to the one taken by Wertsch, McNamee, McLane and Budwig, in that:

> ...Before the child is able to function as an independent (i.e., self-regulated) problem solver, the adult in the adult-child dyad functions to plan, regulate and reflect on the problem-solving task at hand. Instead of having a single individual who is responsible for planning and monitoring the strategies for reaching a goal and for carrying out the behaviors involved, these responsibilities are divided up between two individuals who function in an integrated social system. (1980, p. 1216)

The key words are "integrated social system." Like Wertsch et. al., our thinking was heavily influenced by Vygotsky's idea that learning begins on an interpsychological plane, before occurring on an intrapsychological plane. By having the teacher make explicit metacognitive aspects of the task at hand, and setting the standards for appropriate responses, we hoped children would begin to develop these strategies on their own.

Our discussion of this construct should not be interpreted to mean none of these behaviors occur in a naturally occurring classroom lesson. However, there are at least two differences in an experimental teaching session. One, not only did the teacher specify the curriculum for each lesson in advance, she also identified and used specific strategies to achieve certain goals in each lesson. In short, the task specificity (critical for future replications of the treatment) was greater than what would be found in a regular classroom. Teachers for the most part do not see themselves as researchers who experiment with different techniques, although they may come to accept this role in time if the teacher as researcher movement becomes more accepted.

Second, because our Logo lessons were part of an experiment, we had much more control over sources of random variation than any teacher does in a regular classroom lesson. For example, we never had to deal with interruptions from other children since our pairs worked in a separate room away from the classroom. Interruptions are part of the natural environment and are incorporated into the classroom social structure, but they were eliminated in our treatment. We also had no discipline problems to handle, a standard element of any classroom.

In her discussion of the second construct, Green (1983) noted there were two constructs subsumed under it: 1) contexts are constructed during interactions and 2) meaning is context specific. Again, these constructs are useful heuristics for studying an experimental teaching lesson.

Erickson and Shultz (1981) posed the question "When is a context." In an experiment, one answer is that it begins when the experimenter begins the treatment (or test) and ends when the test is completed. But that answer is too simple. Because our Logo lessons were created as independent entities; they did not flow from naturally occurring events within a classroom; we could easily mark the beginning and end of each lesson. But now that we are beginning to analyze transcripts from the lessons, we notice subtle differences in the context shifts occurring within each lesson. For example, the decision to move from the phase - reviewing old commands - to the phase - teaching a new command - was not entirely under the teacher's control. Differences across pairs indicate that contexts within the lesson itself were constructed jointly by the children and the teacher, taking into account the additional factor of individual differences among children in their ability to master certain concepts. So it has become clear to us that to treat each session as a context which remained stable for all pairs across time (a common assumption in any experiment is that every participant is receiving the same treatment) was a mistake; we need to consider each session as a context in its own right and evaluate outcomes in relation to what occurred in each session. Some features did reoccur on a regular basis, but others did not, and we need this information to examine individual differences in performance.

It also became clear that lessons varied in the type of contextualization cues used to construct meaning. There were differences in gaze direction, use of gestures (e.g., pointing or tracing the turtle's path on screen), proxemic distance, and prosody (pitch, stress, intonation, rythm and juncture). As yet, we are not able to pinpoint how these cues affected the learning process, but it was clear the pairs differed in the types of cues present in each session.

Green's last construct, classrooms are communicative environments, is relevant to our research. Of interest is the idea of the asymmetrical relationship between the teacher and student. Certainly in our case the teacher was the "native" in that she knew Logo and the children did not, and she set the agenda for learning. But there were also occasions when the teacher did not know what to do next (e.g., the entire Logo program disappeared when a child pushed the reset button and she didn't know how to retrieve it); on these occasions, the children were not expert enough to offer assistance. It would be another study to examine the dynamics of the teaching-learning process in a computer lesson when the teacher is not the only "native": how this will change the role relationship is a matter for future speculation.

