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Annemarie S. Palincsar
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Abstract

It is suggested that some of the difficulties students experience in solving academic problems are due to their failure to distinguish between those skills needed for everyday thinking and those needed for academic thinking. It is argued that certain characteristics of everyday thinking are ill-matched to the needs of formal education, and that the failure to identify contexts in which intentional cognition is required may prevent successful problem solving. As evidence for this view, research is discussed which shows that the comprehension failures of poor readers are often associated with their inadequate comprehension monitoring skills; but, it is also shown that effective monitoring skills can be taught. The possibility of extending these intervention procedures to foster problem solving in science and math are discussed.

Everyday and Academic Thinking: Implications for Learning and Problem Solving

In this paper we explore the view that the difficulties some students experience in learning from texts, and in solving other types of academic problems, are due to their failure to distinguish between those skills needed for everyday thinking and those skills needed for academic thinking. Functionally, the distinction between <u>everyday</u> and <u>academic</u> thinking skills is somewhat akin to a difference between effortless or incidental cognition and deliberate effortful cognition. In general, everyday thinking skills provide the means for interacting with our world on a day-to-day basis, involve routine scripted activities, and are executed relatively automatically. Problems requiring academic thinking skills, in contrast, place a far greater emphasis on precision, deliberate evaluation, accurate understanding, and predictions consistent with the provided facts.

For the purposes of this paper we treat the distinction between everyday and academic thinking skills as a heuristic distinction, rather than one which emphasizes a continuity of skills, or one which implies the existence of two qualitatively different skill categories. However, we believe that the overreliance on everyday thinking skills in academic domains will cause students difficulty in solving intellectual problems.

As a means of advancing our view we examine the effective learning strategies that are supposedly in the repertoire of expert readers but which must be acquired by novices if they are to become experts. First, we discuss the types of processing problems children experience when asked to read in order to meet a strict criteria of understanding or remembering. Second, we suggest that the reason some students have pervasive problems with academic learning is because their thinking has all the strengths and biases of everyday thinking. Third, we then argue that certain characteristics of everyday thinking are particularly ill-matched with the demands of formal science education. Forth, we discuss, briefly, possible interventions that have worked in introducing more effective learning and teaching strategies in the general realm of reading comprehension. We also speculate on possible extensions of that work to the teaching of math and science, at least at the level of basic number principles.

Cognitive Monitoring and Comprehension

Many reading activities, at least by the latter part of grade school, actually call for a variety of thinking and study skills (Brown & Palincsar, in press); students are not only required to decode, they are also required to understand the meaning, to evaluate the message, and even use what they read to solve problems. In order to do this, they must engage in a variety of activities that will foster comprehension and

retention. Trouble will ensue if students choose to remain passive in the hope that learning will occur automatically. In order to learn effectively they must engage in intentional cognition rather than rely exclusively on incidental learning (Brown, 1975; Berieter & Scardmalia, 1985).

It has been argued that effective learning from texts involves a split mental focus (Brown, 1980): students must focus on the material to be learned, and, at the same time, monitor their understanding and retention of it. In addition, they must check to see if they are employing those mental operations that will produce learning.

Students who know how to study efficiently proceed very differently when they are reading for pleasure or to obtain a quick impression of the gist, compared with when they are reading in order to remember the text, or compared with when they are attempting to resolve comprehension difficulties (Brown, 1980; Brown, Armbruster, & Baker, in press; Forrest-Pressley & Waller, 1984). In the first state (incidental learning), they read rapidly and, seemingly, effortlessly; but in the latter state (intentional and effortful learning), they proceed slowly and laboriously, calling into play a whole variety of learning strategies and comprehension-fostering activities.

The deliberate use of understanding processes requires the judicious allocation of effort which does not come naturally to. all learners. For example, one seventh grade student, asked how he reads when he wants to make sure he will understand and remember, responded, "... well ... I stare real hard at the page, blink my eyes and then open them -- and cross my fingers that it will be right here (pointing to his head)." This may be a somewhat extreme example, but consider another student who replied -- "I read it two times if she (the teacher) says study, once if she says read" -- yet another -- "I read the first line of every paragraph" (see Brown & Palinscar, in press, a, b). Some of these "strategies" are going to be more efficient than others, but note that these students, confident in their method, are far short of understanding the need for the flexible application of strategies to meet variations in the task at hand.

