How are living things alike and different? First graders' knowledge of basic life science concepts

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Six-year-olds tend to emphasize superficial characteristics when comparing organisms, but they also show partial knowledge of the fundamental properties that define living things

Introduction

The past 15 years have seen an increasing coordination between the interests and activities of cognitive researchers and curriculum developers. An area of ongoing research in both curriculum development and cognitive psychology has been how best to design educational materials to capitalize on (and improve) the existing conceptions of students, in order to achieve educational goals (cf. Clough and Driver, 1986; Driver, 1989; Genter and Stevens, 1983; Novak, 1990; Osborne and Freyberg, 1985). At younger ages, the goal of 'developmentally appropriate education' is the same: to maximize the pedagogical power of curricular content by designing it to capitalize on the existing competencies of students (National Association for the Education of Young Children, 1989).

Abstract

Children's abilities to compare living things, and to articulate their fundamental properties (eating, breathing, etc.), were assessed. Forty first-grade children were asked to identify similarities and differences among pairs of different organisms (bears, trees, frogs, fish, and ants). Results indicated that: (a) children were consistently more able to generate differences than similarities; and (b) they used the same superficial properties (size, colour, etc.) as a basis for both types of judgment. While the fundamental properties of living things were used by some children as a basis for similarity judgements, these properties were inconsistently applied across different types of organisms. Implications for life sciences curricula in the early primary grades are discussed.

Key words: Living things, Life science concepts, Similarities, Differences.

The present study was conducted to inform the development of a new life sciences curriculum for first-grade children. The purpose of the study was to examine the match between one of the curriculum's stated goals, the method intended to achieve it, and young children's existing competencies. The intent is to examine the goal and method in relation to existing developmental research, and then to assess empirically children's performance on tasks derived from the goal, in order to determine if they match the expectations of the curriculum.

A common goal of life sciences curricula in the early primary grades is to get children to recognize the common characteristics of all living things, typically defined as: a need for food, water, and air; growth; reproduction; and being composed of smaller structures (birds are composed of beaks, wings, feet, and feathers, for example, cf. California Board of Education, 1990). There is existing evidence that recognizing the universal features of living things is problematic for children. There is abundant data indicating that young children do not see all living things as sharing these common attributes (Carey, 1985; Inagaki, 1990; Ochiai, 1989; Stavy and Wax, 1989). When questioned about specific characteristics of being 'alive' (eating, breathing, reproducing, etc.), for example, young children tend to regard them as properties of humans and mammals, but do not consistently extend these attributes to insects, plants, or fish (Carey, 1985; Stavy and Wax, 1989).

One method frequently recommended to help children recognize the universality of the common features of living things is that of comparison. One popular curriculum describes comparing as '. . . The scientific thinking process that deals with concepts of similarities and differences (California Board of Education, 1990)', and comparing is defined as the process of *identifying and describing* similarities and differences, with the latter being treated as cognitively equivalent. Surprisingly, the success of comparing as a method for promoting children's awareness of traits shared by organisms has never been assessed. In fact, children's ability to verbally identify similarities and differences between objects has not been systematically researched. The Stanford–Binet intelligence test, however, contains scales and items that specifically focus on both these aspects of comparing ('How are an apple and an orange alike?'; 'How are a bird and a dog different?'), and the norms for this test suggest that children may not be able to reflect on differences and similarities with equal competence. The ability to identify differences is attained by the age of six, but the ability to identify similarities is not attained until one full year later, at the age of seven (Terman and Merrill, 1973).

A more specific issue regarding the use of comparison in life sciences learning is how children spontaneously characterize the similarities and differences among living things. An implicit assumption behind the use of comparing as a method to aid children in recognizing fundamental life properties, is that children consider these properties to be significant features of the organisms being compared. But what role do the fundamental life properties actually play in children's comparisons? If other aspects of living things are more salient to children, it is possible that fundamental life properties may not even feature in children's reflections on what living things have in common.

The present study was conducted to assess the validity of the curriculum's expectations of children's performance using comparison to identify the shared attributes of living things, and to provide the curriculum with a developmentally appropriate baseline for lesson design. The goal was to determine:

(a) children's spontaneous characterizations of the similarities and differences among different living things from the forest; and
(b) the degree to which children's spontaneous characterizations of similarities, in particular, reflect fundamental life properties.