We did notice that students using Logo had greater freedom to introduce topic shifts or initiate new actions; we suggest this freedom is intrinsic to the use of computers. Computers expand the possibilities of mind; and in a free-learning environment, children can experiment with as many ideas as they can create. Again, whether this freedom will continue or whether computers will be fitted into a more structured classroom environment is a question for further research.

To conclude this section, the constructs of teaching as a lingusistic process are applicable to our experimental teaching sessions as a starting point for our model. We feel that an experiment should be studied as a context in its own right, but recognizing the differences which arise in a manipulated vs. a naturally occurring event. A fuller description of how these constructs (and any others) apply to an experimental teaching session remains to be written, but we begin by acknowledging the work of others in beginning this task.

C. The anthropological perspective

Anthropologists have long been interested in the topic of cognition, learning and education. However, many anthropologists share Lave's (1982) view that psychological theory has little to offer for a study of the socio-cultural effects on learning. We disagree, and we suggest in this section that when psychological theories are wedded to anthropological concepts, an unusually powerful model of learning results. We have already discussed psychological concepts drawn from Vygotsky, and sociolinguistic concepts (which are very close to anthropological concepts); we now take up the anthropological perspective.

In our experiment, we deliberately arranged the context to facilitate the learning of specific Logo concepts, in contrast to simply providing children with an environment in which they used Logo. This difference is similar to the distinction made by Strauss (1984) between "incidental" and intentional" learning. Erickson (1981) has also discussed the idea of "taught cognitive learning," particularly with reference to individual differences in learning, and the "manifest curriculum." He further noted studies of taught learning need descriptive adequacy. According to Erickson, such a description should: 1) account specifically for the actions of an individual learner; 2) account specifically for relevant features of the environment (including the intentions of the teacher if one or more is present in the learning environment); and 3) show specific change in individual environment interaction across time, from before learning, through during learning and after having learned. (1981, p. 159)

For purposes of our model, we interpret his remarks to mean that we need to look at individual difference in pairs' actions across the treatment sessions, we need to specify the teacher's intentions (which is easily done since one of the investigators, Gloria Miller, was the teacher) and we need to record and assess changes on specific behaviors across time, (both in terms of the process-qualitative changes in children's language) and pretest-posttest differences on selected measures. One difference we do recognize at this point is that we are unable to relate learning in our experimental context to other forms of learning in the regular classroom context. As Bateson (1972) cogently noted, learning always occurs in some context which has formal characteristics and this structured context is embedded within a wider context - a metacontext - which is embedded in another context ad infinitum. Recognition of the broader cultural contexts in which shape learning has always been the anthropological strong suit; where we part company with Erickson's model (which is considerably more complex and interesting than the few ideas we have discussed here) is how a model should be empirically tested. ERickson's "story of learning," using as a model the description by Annie Sullivan of Helen Keller's recognition that words were names for things and actions, is a lovely idea, but it is difficult to move from that description to describing the problems many special education children encounter in learning the simplest concepts. If we cannot operationalize variables and compare groups on differences in outcomes, we will not be able to translate our findings to actual classroom situations. But we can use the "story of learning" to formulate the variables; what factors are associated with learning specific concepts by different learners in different situations? We have adapted Erickson's point of view to attempt a "story of learning"; our story occurs within a setting we created, and perhaps later we can add further chapters for the classroom environment.

At the conclusion of his paper, Erickson (1981) called for a rapprochement between cognitively oriented psychologists of learning and contextually oriented anthropologists of learning; a call echoed by Strauss (1984). We wonder if they were aware that some twenty five years ago Campbell (1961) made a similar point; he noted anthropologists provide the descriptive humanist perspective, while psychologists provide the abstractive/generalist perspective. The real wonder is that it has taken so long for both sides to recognize the strengths of the other. Just as the computer may bring new forms of learning and instruction into the classroom, it may also effect the combining of disciplines to assess changes in children's development.