Researchers in the areas of metacognition and reading will tell you that effective reading demands, but young students rarely produce, a whole variety of self-regulatory activities such as planning ahead, checking one's understanding, evaluating the cost-effectiveness of any strategy, and correcting comprehension or retention failures by a variety of fix-up strategies. All of this flurry of furious activity is a reflection of intentional cognition, with the student taking charge of her own learning processes, and critically evaluating her own thinking. The rhetoric is undoubtedly familiar and part of metacognitive lore; nevertheless, the notion of comprehension-monitoring needs to be examined more closely.

What do we mean when we tell students to monitor their own learning processes? Comprehension admits of degrees: it is surely more difficult to check that one understands fully the logical entailments of a complex theory than it is to check that we understand the main point of a well-formed narrative. How do students set acceptable comprehension criteria and know when they have been met? The same is true of memory monitoring—what are we teaching when we teach students to monitor their own memory? We are more likely to be successful if we require students to check that their retention of material exceeds some criteria of verbatim recall; it is much more difficult to show students how to set abstract criteria for gist retention. But effective studying is more likely to require the application of such abstract criteria, unless we are satisfied with the rote retention rather than the critical evaluation of context. Whitehead, in his address to the British Mathematical Society in 1916, railed against an educational system that resulted in the rote acquisition of <u>inert knowledge</u> (i.e., facts and procedures that were acquired but rarely applied because the goal of learning was retention for its own sake), and argued in favor of procedures that would promote critical thinking, evaluation and reflection.

What we mean when we talk about effective studying, then, is critical thinking about the material, rather than rote retention or the ability to regurgitate someone else's gist. Here the parallels with the needs of science education are clear: We want students to engage in the equivalent of Socratic dialogues with themselves, questioning and elaborating their own understanding of the contents of the text, testing possible generalizations by raising counterexamples, extracting and applying principles, detecting tautologies and internal inconsistencies, and so on. Scholarly journals are replete with examples of how young students experience what seem like extraordinary difficulty with such precise, effort-demanding, knowledge-extending and knowledge-refining activities; however, little is understood of the source of these difficulties.

Everyday Thinking: The Intuitive Scientist

Why do students look like such ineffectual thinkers? Why do even the well-intentioned appear to be such sloppy learners or lazy processers, unwilling or unable to evaluate texts for internal consistency, compatibility with known facts, or just plain common sense? Some of these pervasive biases may be due to the fact that the learners are young, or just plain human? We would like to argue that these pervasive tendencies are characteristic of everyday thinking in general rather than problems of the young in particular.

Human beings are extremely facile at certain forms of reasoning which suffice for their daily concourse with the world around them. When we characterize the child as a little scientist creating and testing hypotheses about his world, we are

really making a comparison with the intuitive scientist of everyday thinking rather than the formal scientist's method of logical deductive reasoning that human beings are capable of--if circumstances force them to be! (Johnson-Laird, 1983; Nisbitt & Ross, 1980; Ross, 1977, 1981; Schweder, 1977, 1980). Much of human thinking has been called scripted, overlearned, even mindless (Chanowitz & Langer, 1980), reflecting the fact that it can run off without a great deal of cognitive effort. Everyday learning is more often than not a by-product of efficient incidental cognition rather than the just rewards of intentional cognition; and it is very efficient for organizing everyday life.

Certain charateristics of the intuitive scientist's thinking, however, will cause difficulty when the learner must operate within the realm of formal science education. The very efficiency of everyday thinking comes at a cost because human thinking is characterized by certain biases of reasoning that lead to trouble in formal domains of learning.

