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ABSTRACT

This paper examines the cognitive process of concept development in preschool children, based on recent psychological research. Rather than attempting an exhaustive review of the more than 7000 articles written on children's concepts of categories, the paper highlights and illustrates four key themes that emerge from recent research: first, concepts are tools with powerful implications for children's reasoning; second, children's early concepts are not necessarily concrete or perceptually based, as even preschoolers are capable of abstract reasoning; third, children's concepts are not uniform across content areas, individuals, or tasks; and fourth, children's concepts reflect their emerging theories about the world. The paper notes that these four themes contradict some widely held, but erroneous, views of early concept development and explores a variety of issues regarding early education raised by these themes. Contains 52 references. (JPB)

CONCEPT DEVELOPMENT IN PRESCHOOL CHILDREN

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This paper addresses concept development in preschool children, based on recent psychological research. Over the past thirty years, there have been more than 7,000 journal articles written on children's concepts or categories. Scholars are attracted by the opportunity to understand fundamental theoretical issues (How can we characterize early thought? How does it change over time?) as well as by the practical concern of determining how children reason about concepts that are directly relevant to their lives and schooling (including mathematics, biology, and physics).

I will not attempt an exhaustive review of this vast topic in so few pages (see Siegler & Kuhn, 1997, for extensive, state-of-the-art reviews). Instead, I will highlight and illustrate four key themes that emerge from recent research:

- Concepts are tools, and as such have powerful implications for children's reasoning—both positive and negative.
- Children's early concepts are not necessarily concrete or perceptually based. Even preschool children are capable of reasoning about non-obvious, subtle, and abstract concepts.
- Children's concepts are not uniform across across content areas, across individuals, or across tasks.
- Children's concepts reflect their emerging "theories" about the world. To the extent that children's theories are inaccurate, their conceptions are also biased.

These four themes contradict some widely held (but erroneous) views of early concepts, and raise a variety of issues regarding early education.

CONCEPTS AS TOOLS

Concepts provide an efficient way of organizing experience. If children were *unable* to categorize, their experiences would be chaotic—filled with objects, properties, sensations, and events too numerous to hold in memory. In contrast to this hypothesized "blooming, buzzing confusion" (to use the words of William James), children from earliest infancy form categories that are remarkably similar to those of adults. Before they have even begun to speak, infants form categories of faces, speech sounds, emotional expressions, colors, objects, animals, and mappings across modalities (see Gelman, 1996, for review). By eighteen months of age, most children have begun a vocabulary "explosion," adding roughly nine new words each day to their vocabulary (Carey, 1978). Assuming that most new words encode concepts, this suggests that one- and two-year-old children are adept at concept acquisition.

However, concepts do more than organize information efficiently in memory. They also serve an important function for a range of cognitive tasks, including: identifying objects in the world, forming analogies, making inferences that extend knowledge beyond what is already known, conveying core elements of a theory, etc. Many of these tasks are central to school performance; thus, concepts can be thought of as the building blocks to these more complex skills. I focus here on one of these cognitive functions, namely, how concepts foster inferences about the unknown (also known as *induction*).

Both children and adults use categories to extend knowledge beyond what is obvious or already known (Carey, 1985; Gelman & Markman, 1986, 1987). For example, if four-year-old children are told a new fact, that a particular dog has leukocytes inside it, they are likely to infer that other dogs also have leukocytes inside them. Importantly, children form such inferences even when they are not supported by outward appearances. For example, on one of Gelman and Markman's items children saw a brontosaurus, a rhinoceros, and a triceratops, which were labeled as "dinosaur," "rhinoceros," and "dinosaur" respectively. Category labels and outward appearances conflicted: the brontosaurus and triceratops are members of the same category, whereas the rhinoceros and triceratops look more alike outwardly. Then children learned a new property of the brontosaurus and the rhinoceros (that they had cold blood and warm blood, respectively), and were asked which property was true of the triceratops. When children were informed that both the brontosaurus and the triceratops were dinosaurs, they inferred that the triceratops has cold blood like the brontosaurus, even though it more closely resembled the rhinoceros. The results of this and other related experiments showed that by 2-1/2 years of age, children base inferences on category membership, despite conflicting surface appearances (Gelman & Coley, 1990).

Although induction can be viewed as positive, because it allows children to expand their knowledge base, it also poses some problems for young children when they draw inappropriately broad inferences. One problem that results is stereotyping: preschoolers often treat social categories as if they were biological categories, assuming for example that members of a social category (e.g., based on gender or race) will be alike with respect to ability or occupation (Hirschfeld, 1996; Taylor, 1996). A second problem is that young children at times ignore relevant information about statistical variation *within* a category (Lopez et. al, 1992; Gutheil & Gelman, 1997). For example, four-year-olds do not seem to realize that a property known to be true of five birds provides a firmer basis of induction than a property known to be true of only one bird. They also do not seem to realize that *variability* in a category is relevant to the kinds of inductions that are plausible.