To summarize this section a list of the premises guiding our research is presented:

1) The computer embodies both the properties of a tool and sign; both are a function of mediated activity;

2) Learning is mediated through social interaction; children learn through jointly constructed activities with older peers and/or an adult teacher;

3) Language is the primary means of transmission of metacognitive knowledge; through the child's speech and the language of instruction metacognitive strategies can be first externalized and later internalized by the child;

4) The primacy of language implies a focus on the teaching-learning process as a linguistic process; and

5) The instructional treatment sessions should be treated as contexts in their right; a holistic perspective is needed to see the relationship between this context and other learning contexts.

These premises guided us both in setting up the experimental design and in the analysis of data. We discuss these aspects in the next section.

3. Natural history of an experiment

The term, "natural history" was used by Scheflen (1973) to describe a method of analysis for a psychotherapy session. In junction with Ray Birdwhistell, he further refined this method, labelling the approach context analysis. In this approach, the investigator chooses a frame of reference (context) and abstracts only those elements that are domonstrably part of this framework. The investigator then studies how these elements are systematically structured and related in a hierarchy of levels. In our case, the context selected was the experimental treatment sessions, and we primarily studied the communicative process as it pertained to the goals of our research. The experimental Logo sessions were embedded in a larger context, the experiment as a whole (which includes the pretest and posttest sessions as well as the CAI sessions); for purposes of this discussion we will focus only on the Logo sessions. The primary question of interest in the study was whether the use of Logo programming had any effect on preschool children's self-monitoring and comprehension processes.

However, we did not stop at simply comparing the performance of a Logo group to another group (CAI) on selected outcome measures. Consistent with the approach described in our reference model, we were also interested in changes in children's self-monitoring and comprehension skills across the sessions, and the communicative process by which these changes occurred. We wanted to describe the factors contributing to those changes; the primary factor of course being the teacher's role in modelling use of metacognitive strategies. What follows is a discussion of the qualitative changes occurring within the treatment sessions; the quantitative changes having been described elsewhere. (Miller, Emihovich, Clare & Froning; note 5). To set the context for the reader, a brief methodological description is presented first.

Method

Subjects and Design

Fourteen children (mean age = 5-5years; age range = 4-8 to 6-2 years) from the University Preschool of a major Southeastern city were selected for the study. All 14 children had obtained vocabulary scores within the average to low average range on the Peabody Picture Vocabulary Test (PPVT-R; Dunn & Dunn, 1981) and had passed an informal pretest which assessed knowledge of color names, shapes and the concept of same and different, Seven children were randomly assigned to either a Logo Instruction or a Control Instruction condition with the restriction that race, sex and SES status was approximately equivalent across the two groups. No differences were found between the Logo and Control conditions on the PPVT-R standard scores, 98171 versus 100.29 respectively.

Materials

Children were given the Matching Familiar Fisures Test (MFFT; Kagan, Rossman, Day, Albert & Phillips, 1964) as a measure of reflectivity and an analogue block building task (after Flavell, Speer, Green & August, 1981) to assess monitoring behavior both before and within two days after the conclusion of training. Alternative forms of each measure were used for the pre and posttesting. On the MFFT, children select one picture form an array of six that is identical to a standard. The examiner records the time elapsed until the first selection and the number of errors made until the correct answer is chosen. During the block building task, children listen and then try to construct nine different buildings presented on a cassette recorder that had been recorded by a 12 year old female confederate. Six of the building directions contained purposefully embedded inconsistencies or ambiquities that made it impossible to construct the building while the other three directions were nonproblematic.

(See Figure 2 for an example of a problematic and nonproblematic direction, respectively.) The children were video- and audio-taped during the pre and posttest as they constructed their buildings on small plastic trays.