Let us consider some of the characteristics of everyday thinking that have been described in classic "cognitive" works such as Bartlett's (1958) book on thinking, Tversky and Kahneman's work on subjective probability and judgment under uncertainty (see Kahneman & Tversky, 1971, 1973; Tversky & Kahneman, 1973, 1974), and social cognitive considerations of "intuitive social scientists" (Nisbitt & Ross, 1980; Ross, 1977, 1981; Schweder, 1977, 1980). In everyday thinking intuitive concepts predominate. Intuitive concepts are acquired without explicit instruction and regardless of the desire to learn. In contrast, nonintuitive concepts are relatively difficult to learn, often involve special learning environments for their acquisition and massive instructional input; they require an orderly and explicit organization of learning experiences (Schweder, 1977, 1980). The claim is also made that the products of such formal learning experiences are generally absent from the thinking of normal adults, and of all adults most of the time.

Many have claimed (Nisbitt & Ross, 1980; Schweder, 1977; Tversky & Kahneman, 1971, 1973) that basic statistical concepts having to do with chance and probability are nonintuitive (e.g., correlation and contingency). Adults, including social scientists, typically avoid correlational reasoning. They have erroneous intuitions about the laws of chance, and tend to regard a small sample, randomly drawn from the population, as highly representative. Tversky and Kahneman (1971), for example, found that research psychologists were more impressed by a single experimental outcome which provided strong support for a hypothesis than by the conjuction of the same result with another, which provided positive but weaker support for the hypothesis. Further, reasoning is unduly weighted by such factors as personally experienced frequency of occurrence, ease of retrievability and imaginability of examples (i.e., the ease

with which relevant instances come to mind). Unwarranted generalizations are made from specific personal cases, due importance is rarely given to base rate or consensus information (see Tversky & Kahneman, 1971, 1973).

Argument and decision making in everyday thinking also differ from "scientific thought." Four hundred years ago, Francis Bacon deplored the human tendency to maintain preconceptions in the face of seemingly overwhelming logical or empirical challenges to their validity. And from Bartlett on, we have seen many examples of such resistance to the weight of evidence. Everyday thinking is biased in favor of positive exemplars, negative evidence is given less weight and often not invoked at all. Everyday arguments are slanted towards definite decisions, even if the evidence is inconclusive or does not warrant them. Most conversational arguments are inductive, not deductive, and the inductions of everyday conversations are rarely explicit; the inferences are not entailed by the premises. Empirical evidence is preferred even when premises can be evaluated in terms of their nonempirical truth values (internal contradictions and tautologies) (Osherson & Markman, 1975).

The model of the everyday human is one of an intuitive scientist, whose high level of overall proficiency is marred by specific inferential shortcomings. For everyday life, these shortcomings are rarely fatal. But for academic life, and particularly for the development of formal scientistic thought, they are costly indeed. As Tversky and Kahneman (1971) argue, these intuitive concepts are sometimes shared by trained scientists as well as naive everyday thinkers, and this has unfortunate consequences for scientific enquiry. Indeed, there has been a spate of studies showing that intuitive scientific knowledge is strongly held and often gets in the way of the acquisition of scientific theory (diSessa, 1983; McCloskey, 1983; White, 1983).

diSessa's (1983), for example, showed that relatively sophisticated M.I.T. undergraduate physics students are often "welded" to their naive theories. He demonstrated that when instructors give explicit problem solving prompts, or offer an alternative explanation, students often distort evidence or present counterexamples designed to support their own position and/or sabotage that of the instructor. McCloskey (1983) believes that on the basis of everyday experiences, most people development remarkably well-articulated naive theories of physics--theories that are inconsistent with the fundamental principles of classical Newtonian physics. In his work, McCloskey (1983) has shown that college students' often make judgement errors about the motion of solid objects because they subscribe to a particular naive theory of motion (the impetus theory). Moreover, McCloskey, like diSessa, believes that naive theories are strongly held and may not easily be changed by

instruction, unless instructors make explicit comparisons between naive beliefs and classical theory.

<u>Steps to Overcoming the Problem</u>

All this may sound depressing, but it does not have to be interpreted this way. A first step to overcoming a problem is recognizing that it exists and identifying its nature. The more we know about how students prefer to think, the more we know about their biases as well as their strengths, the more likely it is that we will be able to design effective instruction tailored to their needs; that is, instruction designed to overcome their thinking "bugs" (J. Brown & VanLehn, 1982). The ability to characterize students' misconceptions and procedural biases, and to map the steps between entering competence and desired competence, are necessary first steps before we can design effective instruction to bridge the gap.