In sum, this theme illustrates four important points:

- Concepts are used by children and adults to extend known information to previously unknown cases, by a process of inductive inference.
- Such inferences are not based on perceptual similarity alone.
- Naming is an important vehicle for conveying category membership and thus guiding induction. Naming leads children to search for similarities among category members. This function thus is a highly useful tool that is available to children by at least preschool age.
- Despite children's ability to use categories for induction, even in the preschool years, they do not always constrain these inferences appropriately.

NON-OBVIOUS FEATURES

On many traditional accounts, conceptions are said to undergo a fundamental, qualitative shift with development. That is, children and adults are often said to occupy opposite endpoints of various dichotomies, moving from perceptual to conceptual (Bruner, Olver, & Greenfield, 1966), from concrete to abstract (Piaget, 1951), or from similarity to theories (Quine, 1977).

These developmental dichotomies are intuitively appealing, in part because children often do seem to reason in ways that are strikingly different from how adults reason. For example, in the well-known "conservation error" studied by Piaget, children below six or seven years of age report that an irrelevant transformation leads to a change in quantity (e.g., concluding that the amount of a liquid increases when it is simply poured from a wide container into a taller, narrower container). Children appear to focus on one salient but misleading dimension (e.g., height), forgoing a deeper conceptual analysis. Throughout the past several decades there have been many demonstrations that young children are "prone to accept things as they seem to be, in terms of their outer, perceptual, phenomenal, on-the-surface characteristics" (Flavell, 1977).

However, as an account of what children are *capable* of doing, such developmental dichotomies as the "perceptual-to-conceptual shift" are inadequate (also Bauer & Mandler, 1989; Gelman, 1978; Gibson & Spelke, 1983; Markman & Hutchinson, 1984; Nelson, 1977). With appropriately sensitive tasks, children can display abilities that do not appear in their everyday actions (see "Expertise and Task Effects," below; see also R. Gelman & Baillargeon, 1983, for extensive discussion).

Indeed, not only are children capable of overcoming misleading appearances, they are even able to reason about concepts that are altogether non-obvious. Several scholars have recently begun studying how three- to five-year-old children reason about non-obvious entities across a range of topic areas, including:

- energy (Schultz, 1982);
- bodily organs, such as muscles, bones, and brains (R. Gelman, 1990; Johnson, 1990);
- germs and contagion (Kalish, 1996);
- inheritance (Springer, 1992);
- dissolved substances and contamination (Au, 1994); and
- mental entities such as thoughts and desires (Wellman, 1990).

Although for most of these topics preschool children have very little in the way of detailed, concrete knowledge, they have begun to appreciate *that* these non-obvious constructs exist, and *how* they affect other, more observable outcomes and behaviors. For example, even three-year-olds have a core understanding that "germs" can cause illness, and that foods may appear clean yet still have disease-causing germs (Kalish, 1996). It is intriguing that children are capable of this understanding at an age when they have not yet learned anything about the mechanisms by which viruses and bacteria affect human physiology (Au & Romo, in press). That children are open to reasoning about these topics, and that they do so with considerable accuracy, despite an impoverished knowledge base, argues strongly that non-obvious entities are *not* beyond the capacity of preschool children.

EXPERTISE AND TASK EFFECTS

The previous section illustrates that detailed knowledge is not a prerequisite for learning some of the core concepts in a domain (such as "germs"). Nonetheless, specialized knowledge can exert surprisingly powerful effects on cognition (Hirschfeld & Gelman, 1994; Wellman & Gelman, 1997). Twenty-five years ago, Chase and Simon (1973) found that chess experts have superior memory for the position of pieces on a chessboard, although they are no better than non-experts in their memory for digits. Chi (1978) demonstrated the same phenomenon in children: child chess experts even out-perform adult chess novices, which is an interesting reversal of the more usual developmental finding. In these examples, experts are not *in general* more intelligent or more skilled than novices. The effects are localized within the domain of expertise.

Regarding concept development, too, the child's level of sophistication varies markedly by content area (Keil, 1989, in press). Chi, Feltovich, and Glaser (1981), focusing on the domain of physics, find that expert versus novice problem-solvers approach physics word problems quite differently, focusing on altogether different features of the task. Similarly, Chi, Hutchinson, and Robin (1989) find that child dinosaur experts perform differently from novices in how they reason about the domain of dinosaurs, generating a richer set of inferences and causal explanations.

Conceptual structure varies not only by domain but also by task. Even within a domain, children use different information in different contexts, depending on the task or function at hand (Deak & Bauer, 1995, 1996; Taylor & Gelman, 1993). For example, children display markedly different strategies for sorting pictures into groups, depending on whether the researcher provides the standard open-ended instructions ("See this picture? Can you find another one?") or teaches the child a new word and asks the child to extend it ("See this dax? Can you find another dax?") (Markman, 1989). Similarly, children provide altogether different responses when asked to come up with the category label for an ambiguous item versus when asked to come up with a property inference for an ambiguous item that has been labeled by the experimenter (Gelman, Collman, & Maccoby, 1986). Children consider a variety of information and flexibly deploy different sorting strategies depending on the task, displaying links between task and strategy that are precise and predictable. These variations in performance are not random or idiosyncratic. Rather, they reveal that concepts have multiple functions, even for preschool children, and that children have learned to attend to different kinds of information, depending on the task at hand.