Method

Subjects

Forty first-grade children (20 boys, 20 girls) from urban schools in Lincoln, Nebraska, and Plainfield, New Jersey, participated in the present study. All children were performing at or above grade level.

Procedure

Children were interviewed in their schools in a room near their usual classroom. The children's comparisons were collected as part of a wide-ranging interview about forests and forest life. All interviews were videotaped for later analysis. Children's judgments of the similarities and differences among different types of living things were assessed by asking them to describe what was 'alike' and 'different' among different pairs of organisms. The terms 'alike' and 'different' were chosen based on pilot interviews indicating that these words were universally understood by children, The actual instructions for the children in the present study were, *'Now I'm going to ask you about some things that live in the forest. For each pair, I say, tell me some things that are alike and some things that are different between them.'* The pairs were selected to represent different types of living things that previous studies had shown that children view as not sharing the same life properties: mammals, lizards/amphibians, fish, bugs, and plants. The 11 pairs tested were: bear–tree, bear–ant, bear–frog, tree–ant, tree–frog, ant–frog, tree–flower, fish–bear, fish–ant, fish–tree, and fish–frog.

After the children provided an initial difference or similarity, they were prompted for the opposite comparison. For example, if a child stated that a fish and frog were alike because they both lived in water, the child was then asked, *'That's a way that the fish and frog are alike. Now can you tell me a way in which they are different?'*

Scoring

The vast majority of children (92.5 per cent) typically provided a single difference and single similarity for each pair of organisms discussed. If a child provided more than one similarity or more than one difference, only the first similarity and the first difference given were scored. The children's answers were scored in two ways. First, whether children volunteered the difference or the similarity first was noted for each pair. If children did not provide both differences and similarities, whichever type of comparison they did provide was scored as being the first mentioned.

Next, children's answers for both differences and similarities were categorized. There were 10 response types: no response/I don't know, eight content-based valid comparisons, and invalid comparisons. These were defined as follows:

No response/I don't know (NR/DK). Responses such as 'I don't know', 'nothing', etc., as well as refusals to answer, were scored as in this category.

For an answer to be considered a valid comparison, the two organisms in the pair had to be compared on the same type of attribute. Eight valid content-based response types were identified:
Colour. The child's answer referred to the coloration of the organisms in question: 'They both have green', or 'One is brown and one is black'.
Size. These responses made reference to the relative sizes of the organisms in the pair ('The fish and frog are about the same size', or 'The tree is much bigger than the ant').
Movement. Two types of answer were counted as movement-related. First, the child's answer referred to the form of locomotion the organisms employed ('They both can run', or 'One swims and the other hops'). Alternatively, the child's answer referred to the speed of the two organisms ('The bear can run fast and the fish can swim fast', or 'The tree doesn't move, but the bear does').
Body parts. These answers referred to the body structures of the different organisms ('A tree has leaves and an ant doesn't', or 'They both have legs').
Habitat. Answers fitting this category referred to the places where the organisms were asserted to live ('The frog and fish both live in the water', or 'The fish lives in the water, but the ant lives in the ground').
Food. Answers classified as food-related referred to what the two organisms were asserted to eat or drink ('The fish eats bugs and so does the bear', or 'The bear eats meat but the tree doesn't').
Valid other. This category was used to classify responses that were valid in form, but the content of which was highly idiosyncratic and often fanciful, such as 'People pick flowers, but they don't pick trees!' or 'Bears love their mommies and so do frogs'.
Fundamental life property. Responses that made reference to any of the defining characteristics of living things, identified by the California Framework (1990), were assigned to this category. The set of defining characteristics were: needing food/eating, needing water/drinking, breathing, growing, reproducing and excreting.
Invalid comparison. Several response types fell into this category. The first were functional relationships that were not comparative, such as 'The ant lives on the tree', or 'The frog eats the ant'. The second were comparisons that did not share or rely on a common attribute, for example, 'A tree will grow but a fish won't walk'. Finally, circular arguments such as 'The bear eats the fish but the fish doesn't eat the bear', were included in this category as well.

Results

Site differences in children's responses

No significant differences were obtained between the Nebraska and New Jersey samples on any measure in the present study; the two samples were combined for all the analyses reported below.