Over the last four years several successful instructional studies, guided by these considerations, have been conducted in our labatory. (Brown & Day, 1983; Brown & Palincsar, in press-a, b; Day, 1980; Palinscar & Brown, 1984). These instructional progams have worked in the sense that a detailed analysis of the task components was conducted, the students' entering biases were diagnosed and the mismatch between these and the strategies required for competence were identified, and the instructional procedure leading to efficient performance was successfully implemented. We will give as an example some recent work on teaching students to comprehend beginning scientific text, because clear generalizations can be made from these studies to science and math education (at least in the early grades). We will describe briefly the highlights of the program and then end with some speculations about extensions to science education.

The students were generally disadvantaged seventh graders with average decoding skills, with generally weak academic records, who experienced particular difficulty on both standardized and criterion-referenced reading comprehension tests. They tended to score about 20% correct on these types of tests in the classroom and in the laboratory before the intervention began. It appeared that the student's low level of performance was due to their extreme passivity in such situations, their favorite strategy being the one-shot read -- or, if under pressure, the desperate re-read. Whereas the desired behavior on such tests is the deployment of active comprehension-fostering and -monitoring strategies.

The instructional procedure developed by Brown and Palincsar, called reciprocal teaching, was designed to mimic the main features of expert tutoring, or expert scaffolding, to use Bruner's (1978) term. Expert scaffolding is a natural teaching style whereby an expert (a teacher, a peer, a parent, a mastercraftsman) provides a supporting context in which students acquire skills (Brown & Reeve, in press). The expert initially takes on the major responsibility for the group's activity. The

expert performs, models, and explains, relinquishing part of the task to the novices only at the level each one is capable of negotiating at any one point in time. As a novice becomes more competent, the expert increases her demands, requiring participation at a slightly more challenging level.

In Palincsar and Brown's (1984) procedure the teacher and student took turns leading a dialogue on sections of the text they were reading. The teacher assigned a segment of the passage to be read and either indicated that it was her turn to be the teacher or assigned a student to teach that segment. The adult and the students then read the assigned segment silently. After reading, the teacher (student or adult) for that segment summarized the content, asked a question that a teacher or test might ask on that segment, discussed and clarified any difficulties, and finally made a prediction about future content. All of these activities were embedded in as natural a dialogue as possible, with the teacher and students giving feedback to each other.

Palincsar and Brown (1984) instructed students in the use of four strategies used by expert readers: Summarizing, questioning, clarifying, and predicting. These four activities were selected because they can be both comprehension-fostering and comprehension-monitoring activities if used properly. Recalling the gist of what has been read is a good way of testing whether important material has been identified; if an adequate synopsis cannot be produced, it is a sign that remedial action is called for. Thus, summarizing what one has read, and asking questions of clarification, interpretation, and prediction are activities that both improve comprehension and allow students to monitor their own understanding.

Reciprocal teaching involves more than just taking turns: it involves what has been called proleptic teaching. Proleptic means "in anticipation of competence," and in the context of instruction refers to situations where a novice is encouraged to participate in a group activity before she is able to perform unaided; the social context supports the individual's efforts (Brown & Reeve, in press; Reeve & Brown, 1985). In these teaching situations, a novice carries out simple aspects of the task while observing and learning from an expert, who serves as a model for higher level involvement. At first the novice participates more or less as a spectator responsible for very little of the actual work. But as she becomes more experienced and capable of performing at a higher level, the expert guides her to increasingly more competent performance. The teacher and student come to share the cognitive work load equally. Finally, the adult fades herself out, as it were, leaving the student to take over, and the adult teacher to assume the role of a sympathetic coach.

