THINKING AND LEARNING SKILLS

Volume 2:

Research and Open Questions

Edited by
Susan F. Chipman and Judith W. Segal
National Institute of Education

Robert Glaser
University of Pittsburgh

LEA
1985
LAWRENCE ERLBAUM ASSOCIATES, PUBLISHERS
Hillsdale, New Jersey London

23 The Developmental Perspective on the Problem of Knowledge Acquisition: A Discussion

Rochel Gelman
University of Pennsylvania

In the past, developmentalists have urged those who study learning to pay heed to a particularly compelling claim. The claim, made on firm ground, held that cognitive structures develop through qualitatively different stages. Taking a strong cue from Piaget, many asserted that young children lack concrete operations; they fail in tests of their ability to conserve, seriate, and classify. Additionally, it was claimed that preschoolers are precausal and apparently willing to allow causes to follow their effects (e.g., Piaget, 1930), egocentric, perception-bound, and so on. If it is indeed true that the young have qualitatively different structures, there will be things they cannot learn. Likewise, they will often interpret stimuli in a fundamentally different way than do older children and adults. However, evidence from recent research on the nature of cognitive development in preschoolers calls into question the idea that they have structures that differ fundamentally from those of older children, or that they lack pieces of mental structures that older children have. Although understanding how and why the young are different remains an important question for research, appeals to an absence or difference in basic structure does not seem to provide the answer. Does it then follow that developmentalists can be ignored by those who study learning? I submit not. For I believe that recent findings on the cognitive capacities of young children shed new light on critical issues in the study of thinking and learning skills. To show why I need to first outline some of these new findings.

Two of the chapters presented in these volumes lend support to an ever growing body of evidence undercutting the view that the young child has a fundamentally different set of mental structures guiding his or her acquisition of knowledge.

Chi's elegant studies (this volume) on the role of knowledge in memory development speak directly to the claim that preschoolers lack certain mental structures. I draw attention to the fact that her 4½-year-old dinosaur expert was able to organize his knowledge within a class-inclusion structure. This should not be possible according to a theory that holds that a preschooler lacks concrete operations and therefore cannot deal with such a structure. Carey's chapter (this volume) provides further evidence that there are classification structures available to young children and that these are used under some circumstances.

Bullock, Gelman, and Baillargeon (1982) show that there are, likewise, cases where preschoolers use the same principles as do adults when reasoning about physical cause and effect relations. They report preschoolers use a priority of order principle much as do adults. Consider Bullock and Gelman's (1979) demonstration. They had young children watch the exact same event—a ball rolling down a runway and disappearing into a box—before and after a puppet jumped up from the box. When asked to choose the ball that made the puppet jump, 3- to 5-year-old children systematically chose the ball that was dropped first. They did this even when the order information conflicted with a cue of spatial contiguity, i.e., when the before event was in a runway that was separated from the box, but the after event was not. These findings favor the view that preschoolers can sometimes honor a principle of priority when reasoning about physical cause and effect relations. Bullock et al. summarize the evidence that preschoolers also make implicit use of the principles that effects have causes and that mechanisms relate cause and effect sequences.

Recent research on number concepts reveals the availability to young children of some arithmetic reasoning principles used by older children and adults. (See Gelman & Baillargeon, 1983, for a review.) Research on concepts of order undercuts the presumption that young children are insensitive to ordering relations (e.g., Trabasso, 1975). Carey provides still other examples of early cognitive competence. And for those who might still resist the idea that preschoolers do make implicit use of the kinds of structures that we once were sure they lacked, there are further examples in Flavell and Markman (1983).

Findings of the foregoing kind highlight the fact that young children's competences are more like older children's than once assumed. They cast serious doubt on the hypothesis that age differences in performance reflect fundamental differences in structural (or, in Carey's terms, format) characteristics. Indeed, as Simmons (this volume) points out, comparable findings in the cross-cultural literature rule out such a hypothesis regarding different levels of performance across cultures and subgroups within cultures. Is it that the differences observed are trivial and can be ignored? I think not. Indeed, I believe that an explanation of the differences provides answers to some of the questions raised in these volumes, or at least helps to better focus the questions.

I want to highlight a general characteristic of the work with young children. To demonstrate competence, it was necessary to design tasks especially suited for them (Donaldson, 1978; Gelman, 1978). A variety of intuitions led people to develop tasks that cut through or sidestepped variables judged to be irrelevant to the basic question "Is the competence there?" The search for competence has often been a search for appropriate tasks, special settings, "just right" stimuli, and instructions. These stripped-down versions of the original task succeeded; we managed to devise (or stumble upon) assessments that got to the core of the piece of cognition we wanted to demonstrate.