Primacy of difference and similarity responses

A standard measure of item difficulty is latency to response. The longer it takes to generate an answer, the larger the amount of processing effort required to produce it. When two different answers are to be sought, the answer that requires the least processing will be generated first. Thus, an examination of the patterns of which answer was produced first, provides valuable insight into the relative difficulty of the two problems. The frequencies of which comparison, similarity, or difference was offered first are shown in table 1. One-variable chi-squared tests were used to determine if the difference in frequencies was statistically significant. As the table indicates, for eight of the eleven pairs tested, differences were provided first, and for six of these eight pairs, the difference in type of first response is statistically significant. Only three pairs showed a distribution favouring similarities, and none of these differences were statistically significant.

Children's tendency to emphasize differences over similarities was apparent in a qualitative aspect of their responses to the interview questions as well. When children had provided a difference, and were then prompted to provide a similarity, they frequently responded with yet *another difference, not a similarity.*

Content of children's similarity and difference comparisons

The children's responses to each pair, organized by the content of their comparisons, are shown in tables 2

Table 1 Percentages of children providing difference or similarity first

Animal pair	Difference first	Similarity first
Bear – Tree	47.5	52.5
Bear – Ant*	80	20
Bear – Frog*	80	20
Tree – Ant	62.5	37.5
Tree – Frog	60	32.5
Ant – Frog*	62.5	30
Tree – Flower	35	55
Fish – Bear*	77.5	17.5
Fish – Ant*	80	17.5
Fish – Tree*	67.5	25
Fish – Frog	42.5	50

Note: Percentages for some pairs do not total 100 per cent because some children did not respond to the question.
* Difference in frequency of responses is significant at the $p < .01$ level.

and 3. The most striking feature of the results presented in the tables is that with the exception of fundamental life properties, the same set of concrete characteristics forms the basis for children's attributions of both similarities and differences. This does not mean that the pattern of responses is alike for both types of comparison. While children did use the same characteristics to generate both types of comparison, the frequency with which each characteristic is used to justify the child's judgements varies depending on whether a similarity or difference is being requested.

One way to examine differences between similarity and difference judgements, in the frequency of the various content types, is to compare the median frequency of each content category for both types of judgement. If a difference in median frequency of 5 per cent or more is used as a criterion for a notable difference, then such an examination yields several intriguing results. First, three categories of response were more frequently used for difference than similarity judgements: colour (median 20 per cent of differences, but 12.5 per cent of similarity judgements), size (median 17.5 per cent of differences, but 2.5 per cent of similarities), and movement (median 17.5 per cent of differences, but 7.5 per cent of similarities). It appears that contrasts between the different organisms in each pair were most easily identified along these dimensions.

Second, of the remaining categories, three showed no difference between the two judgement types and three were more frequently used for similarity judgements. There were no differences in the frequencies of judgements based on body parts (median 12.5 per cent for similarities and 10 per cent for differences), habitats (median 2.5 per cent for both judgement types), or foods (median 0 per cent for similarities and 2.5 per cent for differences). Similarity judgements were based more frequently on fundamental life properties

Table 2 Differences between pairs of organisms, six-year-old children

	Nature of difference								
Pair	NR/DK	Colour	Size	Movement	Body parts	Habitat	Food	Valid other	Invalid
Bear – Tree	0	17.5	15	17.5	27.5	0	0	12.5	10
Bear – Ant	0	15	55	2.5	12.5	2.5	2.5	5	5
Bear – Frog	0	27.5	17.5	27.5	5	7.5	2.5	7.5	5
Tree – Ant	2.5	22.5	27.5	12.5	12.5	2.5	0	0	20
Tree – Frog	7.5	27.5	7.5	30	10	2.5	2.5	7.5	5
Ant – Frog	7.5	22.5	17.5	12.5	10	2.5	0	15	15
Tree – Flower	7.5	30	17.5	0	10	0	0	25	10
Fish – Bear	5	17.5	12.5	7.5	5	10	2.5	2.5	37.5
Fish – Ant	5	20	17.5	17.5	7.5	7.5	5	5	15
Fish – Tree	7.5	15	10	25	20	15	0	2.5	5
Fish – Frog	2.5	20	7.5	27.5	7.5	12.5	7.5	5	10