Within these systems of tutelage, the child learns about the task at his own rate; in the presence of experts, participating

only at a level he is capable of fulfilling--or a little beyond--thereby presenting a comfortable challenge. The child is taken gradually to the limits of his ability, and the mental jumps expected of him on his way to competence are never large. The expert, then, (a) models appropriate comprehension activities, (b) makes the usually covert strategies, overt, (c) engages in an "on-line" diagnosis of difficulties and monitors understanding, and (d) gives appropriate feedback, and asks a little more of the child as the child acquires competence. The novice, in contrast, (a) participates at his or her own current cognitive level, (b) makes overt current competence, (c) receives feedback that rewards and stretches, and (d) gradually progresses to competence (see Brown & Palincsar, in press-a, b; Palincsar & Brown, 1984, for example of students progress).

The results of using reciprocal teaching procedures with grade school and junior high school students has been encouraging. Ten main outcomes have been found: (1) there was clear evidence of improvement in the students' ability to paraphrase, question, clarify and predict when called upon to do so; (2) the students progressed from passive observers to active teachers, able to lead the dialogue independently, and in some case, eventually take the role of the peer tutor; (3) there was a large and reliable quantitative improvement on the comprehension tests (from 20 to 80% correct), bringing these poor readers up to the level set by good comprehenders; (4) the effect was durable;

there was no drop in the level of performance for up to an eight week period, and little after six months; (5) the effect generalized to the classroom setting, with students reaching or surpassing the average level for their age mates; (6) training resulted in reliable transfer to laboratory tasks that differed in surface features from the training and assessment tasks; writing summaries, predicting appropriate comprehension questions, and detecting text incongruities all improved; (7) sizeable improvements in standardized comprehension scores were recorded, averaging two years; (8) the full reciprocal teaching procedure always resulted in greater improvement and more durable performance than competing instructional procedures, such as direct instruction in the use of the strategies; (9) the intervention was instructionally feasible; that is, it was no less successful in natural group settings conducted by regular teachers than it was when conducted by the experimenter in a laboratory; and (10) the teachers were uniformly enthusiastic about the procedure once they had mastered it and many planned to incorporate it into their routine teaching repertoires.

Extensions to Math Education

There is no reason, in principle, why reciprocal teaching procedures cannot be used in other domains. We have already used the techniques to improve listening comprehension in first grade children (Palincsar & Brown, in press); and, Berieter and Scardamalia's work suggests that the reciprocal teaching

procedure can be used to foster writing skills (Berieter & Scardamalia, 1985; Scardamalia, Bereiter, & Steinbach, 1984).

Can the techniques be be used outside of the language arts to facilitate problem solving in science and math? In principle, what is needed is a task analysis to identify what a particular form of problem demands in terms of knowledge and processing strategies, what strategies the child possesses that may be helpful or misleading, and then a script for making the desired procedures simple, concrete, explicit and readily modeled by the teacher. This may appear a difficult problem, but it is unlikely to be insoluble considering the enormous amount of work that is now appearing analyzing the systematic error patterns typical of early learning in mathematics and science (Brown & Campione, in press).

Recent research aimed at uncovering the principles involved in arithmetic learning suggest methods of intervention that go beyond blind drill and practice. Progress has been made, for example, in mapping the development of number concepts (Gelman & Gallistel, 1978; Gelman & Meck, in press), arithmetic facts (Ashcraft, 1982; Baroody, 1983; Siegler & Schrager, 1984), principles underlying place value notion (Resnick, 1982, 1984), and the systematic errors, or "bugs", children make in completing written subtraction problems (J. Brown & VanLehn, 1982). These developments have made possible sensitive diagnosis of the child's understanding, or misconceptions, of arithmetic facts and procedures (Allardice & Ginsburg, 1983). We consider that procedures, modelled on those designed to foster reading and listening comprehension, could be developed to help young children understand their procedural arithmetic bugs. Even with very young children understanding can be the aim of instruction.

What kind of remedial instruction should be instigated, once the "pattern of errors" in a child's thinking have been identified? We cannot provide an empirical answer to this question yet, but consistent with the views specified earlier, we believe that instruction should help children reflect on the purpose and meaning of arithmetic procedures. A concrete instantiation of this suggestion exists in Open Court's Real Math Thinking Stories (Willoughby, Bereiter, Hilton, & Rubinstein, 1981: see Table 1). The stories pose problems that tap the child's understanding of not only mathematical principles but also a whole variety of everyday thinking biases that impede deductive thinking. At intervals through the story, as a story character makes a thinking error, the teacher is encouraged to stop and engage the children in an argument on why a situation might lead to difficulties. With careful consideration of the sequencing of problems and the design of scripts to help the teachers lead the dialogues initially, the exact equivalent of the reciprocal teaching procedures could be used to foster mathematical thinking skills.