CONCEPTS AND THEORIES

Adults' concepts are influenced by theoretical belief systems. This can be readily illustrated with a very simple example. Until recently, a biological mother could be defined or understood as the woman who gives birth to a child. More recently, however, with new reproductive technology (including surrogate mothers and donor eggs), a biological mother need not be the woman who gives birth. Thus, even a concept so basic and fundamental as "mother" undergoes change as one's theory of reproduction changes (which itself is influenced by changing technology).

A central developmental question is when and how children begin to incorporate theories into their concepts. One long-held view was that children's initial categories are similarity-based, and only begin to incorporate theories as children gain experience and formal schooling (Quine, 1977). Likewise, Piaget argued that pre-operational children do not have the logical capacity to construct either theories or true concepts.

In contrast, many researchers now believe that concept acquisition in childhood may *require* theories. Murphy (1993) notes that theories function to help concept learners in three respects:

- Theories help identify those features that are relevant to a concept.
- Theories constrain how (e.g., along which dimensions) similarity should be computed.

- Theories can influence how concepts are stored in memory.

The implication here is that concept acquisition may proceed more smoothly with the help of theories. If so, this is reason to expect that theories may play a role in children's concepts, even though the theories themselves are changing developmentally.

Indeed, recent studies provide compelling demonstrations that young children use theoretical knowledge in their classifications. Barrett, Abdi, Murphy, and Gallagher (1993) present data suggesting that children's intuitive theories help determine which properties and which feature correlations children attend to in their classifications. For example, in a task that required children to categorize novel birds into one of two novel categories, first- and fourth-grade children noticed the association between brain size and memory capacity and used that correlation to categorize new members. Specifically, exemplars that preserved the correlation were more often judged to be category members, and to be more typical of the category. The children did not make use of features that correlated equally well (i.e., were presented together equally often in the input) but were not supported by a theory (e.g., the correlation between structure of heart and shape of beak).

In a second experiment, Barrett et al. (1993) found that children attended to different feature-pairs, depending again on whether they were supported by a pre-existing theory. Third grade children were presented with hypothetical categories that were described as either animals or tools, and then learned five properties about each category. When the category was described as an animal, children selectively focused on correlations between one subset of the properties, for example, "is found in the mountains" and "has thick wool." In contrast, when the category was described as a tool, children selectively focused on correlations between a different subset of properties, for example, "is found in the mountains" and "can crush rocks." These studies show that children focus their attention strategically on information that is relevant to the implicit theory they have formed.

More generally, errors in children's theories may constrain or shape children's concepts. I illustrate with one brief example, regarding children's number concepts. Rochel Gelman has found that preschool and early elementary school children's understanding of arithmetic is heavily influenced by the theory that numbers are *countable* entities, starting with one and continuing sequentially by adding whole numbers. Based on this assumption, children experience tremendous difficulty when first encountering fractions, often treating them as if they were whole numbers (R. Gelman & Williams, 1997). For example, when asked to sort cards (representing different amounts) onto a number line, children will treat a card with 1-1/2 circles on it as if it represented "2" on the number line. The difficulty children have here is not simply that they are encountering a new set of mathematical operations, but additionally that their prior theory clashes with the new system they have encountered. Similarly, theory-driven errors can be found in young children's reasoning about physics (Kaiser, McCloskey, & Proffitt, 1986) and biology (Carey, 1985; Coley, 1993).

Although a number of studies have begun to examine the influence of theories on early concepts, little work addresses the reverse question, regarding the influence of concepts on early theories. However, it seems plausible that certain conceptual assumptions may constrain aspects of children's theories. For example, children appear to hold an "essentialist" assumption about categories (Gelman et al., 1994; Medin &

Ortony, 1989; Atran, 1990), treating members of a category as if they have an underlying "essence" that can never be altered or removed. Essentialism is more compatible with creationist than evolutionary views of species origins (Mayr, 1988), and may even discourage children's learning of evolutionary theory (Evans, in press). Thus, the structure of early concepts may have broader implications for science education.

CONCLUSIONS

The brief summary provided in this paper shatters several myths about children's early concepts, including: that the sole function of concepts is to organize experience efficiently; that there is qualitative change in children's concepts over time, with major shifts between four and seven years; that until about age 7, most children are unable to reason about abstract concepts or non-obvious features; and that children's concepts start out perceptually based, becoming conceptual with development. I have briefly reviewed recent evidence documenting, to the contrary, that even preschool children make use of concepts to expand knowledge via inductive inferences, that children's concepts are heterogeneous and do not undergo qualitative shifts during development, that children's concepts incorporate non-perceptual elements from a young age.

Given that children's concepts are in fact far more sophisticated than has been traditionally assumed, it becomes all the more important to ensure that early education exploits the capabilities that young children have. At the same time, given the close link between early concepts and emerging theories, one of the central challenges is to help children overcome pervasive faulty theories, some of which appear to persist into adulthood.

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