Procedure

All children were pretested on the PPVT-R, concept test, MFFT, and the analosue building task, Following the pretesting, the children in the Logo condition received twelve 30 minute Logo lessons on Apple II Plus microcomputer, four per week over a span of three weeks. These sessions were vidoetaped for all children. All children except for one were taught in pairs consisting of one male and one female. The Logo sessions followed the sequence of lessons employed by Clements and Gullo (1984) in which the children first learn isolated "turtle" commands and then learn to write procedures that incorporate the commands using a special support program for young children developed by Clements (1983). At each stage, children first planned and drew what they would program the turtle to do and, throughout, children were encouraged to "debug" their programs and to find errors. Children in the Control condition received approximately equivalent exposure to the experimenter in play groups of either two or three during the same three week period. Additionally, these children received an average of seven sessions on the microcomputer during which they played a series of computer games designed to teach prereading and arithmetic skills (i.e., Preschool IQ Builder by Applesoft, 1981; Elementary Language ARts by MECC, 1981). Following the conclusion of training, all children were posttested on an alternative form of the MFFT and the analogue building task.

Analysis

Videotapes of the lessons for three time periods, one session per week, on two pairs of children, one Chinese-American boy, one Black American girl (pair 2); one Ethiopian boy, one Black American girl, (pair 1), were transcribed in terms of both verbal and nonverbal behaviors. The transcripts were then recoded following procedures described by Sinclair and Coulthard (1975). In addition to the speech acts developed by Sinclair and Coulthard, we also developed a set of metacognitive teaching acts based on the goals of the study which were used deliberately by the teacher, Gloria Miller, the co-investigator in the study (Figure 1). Two types of differences are discussed: differences between pairs within a single session, on two types of exchanges: Initiate and Co-Direct.

The lesson was segmented into three phases: phase 1 - discussion of cooperative behavior; phase 2 - review of commands previously learned; and phase 3 - introduction of new commands. The lesson was the second one for the week, where children were taught the commands to control the turtle's actions. For both pairs, virtually no differences appeared in phase 1, and phase 2 began in a similar fashion for both pairs. G began in both cases with an Elicit exchange, using a metaelicit (mel) act to get the children to recall the previous commands: (Figure 3 - examples 1 & 2)

There are slight differences in that pair 2 receives more information for producing the desired monitoring response (mr), and K's answer in pair 1 is more elaborated; she describes both the components of the command, "forward" (FD) and its function. However, we do not feel these differences were significant across the entire lesson. Both pairs also spend approximately the same amount of time in phase 2 practicing their mastery of the old commands. We did find differences in two types of exchanges that may prove significant in demonstrating how children master new material.

Differences in Initiate Exchanges

In our analysis, we found it necessary to create several new types of exchanges, in addition to using the ones developed by Sinclair and Coulthard (1975). One type we labelled Initiate: an agent attempts to get an action underway; if successful, this action will be adopted by others and acted upon. In a traditional classroom, it is assumed the teacher controls the agenda; there is little opportunity for children to initiate new actions apart from the teacher's agenda, let alone the possibility the children's ideas will become the next activity. However, we found this to be a common feature in Logo learning. Children would hit upon an idea they wanted to try with the turtle, and G would let them work on it until she was ready to introduce a new concept. In a sense, the teacher did maintain control over the agenda as a whole, but the children were able to change actions within frames. This freedom is a desirable aspect of Logo instruction; in fact, we hoped to see an increase in initiate exchanges with child as agent across the lessons as children become more proficient in using Logo. We would expect initiate exchanges where the teacher is agent to be more frequent when new material was being introduced, since the children would need time to master the concepts before trying out their ideas.

When we examined pair differences in this dimension, an interesting pattern emerged (Table 1)

In phase 2, K (black girl), was anxious to show A (black boy) how to do things on the computer. She took on the role of quasi-teacher (a role not always appreciated by A), and she felt very comfortable with her knowledge of how to use the commands she had already learned. Consistently throughout the lesson, she picked up information faster than A, and always wanted to show it off. However, in phase 3, her initiations declined, because it was new material, and she was less sure of her ability to use it. Here she was content to let G initiate the actions to model what was to be learned next.