Insert Table 1 about here

Summary and Conclusions

Much of what has been called reading comprehension research has actually been research in reasoning, with wide applicability to many forms of academic learning situations, including math and science. Science education may involve a particularly extensive version of the general problem of a mismatch between the customary modes of thinking of human beings, but it perhaps is not different in kind. All academic learning involves this mismatch to some extent. In settings of formal education, the goals and contexts of learning are usually not of the child's choosing. The goal is rarely spontaneous discovery dictated by interest, but learning for learning's sake, remembering as a goal in itself rather than as a means to a meaningful end. Much of academic learning is divorced from readily understandable goals, e.g., the play goals of childhood or the work activities of adulthood (Bruner, 1972). The learner is asked to acquire decontextualized bodies of knowledge for knowledge's sake, in the service of no goal other than success in school. Such practices even when undertaken by the gifted or selected student tend to result in the accumulation of Whitehead's "inert knowledge,"-- remembered but not understood facts that are rarely applied appropriately. Even the preferred categories or structuring of knowledge in temporal, spatial scripts or thematic episodes must be replaced by academic forms of organization by hierarchy and taxonomy (Mandler, 1983). School learners are required not only to acquire knowledge in specific domains, such as mathematics and science, they are also required to "learn how to learn" in general, to become something akin to all-purpose learning machines, developing routines for studying in general. Under such circumstances, children's natural learning proclivities are often overwhelmed by the demands of acquiring large amounts of decontextualized material, organized in non-preferred modes, under greater demands for precision and processing capacity than is generally the case in everyday learning and thinking. Recognition of these facts, together with and detailed mappings of the mismatch, has the potential for guiding the design of instruction in new and exciting ways.

References

Allardice, B. S., & Ginsburg, H. P. (1983). Children's psychological difficulties in mathematics. In H. P. Ginsburg (Ed.), The development of mathematical thinking (pp. 319-350). New York: Harcourt, Brace, Jovanovich.

Ashcraft, M. H. (1982). The development of mental arithmetic: A chronometric approach. Developmental Review, 2, 213-236.

Baroody, A. J. (1983). The development of procedural knowledge: An alternative explanation for chronometric trends of mental arithmetic. Developmental Review, 3, 225-230.

Bartlett, F. C. (1958). Thinking: An experimental and social study. New York: Basic Books.

Bereiter, C., & Scardamalia, M. (1985). Cognitive coping strategies and problem of "inert knowledge". In S. F. Chipman, J. W. Segal, & R. Glaser (Eds.), Thinking and learning skills (Vol. 2, pp. 563-578). Hillsdale, NJ: Erlbaum.

Brown, A. L. (1975). The development of memory: Knowing, knowing about knowing, and knowing how to know. In H. W. Reese (Ed.), Advances in child development and behavior (Vol. 10. pp. 103-152). New York: Academic Press.

Brown, A. L. (1980). Metacognitive development and reading. In R. J. Spiro, B. Bruce, & W. Brewer (Eds.), Theoretical issues in reading comprehension (pp. 453-481). Hillsdale, NJ: Erlbaum.

Brown, A. L., Armbruster, B. B., & Baker, L. (in press). The role of metacognition in reading and studying. In J. Orasano (Ed.), Reading comprehension: From research to practice. Hillsdale, NJ: Erlbaum.

Brown, A. L., & Campione, J. C. (in press). Psychological theory and the study of learning disabilities. American Psychologist.

Brown, A. L., & Day, J. D. (1983). Macrorules for summarizing texts: The development of expertise. Journal of Verbal Learning and Verbal Behavior, 22, 1-14.

Brown, A. L., & Palincsar, A. S. (in press-a). To appear in L. Resnick (Ed.), Cognition and instruction: Issues and agenda. Hillsdale, NJ: Erlbaum.