Table 3 Similarities between pairs of organisms, six-year-old children

	Nature of similarity									
Pair	NR/DK	Fundamental life properties	Colour	Size	Movement	Body parts	Habitat	Food	Valid other	Invalid
Bear – Tree	12.5	25	25	2.5	2.5	2.5	0	5	10	15
Bear – Ant	27.5	27.5	15	0	5	17.5	0	0	5	2.5
Bear – Frog	25	15	5	2.5	2.5	30	7.5	0	10	2.5
Tree – Ant	15	25	30	5	0	2.5	2.5	5	7.5	7.5
Tree – Frog	20	20	40	0	7.5	0	2.5	0	7.5	2.5
Ant – Frog	20	25	5	0	17.5	15	0	0	10	7.5
Tree – Flower	12.5	27.5	20	0	10	12.5	2.5	0	10	5
Fish – Bear	27.5	15	7.5	2.5	15	7.5	7.5	0	12.5	5
Fish – Ant	30	32.5	2.5	5	0	5	7.5	5	10	2.5
Fish – Tree	37.5	32.5	7.5	2.5	0	0	2.5	0	7.5	5
Fish – Frog	17.5	12.5	12.5	2.5	12.5	20	15	0	2.5	5

(median 25 per cent for similarities but *no* responses for differences), and other valid responses (median 10 per cent for similarities vs. 5 per cent for differences). In addition, NR/DK responses were more frequent for similarity judgements as well (median 20 per cent vs. 5 per cent for differences).

Comparison content and specific pairs of organisms

An examination of the patterns of responses children provided for each pair of organisms they compared reveals that the distribution of response types is not random. The response frequencies in tables 2 and 3 indicate that there are modal similarity and difference responses for each pair tested. The modal responses to the specific paired comparisons provide insight into the traits children rely on to make similarity and difference judgements, and into their conceptions of the specific types of organisms as well.

Considering differences, 10 of the 12 highest-frequency response types (one pair, bear–frog, is bimodal) were found in the colour, size, and movement categories, and these categories tended to be associated with specific organisms. Size was a modal response only for comparisons of the bear and tree (two, large organisms) with the ant, for example. Similarly, movement-based responses were popular for comparisons using the tree (which does not move at all), frog, and fish (the latter two moving in a highly unique manner). Finally, difference judgements based on colour also appeared to be associated with the frog (which children universally said was green), the tree–flower pair (children typically stated that flowers had more colours than trees), and the fish–ant pair (children stated that fish were gold and ants were black).

The two remaining modal response categories also suggest certain stereotypical associations. Differences based on type of body parts were most frequent for the bear–tree comparison, apparently because of the obvious contrast between animal and plant. Children usually made reference to a specific part that only one of the pair had (leaves, for example, or claws). The fish–bear comparison was the only one to yield a majority of responses that were not valid comparisons, but these answers again reveal an apparent stereotyped knowledge base: the vast majority of children said, 'The bear eats the fish, but the fish does not eat the bear'.

Turning to the similarity responses, the results indicate that as with differences, the majority of highest-frequency answers (10 of 13, the bear–ant and bear–tree pair responses are bimodal) fall into three categories: fundamental life properties, colour, and NR/DKs. The fourth modal category of body part similarities occurs only for the bear–frog and fish–frog comparisons. Answers relying on fundamental life properties do not appear to be strongly associated with a specific organism; while three of the comparisons with high frequencies of life property responses contain the ant as an element, the bear, frog, fish, tree, and flower are also represented. All three modal colour responses, in contrast, involve the tree, and all of these responses relied on the assumption that the tree contains brown or green to match the other organisms in the pairs (bear, ant, and frog).

It is notable that for the third high-frequency modal response category, NR/DKs, the bear, fish, ant, and tree are the common organisms across these modal responses. Similarities across these four organisms in terms of the other response categories are clearly hard to come by, and thus apparently gave children considerable trouble. Several asserted that the organisms in these pairs had nothing in common at all! One additional pattern in the data that is highly suggestive is the relationship between NR/DKs and fundamental life properties as response types. For four pairs of organisms (bear–ant, ant–frog, fish–ant, and fish–tree), these two response types together are either the two modal or the modal and next most frequent responses, regardless of which response type is actually the most common.