In contrast, pair 2 had slightly ewer initiate exchanges, because they spent more time exploring the possibilities of using a command in different ways. For example, MK & Ta became intrigued with the question of how many steps it would take to bring the turtle up to the top of the screen. They spent considerable time on this project before moving to the next one. K, on the other hand, went through the repertoire of commands they learned the day before, but without elaborating on the possibilities of each one (within this pair she was the more dominant partner.)

The pattern changed in phase 3, where MK (Chinese-American boy) now took the lead in initiating exchanges. In this phase3, G was teaching about new commands; and we saw evidence that MK was beginning to assimilate the knowledge and use it in new combinations. Of all the pairs, he was the first child to attempt new ideas; the other children caught on to this after the next lesson. Just in the difference between phase 2 and 3 we saw a "microgenetic" (Wertsch et. al., 1981) change occurring in MK; a child consolidated old knowledge and built new knowledge upon it, which he then combined into new forms of learning.

We feel this difference between pairs (which persisted for the rest of the sessions) illustrates differences in their zones of proximal development. Both pairs were able to master the programming tasks set by the teacher, but mastery was achieved at variable rates. In each case, learning was facilitated not only through the teacher's metacognitive cues, but also by a peer who acquired the concepts more quickly, and then helped the child with whom they were paired. In pair 1, it was K who learned faster: in pair 2, it was M. Both these children would direct their partner's actions in junction with the teacher's assistance. We see this behavior illustrated in the co-direct exchanges.

We created the category, co-direct to describe exchanges where activities were jointly constructed by two or more agents to accomplish a task. We needed this category to differentiate between times when the teacher directed the child to perform an action (e.g., G: "See you can push this one"; child pushes 'delete' key) and situations where it was clear task performance depended upon the collaborative efforts of either the teacher and the two children, or between the two children alone. This behavior is illustrated in example 5 for Pair 1, and in example 6 for Pair 2. (Figures 4 & 5)

The goal of this mini-lesson was to teach A how to use the control-d function to delete letters (K had already mastered this). In lines 98-105, G directs A to delete the letter 'm'; A asks for clarification, and K echoed both G's directive, and her reply to A's question. K often did this; she adopted G's behavior to direct A's behavior. But in lines 106-125, there is a subtle shift in K's role; she now assumes an active role in the teaching process, even to the extent of actually guiding A's hand over the keys. Later in the lesson, as A gained more confidence, he and K would begin to construct an action together along with G's help. In sequences like this, each child received support not only from the teacher, but from the other peer.

The same behavior occurred with pair 2, as illustrated in example 6 (Figure 5).

In this little sequence, the children are working on the problem of bringing the 'turtle' up to the top of the screen without disappearing. MK guesses 20 more steps are needed, which at first G is not sure will work. Her attention is then deflected by Ta, who wants to do something else (line 123), but G pulls the lesson back on track and then asks MK for his opinion (line 130). MK then directs Ta to try his idea out; instead, Ta puts in her own number, 12, which proves to complete the task.

The difference between pairs on this dimension is illustrated in Table 2. Initially, pair 1 did not have as many codirect exchanges as pair 2 in phase 2 because it took them longer to master the idea that they could make the turtle perform better by working together. But by the time they reached phase 3 (about halfway through the lesson) they had caught on, and their performance was similar to pair 2's performance. In this context, we actively encouraged cooperative behavior by giving a chieck every time it occurred; if the children receivec 10 checks or more during the lesson, they received a stamp. Although pair 2 consistently performed better overall in using cooperative behavior pair 1 did increase their cooperative behavior over time.

These examples are just a sample of the type of analyses that can be done using this data. In future analyses we will be examining differences within and between pairs across multiple lessons. We also expect to develop indexes of language use in terms of children's metacognitive responses to the teacher's cues, and correlate them to children's s ,res on the monitoring comprehension transfer task.

The probabilities of specific speech acts occurring in predicted sequences can also be tested, using a procedure developed by Mandeville (note 7).