There is another way of looking at the fact that it took the design of tasks especially suited to young children to demonstrate competence. Where the young might reveal a given capacity on one carefully crafted task, the older child will reveal it on many tasks. The implication is that there are major differences in the range of situations to which young children can apply their competence. Put differently, the competence of the younger child is fragile; that of the older child is fluid and generalizable. The young child needs to be tested with a particular set of stimuli in a particular setting with a particular task. The older child can transfer his or her knowledge across a variety of domains. From such facts it follows that part of the tale of cognitive development is a tale of how a restricted piece of competence is generalized and transferred. This alone should be enough reason for those who study learning to look carefully at early cognitive development. For, unlike the situation in many studies of human learning, this is a clear case where transfer and generalization eventually do come about. It would seem that efforts to study this naturally occurring success story could yield insight into the question of what produces transfer and generalized use of a core capacity.

I have stated that part of cognitive development involves a trend from a restricted use of an ability to a more generalized use of it (cf. Fodor, 1972, 1975). This cannot be the whole story, and a consideration of what else occurs yields yet further examples of success stories that could be studied to answer questions raised by various speakers at this meeting.

Carey provides two further candidate accounts of cognitive development. One is that cognitive capacities themselves become the objects of thought; this in turn yields advances in the child's abilities. She suggests, for example, that the development of metacognitive abilities makes it possible for the child to apply classification abilities to the task of organizing newly acquired knowledge. Whether this is correct needs to be studied. But, it is clear that metacognitions come as a function of development (at least in this culture), and they do not seem to be available to very young children. Again, here is a success waiting to be explained. Having read much in this volume about the need to understand how to teach executive-function skills, should we be able to explain this developmental success story, we might better be able to teach these skills to students.

Carey also suggested that part of the story of cognitive development is about theory change. I agree (a fact that should be obvious from her review of the work I and my collaborators have done on the development of causal reasoning). Carey notes that, in some cases, a theory change can be so profound as to yield

qualitatively new insights into the nature of a scientific phenomenon. Indeed, I think that this is the kind of development reflected in Krupa, Selman, and Jaquette's (this volume) findings on the acquisition of scientific concepts. A corollary of my interpretation of the Krupa et al. work is that the observations they report probably do not reflect a shift from concrete to formal operational thought. Let me expand a bit.

There are two components to Piaget's account of the development of scientific reasoning. The first is that young children simply lack the relevant formal operations. The second is that they lack the ability to make causal inferences about physical (including chemical) cause and effect sequences. Both Carey and I have gone over the reasons for rejecting the latter view. As regards the former, Gelman and Baillargeon's (1983) review of the correlational studies that sought to validate Piaget's account and description of concrete operations highlights how unsuccessful this line of research has been. Simply put, the predicted high interitem correlations are not observed. Given this, it is difficult to interpret demonstrated correlations between performances on one of Piaget's tests for the presence of concrete operations and performances on other tasks presumed to depend on the presence or absence of these operational structures. Were it the case that performance on any concrete operational task could be taken as evidence of an underlying homogeneous ability, there would be no problem concluding that the ability of interest, e.g., metamemorial capacities or the understanding of scientific concepts A, B, and C, depend on the acquisition of something akin to concrete operations. But it is not the case. The same logic applies to arguments about the role of formal operations, in which the correlational evidence is even more problematic (Neimark, 1981). Parenthetically, it is hard to interpret the Krupa et al. findings without an analysis that partials out the effect of age.

I do not mean to claim that the Krupa et al. results are uninteresting. But, to the extent that they reveal qualitative developmental changes, I believe they reveal qualitative theory changes and not the acquisition of qualitatively new and more powerful cognitive structures. (See Gelman & Baillargeon, 1983, for further discussion on this point). As Krupa et al. point out, some kinds of theory change come with relative ease. There are, however, other kinds that do not. Green, McCloskey, and Caramazza (this volume) make it clear that many college students' physical intuitions reflect a commitment to a Medieval theory of physics, one that is very resistant to instruction (Champagne, Klopfer, & Gunstone, 1981). I venture the guess that we could line up different theory changes on a continuum of ease and derive some strong clues as to how to proceed to account for them. Again, because some theory changes come with relative ease (consider Carey's work on the development of the concept of animal) in the normal course of development, it would do well to keep developmental matters in mind.