Generality of fundamental life properties

A defining feature of life properties as life science concepts is their universal validity for all living things. Fundamental life properties clearly comprise a solid percentage of children's similarity judgements in the present data, but how consistent are children in applying them across the different pairs of organisms in the present study? Interestingly, children are highly consistent in their *failure* to mention fundamental life properties: 37.5 per cent of the sample never mentioned fundamental life properties as a basis for similarity at all. Of those who did mention them, the median (and modal) number of pairs for which life properties were mentioned was four, with 72 per cent of children applying life properties to four or less pairs, and only 28 per cent of children applying them to five or more. No child extended them to all 11 pairs of organisms.

Discussion

The use of comparison as a method for helping children reflect on the commonalities and differences among living things treats the identification of differences and similarities as two aspects of the same basic cognitive process for children of this age. The present results suggest that this is not the case. Confirming the age-related asynchrony in identifying differences and similarities reported by Terman and Merrill (1973), differences appear to be much easier for six-year-old children to generate than similarities. Not only did the children tend to give differences first when asked for both similarities and differences, but many children who provided valid differences for virtually all the pairs tested in the study were unable to provide similarities for the very same comparisons.

The findings regarding the curricular content goal emphasizing that living things share certain fundamental characteristics are more complex. Perhaps the most striking result from the present study is the finding that children tend to rely on the same basic set of very concrete (and often superficial) characteristics, when asked to evaluate spontaneously how organisms are similar and different. These characteristics tend to be stereotypical, and are applied in a rather global manner. It is intriguing that other dimensions of children's knowledge about organisms, such as their foods and habitats, were very rarely used as a basis for their answers; the frequencies of these response types were low for both similarity and difference judgements. It appears that children's spontaneous thinking concerning living things is quite concrete, and concerned with overt physical features, rather than more substantive and non-physical knowledge.

This does not suggest that children have no notion of fundamental life properties. The specific characteristics defined as fundamental life properties were the only response type to vary from the above pattern, and their distribution in the data is notable: they appeared only as content for similarity judgements. No children stated that two organisms were different because one ate and the other did not, for example, even when there was the potential for such contrasts (such as a comparison between a tree and a bear). These results suggest that children's conceptions of living things do contain elements of the fundamental life properties, that are a common focus of life science education for this age group. Indeed, the fact that more than one third of the sample did not mention life properties at all, should not be taken to indicate that these concepts do not form part of children's understanding. Carey (1985), for example, reported that when children were questioned about the fundamental life properties possessed by individual types of organisms, the percentage of six-year-old children stating that an organism had such properties was higher than those in the present study. Future research on children's comparisons should assess whether, once children are oriented toward these properties, they would indeed produce responses recognizing that they are shared by pairs of highly different organisms.

An examination of the performance of those children who did mention fundamental life properties yields two additional points. First, it appears that fundamental life properties are not assigned the same status as the other, more concrete characteristics used to judge organisms as similar. Fundamental life properties were not just one of many possible categories of similarity judgement produced; they were either the modal or next most frequent response for a majority of the pairs tested. The second point is that although life properties were more frequently cited than other characteristics of the organisms children compared, they still used these responses very inconsistently. As the data showed, 75 per cent of the children cited them for four or fewer comparisons. This finding suggests that while children have a grasp of the nature of fundamental life properties at some level, they may not understand them as the general or unifying concepts that they are meant to be in the life sciences.

In conclusion, the findings in the present study both validate the use of comparing as a method for assisting children in grasping the universality of fundamental life properties, and also suggest avenues for future study. Clearly, children are able to compare organisms accurately. They can easily generate differences among organisms, and a majority are capable of providing similarities, too. In addition, fundamental life properties were generated as similarities by the children at least once for all the pairs of organisms, indicating that these aspects of living things are recognized by them on a basic level. The building blocks of the concept of universality, therefore, are present in children's thinking.

Future research, however, is needed in order to clarify several of the present findings. First, it is necessary to discern the degree to which the patterns of inconsistent attribution of fundamental life properties reported here are merely an artifact of the untutored way in which the comparisons in the present study were collected, or if they actually reflect more substantive aspects of children's understanding. Second, further research on children's apparent difficulty in identifying and articulating similarities must be conducted. The present results match the norms provided by the Stanford–Binet test, suggesting that for six-year-old children reasoning about similarities is, in general, more difficult than reasoning about differences. Why should this be? Understanding the conditions that facilitate children's ability to recognize and articulate similarities would benefit all fields of scientific education, not simply those concerned with living things.

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