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This paper proposes that young children's inability to categorize in a taxonomic or class inclusion manner is a function of (A) their available knowledge and (B) the representation of that knowledge. Young children's failure is not necessarily (C) a problem of access (see Gelman, 1978 for a review), nor (D) the lack of a hierarchical representation (Harris, 1975), nor (E) the lack of a particular classification skill (Inhelder and Piaget, 1964).

The standard format for the task under discussion, sometimes referred to as classification, other times as categorization or sorting, usually involves the presentation of 20 or so cards with pictures of items that fall into 4 or 5 categories. For example, it is expected that pictures of chair, table and couch would be sorted into the Furniture category, and pictures of dog, cat and horse would be sorted into the Animal category, and so on. The classical finding from classification, categorization, and sorting tasks are that (1) young children categorize on the basis of perceptual or concrete properties (those that are observable) whereas older children categorize on the basis of abstract or functional features, those that require an inference of some kind; (2) younger children's categorizations are linear, shallow and non-hierarchical, whereas older children's sortings are more hierarchical; and (3) young children use inconsistent criteria for the categorization whereas older children are consistent. Thus, younger children are more likely to classify cat and couch together because cat often sits on a couch, or they might categorize horse and table together because they are both brown.

The intention of this research is to understand the classical findings, and at the same time, to attempt to provide an explanation for their order of acquisition. That is, why it is that older children manifest consistent hierarchical and abstract categorization and younger children exhibit inconsistent, linear, and perceptual categorization. Specifically, evidence will be provided to support the assertions that children's categorization outcomes are a function of the knowledge that they have and the representation that the knowledge takes, and not necessarily a function of the lack of access, the lack of hierarchical representation, nor the lack of competence. To test these notions, two basic approaches are used. First, the performance of expert and novice children are compared to see how their differences mimic differences produced by age. Second, single within-subject designs are used to carefully uncover individual children's representations, and to compare a single subject's performances under two different stimulus conditions.

Young children's inability to classify in a class-inclusion or taxonomic manner has often been attributed to the lack of a skill that emerges later in development. Or, in Piagetian terminologies, young "children have not yet developed the intellectual structure essential for success" (Thornton, 1982). However, attributing competencies to emerging structures does not constitute an explanation, but rather, is a redescription of the phenomenon. Recently, serious attempts have been made to understand why younger children are less able to categorize in a class-inclusion manner. One explanation has centred on the notion of access. This notion assumes that the necessary knowledge is there, and takes the appropriate hierarchical representation. But for some reason, it cannot be accessed. The evidence for such an argument derives from studies which presumably assess children's semantic representation, through "secondary" tasks such as (1) asking young children specifically to put all the members of a category together (put robin, sparrow in the BIRD category, for example), or (2) asking children to verify that a statement such as "A robin is a bird" is true or not, or (3) seeing if they can ascribe attributes of a superordinate (BIRD) term to a nonsense word (such as "mib") if children are told that mibs are birds. The fact that young children can do all these tasks successfully is taken as evidence of the presence of hierarchical class-inclusion (or canonical) representation, thus the inability to exhibit class-inclusion during classification is the result of limited access. The claim to be made here is that these secondary tasks assess only individual links or pieces of knowledge and not the entire interrelated knowledge structure. Therefore, these secondary tasks are not necessarily valid for concluding that the knowledge is there but not accessible for the (primary) task of classification.

A second approach to explaining younger children's failure to classify taxonomically is to find instances of stimulus material under which they can. For example, young children can answer class-inclusion questions more accurately when good examplars of a category are used, rather than peripheral or non-central examples (Carson and Abrahamson, 1976). Likewise, Rosch and her associates

(1976) have shown that very young children can indeed classify hierarchically when the sets of stimuli are taken from the basic level objects (such as categorizing different variety of chairs into the CHAIR category), but not when they are taken from the superordinate level. However, Rosch's results are entirely consistent with the previous classical findings, mainly because basic objects are those that are perceptually similar to each other. And it is already known that young children can sort according to perceptual features, hence successful sorting at the basic level makes sense. Horton and Markman (1980) have provided further evidence that young children can acquire with ease basic level categories on the basis of their perceptual similarities.

In contrast, the intention here is to find circumstances under which young children can exhibit consistent, adult-like, hierarchical classification at the superordinate level. The first study addresses this question by comparing and contrasting two groups of 7-year-olds. One group of children have a large quantity of knowledge about dinosaurs (they could identify by name about 10 of the 20 dinosaur pictures that were shown to them), and novice children had some familiarity with dinosaurs, but could not identify any dinosaur correctly by name. Each child was presented the set of 20 dinosaur pictures and simply asked to sort them into as many groups as they wish. The results are very striking. Basically, novice children form what I will claim to be basic-level categories and expert children form superordinate-level categories. What are the bases of these claims? First, the categories formed by the novice children are perceptually similar, based on an inspection of the visual features of the dinosaurs. These categories correspond to classes such as the Duckbills, which are dinosaurs which have bills that look like ducks', or the Horned dinosaurs, with distinct notable horns. Second, the explanations given by the children for the groupings support this interpretation. Samples of their protocols are:

"They all look alike. Their heads look alike."