Using videotapes of the lessons, we can study the process of learning Logo as mediated through the teacher's and children's interaction, as well as relating process variables to outcomes on specific performance measures on a transfer task. We feel this approach blends the best of both quantitative and qualitative approaches. In our case, having the videotapes available made it possible for us to specify how changes in learning occurred as well as provide qualitative information to explain the difference in performance on the monitoring task between the two groups. The finding that the Logo children significantly improved in their ability to detect errors on the transfer task is of interest in itself (Miller, Emihovich, Clare & Froning, Note 5), but it is not enough. We need to account for the factors that led to the difference; otherwise, we cannot ensure that the same difference will be repeated in other groups. The history of any innovative educational method is that one group of researchers will claim it works; another group will replicate the study and claim it doesn't. Failure to specify contextual features of the teaching learning process underlying the method is what led to this dilemma: and in the case of Logo, current claims it does not 'work' by some arbitrary criteria independent of the content being taught may lead to its demise in schools before its promise can be realized.

4. Directions for future research

In presenting our ideas in this paper, we make no claim that ours is the definitive approach to assessing Logo instruction. Furthermore, we clearly see that certain components have either been left out of the model entirely or have been given a very cursory treatment. Two examples immediately come to mind. One is that current research on children's metacognitive abilities has not been well integrated into our model. In particular, we have not fully considered the question of what cognitive prerequisites (Pea & Kurland, in press) are needed to program successfully at what age level, although we would argue that children's zones of proximal development in this regard indicate children can achieve more than previously thought possible. How far can children go, at what age levels, and the policy implications of providing children with this training are issues for other researchers to consider, and for us to explore further.

We also recognize that our experimental teaching sessions are but one type of context; our ecological validity (Cole, Hood & McDermott, note 6) cannot be sustained across different learning contexts. At some point, we will need to link learning Logo in our experimental context to learning it in naturally occurring contexts, but as Cole et. al. (note 6) have pointed out, specifying the cognitive skills involved in naturally occurring tasks is a problem which has yet to be resolved. In those contexts, social interaction assumes an even greater importance than it does in our context, since the number of persons whose actions need to be accounted for is greatly increased. Intrapsychological cognitive processing may be lessened since information can be obtained and shared by others. The high degree of social interaction which occurs in a computer lab is a good example: learning may be a function of what is being discussed and shared among the participants. The transmission of knowledge is not a random process; there are constraints on what people get to learn (Gearing, 1979) as well as the constraints imposed by each individual's ability to learn. We need more information on how individual cognitive differences are mediated through social experience in various contexts. Treating an experimental learning session as one type of context is one place to begin, but not end, the research process.

In the final analysis, perhaps Papert promised too much; disappointment is a natural and not unexpected outcome. But another interpretation is that the true potential of Logo and other innovations like it, have yet to be realized. The educational vision Papert created requires an equally visionary approach to assessing its effects; the old models no longer suffice. The models for assessing Logo learning, as well as other computer learning processes such as writing with word processors (Piazza, Note 8) are now being developed. It remains to be seen if translating the models into practice realizes the promise of rethinking how children will be educated for the future.

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Table 1

Differences between Pairs in Initiate Exchanges

Phase	Agent - Pair 1			Agent -Pair 2		
	K	A	G	MK	TA	G
2 (review Old commands)	7	3	3	4	3	3
3 (learn new commands)	3	3	8	7	3	6
Total	10	6	11	11	6	9