Brown, A. L., & Palincsar, A. S. (in press-b). Reciprocal teaching of comprehension strategies: A natural history of one program for enhancing learning. To appear in J. Borkowski & J. D. Day (Eds.), Intelligence and cognition in special children: Comparative studies of giftedness, mental retardation, and learning disabilities. New York: Ablex.

Brown, A. L., & Reeve, R. A. (in press). Bandwidths of competence: The role of supportive contexts in learning and development. To appear in L. S. Liben, & D. H. Feldman (Eds.), Development and learning: Conflicts or congruence? Hillsdale, NJ.: Erlbaum.

Brown, J. S., & VanLehn, K. (1982). Toward a generative theory of bugs in procedural skills. In T. Carpenter, J. Moser, & T. Romberg (Eds.), Addition and subtraction: A cognitive perspective (pp. 117-135). Hillsdale, NJ: Erlbaum.

Bruner, J. S. (1972). Nature and uses of immaturity. American Psychologist, 27, 687-708.

Bruner, J. S. (1978). The role of dialogue in language acquisition. In A. Sinclair, R. J. Jarvella, & J. M. Levelt (Eds.), The child's conception of language (pp. 241-256). Berlin: Springer-Verlag.

Chanowitz, B., & Langer, E. (1980). Knowing more (or less) than you can show: Understanding control through the mindlessness-mindfulness distinction. In J. Garber & M. E. P. Seligman (Eds.), Human Helplessness: Theory and applications (pp. 97-129). New York: Academic Press.

Day, J. D. (1980). Teaching summarization skills: A comparison of training methods. Unpublished Ph.D Thesis, University of Illinois at Urbana-Champaign.

diSessa, A. A. (1983). Phenomenology and the evolution of intuition. In D. Gentner & A. L. Stevens (Eds.), Mental models (pp. 15-33). Hillsdale, NJ: Erlbaum.

Forrest-Pressley, D., & Waller, T. G. (1984). Cognition, metacognition and reading. New York: Springer-Verlag.

Gelman, R., & Gallistel, C. R. (1978). The child's understanding of number. Cambridge, MA: Harvard University Press.

Gelman, R., & Meck, E. (in press). The notion of principles: The case of counting. To appear in J. Hiebert (Ed.), The relation between procedural and conceptual competence. Hillsdale, NJ: Erlbaum.

Johnson-Laird, P. N. (1983). Mental models: Towards a cognitive science of language, inference, and consciousness. Cambridge, MA: Harvard University Press.

Kahneman, D., & Tversky, A. (1971) A subjective probability: A judgment of representativeness. Cognitive Psychology, 3, 430-454.

Kahneman, D., & Tversky, A. (1973). On the psychology of prediction. Psychological Review, 80, 237-251.

Mandler, J. M. (1983). Representation. In J. H. Flavell & E. M. Markman (Eds.), Handbook of child psychology: Cognitive development (Vol. 3, pp. 420-494). New York: Wiley. (P. H. Mussen, General Editor).

McCloskey, M. (1983). Naive theories of motion. In D. Gentner & A. L. Stevens (Ed.), Mental models (pp. 299-234). Hillsdale, NJ: Erlbaum.

Nisbett, R., & Ross, L. (1980). Human inference: Strategies and shortcomings of social judgment. Englewood Cliffs, NJ: Prentice-Hall.

Osherson, D. N., & Markman, E. (1975). Language and the ability to evaluate contradictions and tautologies. Cognition, 3, 213-226.

Palincsar, A. S., & Brown, A. L. (1984). Reciprocal teaching of comprehension-fostering and monitoring activities. Cognition and Instruction, 1, 117-175.

Palincsar, A. S., & Brown, A. L. (in press). Advances in cognitive instruction of handicapped children. In M. C. Wang, H. J. Wahlberg, & M. Reynolds (Eds.), The handbook of special education: Research and practice. New York: Pergamon Press.

Reeve, R. A., & Brown, A. L., (1985). The development of metacognition reconsidered: Implications for educational practices. Journal of Abnormal Child Psychology, 13, 343-356.