"They have small hands...And their skin is rough."

"They have the same heads...And they have horns."

And third, the findings of Rosch et al (1976) and Horton and Markman (1980) would predict that novice children should be able to categorize at this basic level with ease.

The expert children, on the other hand, group them into abstract categories, usually just in terms of whether they are plant-eaters or meat-eaters, and perhaps with the addition of one more abstract category such as whether they are aggressive or not. Samples of their protocols look like the following:

"This group...is protected and harmful dinosaurs that are plant eaters."

"These dinosaurs are plant-eaters. They aren't harmful."

"These are the only meat-eaters I could find."

Hence, the protocols suggest that the expert children are classifying the dinosaurs not on the basis of perceptual features, but rather, on the basis of functional or abstract features. Further support for this interpretation can be obtained by looking at the composition of their basic categories, when they are asked to further subdivide their initial rather large (superordinate) groups. When they do this, they tend to form perceptual groupings, much like the novice children. For example, when the same expert child was asked to subdivide his first group, his explanations now are:

"The guys who are horned in the front of their heads with nothing on their backs."

"And the guys with not much on their heads and lots on their backs and tail."

These data provide evidence in support of assertion A, namely that when the knowledge is available, as is the case in the expert children, they can classify hierarchically at the superordinate level. And when the knowledge is not available, as in the case of the novice children, children of the same age tend to classify at the basic level, relying predominantly on perceptual features. Thus, we have mimicked developmental results with the manipulation of knowledge rather than age. We further claim that the expert children's ability to categorize at the top-level node is not because they have available some inferencing skill, but rather, that their knowledge is already organized in such a way as to permit a retrieval of this organization. Evidence in support of this argument can be gathered from our data in which we initially simply asked each child to describe what he sees in a picture of a dinosaur. Even in such a simple knowledge-production task, experts describe information that goes beyond the pictures given (Bruner, 1957) whereas novices' descriptions were very much bound to the visual or observable properties. This suggests that the elicitation of abstract information was not the result of inferencing, but merely the retrieval of relevant knowledge when the dinosaur picture served as a cue.

The next demonstration is an attempt to find evidence in support of assertions B, C and D. We wanted to assess a child's representation of a familiar domain, such as her classmates. A possible canonical class-inclusion representation might have

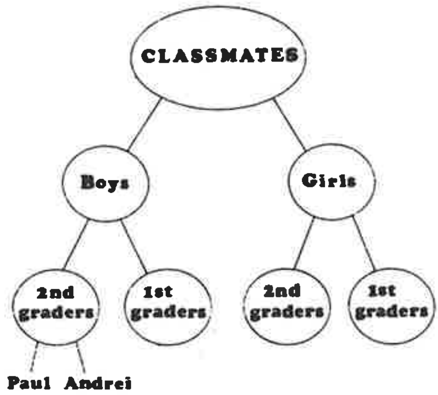

Figure 1: A possible canonical representation of classmates.

CLASSMATES at the top-node, perhaps followed by BOYS and GIRLS at the next level, then within each node, one would get a distinction between second-grade boys and first-grade boys and so on. (This was an open classroom with mixed grades). After much probing, we discovered that the actual internal representation of this 5-year-old child looks more like the schematic diagram shown in Figure 2, where the classmates are divided into SECTIONS according to the children's seating arrangement. We further claim that attributes of a child (whether a child is male or female, first- or second-grade) are attached individually to each child node, because this 5-year-old could easily verify whether a given child is a boy or a girl.

What evidence do we have that this is the dominant representation that the child has? First, when asked to freely generate all the classmates' names, pauses occur after every 5-6 names, corresponding to the boundaries in the seating sections. Second, the pauses between the retrieval of names that cross a boundary are twice as long (6 seconds) as pauses between the generation of two successive names within a section. Third, when we asked the child to generate subgroups of names, such as all the second-grade boys, the sequence of such generation obeyed the representation of the seating arrangement; that is, section-by-section. Finally, when we asked the child to sort the classmates' names into groupings, she did so into four groups, again corresponding to the four seating areas. Hence, her sorting, although not conforming to the canonical representation postulated in Figure 1, was nevertheless meaningful, hierarchical, consistent, and accessible.