Table 2

Differences between Pairs in Co-direct Exchanges

Phase	Pair 1	Pair 2
2	2	6
3	7	7
Total	9	13

Figure 1

Meta-Cognitive Teaching Acts for Logo Training

Name of Act	Description	Examples
Meta elicit (Mel)	Agent asks receiver to recall information previously learned	-Remember what those were for? -What is ___ supposed to do? -How do we get a new line?
Meta evaluation (Mev)	Agent asks receiver to evaluate ongoing actions	-What happened? -What did the turtle just do? -What's going to happen when we put ________? -Do you know why that's there? -How far did he go? -Did the turtle do what you told him? -Did you want him to go that way? -Do you know what I am doing?
Meta prompt (Mp)	Agent is asking receiver to think about or reflect on what they want to do next.	-What do you want the turtle to next? -Which way do you want him to point? -How will you make him go there? -What else do you want him to do?
Planing prompt (pp)	Agent indicates there is a next action planned but it has not been in response to reflective thinking.	-Let's try the other one. -Let's make him go forward and put a line up here.
Direct intervention (Di) or Direct (D)	Agent explains and demonstrates what to do to the receiver Agent explains or tells what to do the receiver	-Let me show you something. -And now put 'd' -Put space and then 70. -Tell Kia what she should do.
Self-cuing (Sc)	Agent verbalizes some meta and other direct statements to guide their actions.	-OK, What am I going to do? -Hmmm, I will have to put in a BK. -I think I know what happened? -How will I make hime get there? -Did that turtle do what I told him?

Figure 2

Example of a problematic and nonproblematic block building instruction.

Type	Instruction	Materials and Problem
Problematic	Put the <u>blue</u> block on the <u>blue</u> tape. Put the <u>yellow</u> block on the <u>yellow</u> tape. Then put the <u>red</u> block on top.	tray with tape colors spaced so it is impossible to bridge any two with a third block. Blue, yellow and red squares. (i.e. Should child assume "on top" means on top of yellow or blue or both, thus, impossible to execute).
Non-problematic	Put the <u>yellow</u> triangle on top of the <u>green</u> square.	tray, yellow triangle and green square. (i.e. No problem executing the directive).

Figure 3

Example 1 - Pair 1

27 G: Remember some of the things we did?

28 K: Like lessee

29 Well uh you have to try to press FD

30 Now press FD

31 Press space

32 A: F?

33 K And then press any number you want

34 A: F?

35 K: And then the turtle will go any amount you want

36 G: Terrific

37 Nice helping K___.

Example 2 - Pair 2

3 G: Remember when-

4 What's going to happen when you put in...
Forward

5 What's the turtle going to do

6 Show me on the screen (points to screen)

7 MK: The turtle's gonna go

8 TA: Forward

9 G: He's gonna go up isn't he

10 Forward

Figure 4

Example 5 - Pair 1

(G has just asked A to delete a letter)

98 G: See if you can't take one of those 'm's" off A____
99 See if you can take one off now
100 Press back

101 (A begins pressing the cursor)

102 K: Back

103 A: This one?

104 G: Yup

105 K: Yeah

106 G: Watch it
107 There you go
108 Now you got it blinking over it
109 Now-

110 K: OK now (takes A's hand to press 'd')

111 G: Control (leans forward to press key)

112 A: Let me try

113 K: Control
114 G: Control

115 G; Press that down

116 And now 'd' (point to 'd' key)

117 K: d (holds A's hand over key)

118 G: d

119 (A presses both keys)

120 K: Take it off

121 G: You have to press control
122 Control...
123 Did he do it?

124 A: Yeah

125 K: Yeah

Figure 5

<u>Example 6 - Pair 2</u>

113 G: And now
114 OK now remember
115 I think-
116 If I had to guess I might guess ten
117 Ten one zero
118 Let's see how far
119 Oh it looks like it can still go up more
120 MK: Maybe twenty
121 G: Maybe another ten
122 MK: Maybe...
123 TA: I want to do another one
124 G: OK
125 Can you-
126 OK well
127 Can we-
128 Let's try one more to see how far up we can get without it disappearing
129 One more
130 What do you think?
131 MK:Twenty
132 MK/TA: Try twenty
133 (Ta begins to type in command)
134 MK: And two two
135 G: Maybe she wanted to try twelve
136 You got it
137 That's perfect you see (points to screen)
138 Cause it's just starting to disappear
139 Perfect
140 So about that far (points) is as far as you can go before it starts disappearing (moves finger up and down screen)
141 Very good