There are yet further candidate accounts of cognitive developmental differences. Although I and my collaborators grant principles of counting and causal reasoning to the very young child, we do not assume that knowledge of these is explicit; quite the contrary. In that young children respond systematically as opposed to randomly, we postulate an underlying set of principles that guide these responses. Following Greeno and Riley (1984), when I distinguish between implicit and explicit knowledge of the counting principles, I mean to distinguish between the ability to verbalize or state the counting principles and the ability to demonstrate that one's behavior is systematically governed by the principles; that is, we invoke the principles as accounts of why performance is systematic, be it error free or error prone. We do not, at the same time, assume that 2- and 3-year-olds know the counting principles in an explicit way, as do adults who can say that there is no largest number, in part, because there is no limit to the continued application of the counting principles.

One might ask why add a shift from implicit to explicit knowledge to the list of candidate developmental functions. Is it not the same as acquiring metacognition? The answer must be both yes and no. Yes for the reasons that lead one to pose this question. No because one could have explicit knowledge without having metacognitive awareness of that knowledge. For example, one could know that everytime one rehearses a text, recall for that text will improve. Still, one might not know that it is a property of memory that is at work here. In the latter case, one looks down on the way memory works; in the former case, one simply makes an empirical generalization. To be sure, we need to be more precise about the differences between the two phenomena before accepting the view that they are different. But the same can be said about metacognition itself. We might know a case of it when we see it, but I am not convinced that we have articulated what it is that we see.

There is another kind of development to which I think we have paid too little attention. Rozin (1976) argues that cognitive development, both phylogenetically and ontogenetically, involves an increase in accessing capacity. Early in development, pieces of cognitive structure(s) serve special, and therefore restricted, purposes. With the development of accessing abilities, these pieces, which are initially used in a restricted way, can be accessed and put together in the service of a new task.

The example offered in Rozin's presentation was the ability to read. He notes that it is likely that there is a genetic program in the service of speech production; yet, it is unlikely that there is one that works in the service of reading. (I know of no one who maintains that we are genetically programmed to learn to read, per se). Nevertheless, many can learn to read. According to Rozin we can because of our ability (with development) to access the machinery that is used to produce and comprehend speech. The ability to do so makes it possible to access components of the speech stream and treat them as sounds to be coded into a visual mode.

Again, there is the question of whether an accessing hypothesis differs from a metacognitive hypothesis about the course of cognitive development. And again, I believe there is a difference. Rozin's notion of accessing provides the

outline of an account of how innate mental structures can be used in the service of acquiring new knowledge and new capacities. Pieces of special purpose abilities are pulled out of that core ability and combined with pieces of other core structures, the result being a new ability that brings with it new mental power—witness the case of reading. Metacognition concerns already existing structures and capacities and not the combinations or recombination of these structures.

I want to switch from a focus on matters of structure to matters of function. In particular, I want to highlight a fact about development that deserves careful attention from those who study learning processes. Historically, developmentalists in the comparative tradition have assumed that learning is guided by innate structural constraints that help the young pick relevant inputs from the environment (see Seligman & Haeger, 1972 for many examples). Put differently, the motive for learning is taken to be part and parcel of the capacity to do X, Y, or Z. Those familiar with Piaget's theory will recognize a similar argument. Structures are said to assimilate and accommodate or to seek out that environment that will support the use of a given structure as well as the eventual development of that structure. An example helps illustrate what is meant here.

I have argued that the counting principles guide the young child's acquisition of skill at counting (e.g., Gelman, 1982). Consider the stable-order principle. As a constraint, the principle requires that children find an ordered list with which to tag items as they count. In our culture, there are two conspicuous candidates, the number words and the letters of the alphabet. By 2½ years of age children usually have fixed on the number list and use it when counting. The compelling case for the argument that the child seeks out the list comes from those instances where the child uses the alphabet to count. Greek and Hebrew allow this but English does not. There is no way to account for the young child who does use the alphabet without allowing for the availability of a structure that guides a search of the environment. Parenthetically, since I first reported that some beginning counters use their own lists, people have been sending me the lists their child first used. A favorite of mine is "1–2–3–4–5–6–7–h–i–j–k" (The switch in lists is most likely due to an acoustic confusion error between 8 and h).

The case of counting is but one example of the view that constraints do not dictate simply that a child respond to a particular environment; there are other compelling cases of how they carry with them a competence motivation that leads them to work very hard at the task of early learning. Recall Weir's (1962) observations about busy toddlers lying in their cribs at night going over what they have learned to say that day. Similarly, it appears that young children need not be told to count the number of steps in their house, or the cows in a field, or the cracks in the sidewalk. They do so spontaneously. A similar tendency to self-rehearse holds for a new-found motor skill. Indeed, it looks like much of early learning is motivated from within.