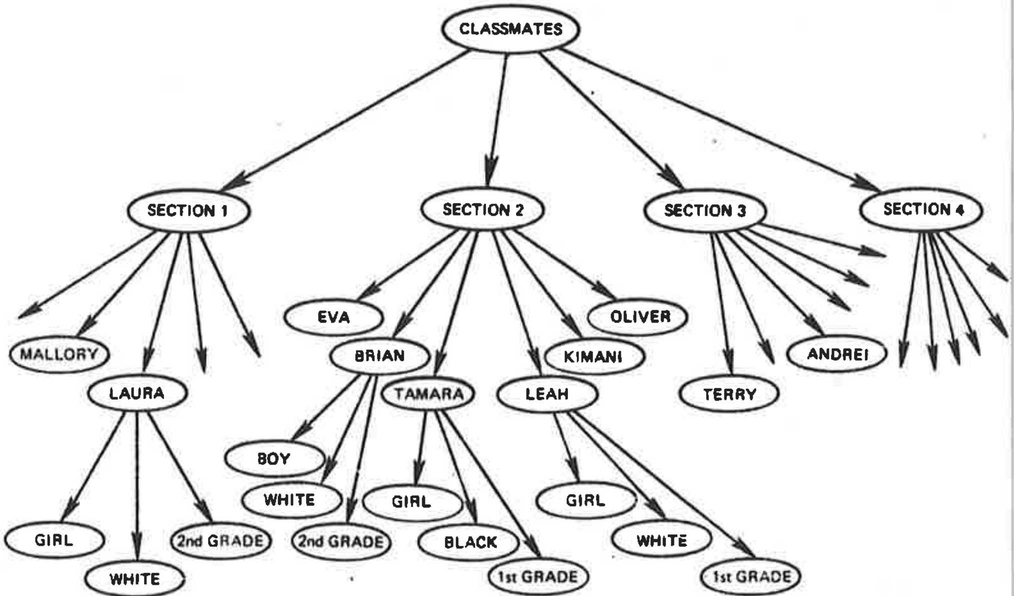

Figure 2: The child's actual representation of her classmates.

The findings from this demonstration support assertion B that not only do we have to be concerned about whether the knowledge is available, but also whether it takes the canonical form that the experimenter expects. Although our child's representation was not in the canonical class-inclusion form, it did take the hierarchical format, and classification was based on the representation that she had. The existence of such a representation also suggests that it is quite possible to perform all the secondary tasks with ease within this as well as the canonical structure.

The next demonstration provides some evidence to bear on assertion E, namely that classification is not necessarily a skill per se that emerges, but rather it is a performance outcome that is a manifestation of the knowledge and its representation that a child has. To test this notion, we examined a single child's categorization of a single domain, dinosaurs, but which was divided into two subsets. Briefly, we asked a 4-year-old child who is very knowledgeable about dinosaurs to categorize two subsets of dinosaurs, 20 in each subset. The one subset of dinosaurs had been determined a priori to be more familiar than the other subset, although both subsets were substantially known to him.

The results show that his categorization scheme for the very familiar subset was identical to those of the 7-year-old experts mentioned above (i.e. using the criterion of meat- or plant-eating), and further, was very consistent and stable across the two trials. For the less familiar subset, on the other hand, he has an inconsistent set of criteria, varying from the diet to the habitat, to the locomotion. The criteria changed from trial-to-trial and showed no signs of stability after three trials.

Such results again show that we can replicate the classical developmental finding that young children use inconsistent criteria in sorting. But this time, developmental differences are not simulated by comparing expert and novice children. Rather, developmental differences are mimicked by the changes that are exhibited by the same child in two subsets of a given domain that differed in the child's familiarity with each. Hence, despite the fact that the child was inconsistent and unstable in his sorting criteria in the less familiar subset, he was very able, on the other hand, to exhibit stable use of consistent criteria in the more familiar subset. Such differential sorting performance from the same child in the same domain suggests that the skill manifested is not a fundamental competence that either exists or not in the child's repertoire, but rather, is an attribute of the particular representation that the existing knowledge takes (Chi and Koeske, in press).

In sum, we have replicated classical findings in categorization and sorting (such as the use of perceptual features) in children who have limited knowledge of a domain. We have also tentatively called into question some of the explanations offered for a young child's failure to categorize in a class-inclusion manner, such as the lack of (1) access, (2) classification skill, or (3) hierarchical representation. Finally, we strongly suggest that the availability of content knowledge, coupled with an appropriate representation, can enable a young child to exhibit competencies that have previously only been attributed to older children (Gelman, 1978). This implies that a skill such as classification, and others like it, are knowledge-derived, and emerge as the necessary domain knowledge and its representation are acquired.

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