Resnick, L. B. (1982). Syntax and semantics in learning to subtract. In T. Carpenter, J. Moser, & T. Romberg (Eds.), Addition and subtraction: A cognitive perspective (pp. 136-155). Hillsdale, NJ: Erlbaum.

Resnick, L. B. (1984). Beyond error analysis: The role of understanding in elementary school arithmetic. In. H. N. Cheek (Ed.), Diagnostic and prescriptive mathematics: Issues, ideas, and insights (pp. 181-205). Kent, OH: Research Council for Diagnostic and Prescriptive Mathematics.

Ross, L. (1977). The intuitive psychologist and his shortcomings. In L. Berkowitz (Ed.), Advances in experimental social psychology (Vol. 10, pp. 173-220). New York: Academic Press.

Ross, L. (1981). The "intuitive scientist" formulation and its developmental implications. In J. H. Flavell & L. Ross (Eds.), Social cognitive development: Frontiers and possible futures (pp. 1-41). New York: Cambridge University Press.

Scardamalia, M., Bereiter, C., & Steinbach, R. (1984). Teachability of reflective processes in written composition. Cognitive Science, 8, 173-190.

Shweder, R. (1977). Likeness and likelihood in everyday thought: Magical thinking in judgments about personality. Current Anthropology, 18, 637-658.

Shweder, R. (1980). Scientific thought and social cognition. In. W. A. Collins (Ed.), Minnesota symposium on child psychology (Vol. 13, pp. 263-272). Hilldale, NJ: Erlbaum.

Siegler, R. S., & Schrager, J. (1984). Strategy choice in addition and subtraction: How do children know what to do? In C. Sophian (Ed.), Origins of cognitive skills (pp. 229-292). Hillsdale, NJ: Erlbaum.

Tversky, A., & Kahneman, D. (1971). Belief in the law of small numbers. Psychological Bulletin, 76, 105-110.

Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. Cognitive Psychology, 5, 207-232.

Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. Science, 185, 1124-1131.

White, B. Y. (1983). Sources of difficulty in understanding Newtonian dynamics. Cognitive Science, 7, 41-65.

Whitehead, A. N. (1916). The aims of education. Presidential address to the Mathematical Association of England.

Willoughby, S. S., Bereiter, C., Hilton, P., & Rubenstein, H. (1981). How deep is the water? A real math thinking story book (pp. 3-4). La Salle, IL: Open Court Publishing Company.

Table 1

An Excerpt From an Open Court Thinking Story

"How many piglets are there?" asked Portia.
"Count them yourselves," said Grandfather with a smile, "if you can."
"Of course I can count," said Ferdie. "That's easy."
Ferdie crouched down beside the pen and counted the piglets as they ran past. He counted, "1, 2, 3, 5 . . ."
"You made a mistake," said Portia.

What mistake did Ferdie make?

What should he have said?

"You skipped 4," said Portia.
"All right, said Ferdie, "I'll start again."
This time he didn't skip any numbers. Every time a piglet ran past, he counted. He counted, "1, 2, 3, 4, 5, 6, 7, 8, 9, 10." Then he shouted, "Ten piglets! That's a lot!"
"Hm," said Grandfather, "I didn't think there were that many."

Could Ferdie have made a mistake? How?

"I think you counted some piglets more than once," said Portia. "You counted every time a piglet ran past, and sometimes they came past more than once. Let me try."
Portia looked into the pen, where the piglets were still running around. She said, "There's a pink one. That's 1. There's a black one. That's 2. There's a spotted one. That's 3. And, oh, there's one with a funny tail. That's 4. Martha has 4 piglets."
"You did that wrong," said Ferdie. "You didn't count all the piglets."

How could Portia have made a mistake?

"You counted only 1 pink one," said Ferdie, "and there's more than 1 pink one. See? And there's more than 1 black one, too. I don't know how many piglets there are. I wish they'd stand still so we could count them."
"Just wait," said Grandfather. "Maybe they will."
In a little while Martha finished eating and lay down on her side. The piglets stopped running around. They went over to their mother and started feeding.
"Now we can count them," said Portia. "They're all in a row." She counted, "1, 2, 3, 4, 5."
How many piglets did she count? (5)