If we grant that there are constraints guiding acquisition, we provide a source of monitoring for errors and the tendency to self-correct. We find that young children are not only motivated to count on their own; they often self-correct. We have transcripts of some children doing so for 5 minutes in a row, e.g., "Let me see, that's 1–2–3–5–10–9–11. No, try 'dat again. 1–2–3–6–9–10," and so on.

Some may be surprised with the finding that young children monitor their own learning and rehearse spontaneously; for, we have heard from some quarters that these are late-developing strategies. They might very well be in the cases where learning is not guided by constraints. But in the case of natural acquisitions, they are part and parcel of early learning. So once again, development offers a case of where something is done and thus another source of clues regarding the nature of knowledge acquisition.

I hope I have convinced you that the study of development is still an important task for those who are interested in the acquisition of learning skills. It provides natural instances of cognitive changes. We should get down to the business of finding out how these work. I could be wrong; it could be that what is acquired naturally in the course of development is too different from what is acquired later on in school. I do not think so; still, I end with a cautionary note.

Research over the last decade has revealed some remarkable abilities in young children. This research has led to questions about implications for curriculum development. But I am not yet sure what they are. The kinds of learning I have focused on here are, I think, natural. Yes, they do require an environmental support system, but they probably do not require an explicit lesson plan. There are tutors in the natural environment (see Simmons, this volume), but they catch the child on the run. At the very least, school places a new set of conditions on the nature of learning. We need to consider whether the learning that takes place in a natural environment is like learning in the structured environment provided by schools. Then, we might better be able to consider the role of early cognitive abiities vis-a-vis school curricula.

ACKNOWLEDGMENTS

Preparation of this chapter was supported by NSF grants BNS–8004885 and BNS–8140573 and a grant from the Sloan Foundation to the program in Cognitive Science.

REFERENCES

Bullock, M., & Gelman, R. (1979). Preschool children's assumptions about cause and effect: Temporal ordering. *Child Development, 50*, 89–96.

Bullock, M., Gelman, R., & Baillargeon, R. (1982). The development of causal reasoning. In W. J. Friedman (Ed.), *The developmental psychology of time*. New York: Academic Press.

Champagne, A. B., Klopfer, L. E., & Gunstone, R. F. (1981). Students beliefs about gravity and motion. *Problem Solving, 3*, 12–14.

Donaldson, M. (1978). *Children's minds*. New York: W. W. Norton.

Flavell, J. H., & Markman, E. M. (Eds.). (1983). *Cognitive development*. In P. Mussen (Ed.), *Carmichael's manual of child psychology* (Vol. 3). Wiley.

Fodor, J. A. (1972). Some reflections on L. S. Vygotsky's thought and language. *Cognition, 1*, 83–95.

Fodor, J. A. (1975). *The language of thought*. New York: Thomas Y. Crowell.

Gelman, R. (1978). Cognitive development. *Annual review of psychology* (Vol. 29). Palo Alto, CA: Annual Reviews.

Gelman, R. (1982). Basic numerical abilities. In R. J. Sternberg (Ed.), *Advances in the psychology of intelligence* (Vol. 1). Hillsdale, NJ: Lawrence Erlbaum Associates.

Gelman, R., & Baillargeon, R. (1983). A review of some Piagetian concepts. In J. H. Flavell & E. M. Markman (Eds.), *Cognitive development*. In P. Mussen (Ed.), *Carmichael's manual of child psychology* (Vol. 3). New York: Wiley.

Greeno, J. G., & Riley, M. S. (1984). Process and development of understanding. In F. E. Weinert & R. Kluwe (Eds.), *Learning by thinking*. West Germany: Kuhlhammer.

Neimark, E. (1981). Explanation for the apparent nonuniversal incidence of formal operations. In I. E. Sigel, D. M. Brodzinsky, & R. M. Golinkoff (Eds.), *New directions in Piagetian theory and practice*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Piaget, J. (1930). *The child's conception of physical causality*. London: Routledge & Kegan Paul.

Rozin, P. (1976). The evolution of intelligence and access to the cognitive unconscious. In J. M. Sprague & A. D. Epstein (Eds.), *Progress in psychobiology and physiological psychology* (Vol. 6). New York: Academic Press.

Seligman, M. E. P., & Haeger, J. (Eds.). (1972). *Biological boundaries of learning*. New York: Appleton–Century.

Trabasso, T. R. (1975). Representation, memory and reasoning: How do we make transitive inferences. In A. D. Pick (Ed.), *Minnesota Symposium on Child Psychology* (Vol. 9). Minneapolis: University of Minnesota Press.

Weir, R. (1962). *Language in the crib*. The Hague: Mouton.