# ON THE NATURE OF CHILDREN'S NAIVE KNOWLEDGE

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## ABSTRACT

We argue that children construct a naive understanding of the world which gradually becomes modified to conform to adult-scientific views. This naive understanding consists of a number of discrete ontological beliefs, such as that the ground is flat, that things fall down, and that stars are small objects. Children are capable of synthesizing their ontological beliefs to form relatively consistent conceptual structures. However, they also seem to be operating under an epistemological constraint according to which these ontological beliefs represent the true state of affairs about the world. In the process of conceptual change children replace their ontological beliefs with a different explanatory framework.

## INTRODUCTION

One of the most interesting results of recent work in cognitive science has been the realization that science-naive individuals have an understanding of the natural world which is based on their interpretation of everyday experience. This naive knowledge is usually quite different from the knowledge expected from the scientifically literate adults in our society. In the process of learning science novices must change their naive knowledge to make it conform to the currently accepted scientific knowledge. This process of conceptual change can be a rather lengthy one to accomplish because naive ideas appear to be robust and difficult to extinguish (e.g., diSessa, 1982; White, 1983).

There is currently a lot of debate about how it is best to characterize the nature of naive knowledge and the mechanisms thereby which it can be modified. Some researchers believe that novices' ideas can be conceptualized as consisting of a coherent and systematic set of ideas which have a status similar to that of a scientific theory (McCloskey, 1983; Wiser & Carey, 1983). Others think that naive physics consists of a fragmented collection of ideas which are loosely connected and do not have the systematicity that one attributes to a scientific theory (e.g., diSessa, 1988).

In addition to its considerable theoretical interest the debate on the nature of naive knowledge has important instructional implications as well. Depending on one's beliefs about the nature of naive knowledge different instructional implications can be drawn. Researchers who view novices as having relatively well organized and internally consistent naive theories think that the process of science learning requires a change in theory similar to the kind of theory change observed in the history of science (Hanson, 1958; Kuhn, 1962; 1970). Although the mechanisms for achieving this kind of theory change are not yet known, most of these researchers believe that it is necessary to confront novice students with enough evidence to make them realize the limitations of their theories and to change them (Anderson, 1977; Collins, 1986; McCloskey, 1983).

On the contrary, researchers who believe in the fragmented nature of naive knowledge think that a one-by-one attack of the knowledge fragments that constitute naive physics is a hopeless task. Some of them suggest that what is needed is to collect and unify these fragments to develop the scientific understanding that a science-naive individual lacks (diSessa, 1988).

In this paper we present an intermediate position based on the results of our investigation of the process of knowledge acquisition in the domain of astronomy (Vosniadou, 1987; Vosniadou & Brewer, 1987; in press; submitted). Crucial to our position is the distinction between global and domain-specific theories. We believe that children start their knowledge acquisition process with a global theory consisting of a set of core concepts and a notion of causality which forms the basis of their ontology and epistemology. This global theory becomes differentiated and restructured into domain-specific theories.

Children's naive understanding of the world is conceptualized as consisting of a set of discrete ontological beliefs which are constructed on the basis of their everyday experience under the constraints of their global theory. Children seem capable of synthesizing these discrete beliefs into larger conceptual units and are sensitive to the internal consistency of these conceptual structures. Ontological beliefs are, however, different from the hypotheses of a domain specific theory in that they are considered by children to represent the true state of affairs about the world and, thus, in no need of being questioned. The emergence of a domain-specific theory requires the replacement of some of the ontological and epistemological beliefs of the global theory with a different explanatory framework.

## KNOWLEDGE ACQUISITION IN ASTRONOMY

Everyday experience provides children with enough information to construct an intuitive understanding of many of the phenomena that a theory of observational astronomy accounts for (such as the shape, size, movement and location of the earth, the sun, the moon, and the stars, the day/night cycle, the phases of the moon, etc.). We hypothesized that if children utilize their everyday experience to construct a naive understanding of the physical world, they should believe that the earth is flat and stationary and that it is located in the center of the universe. We also hypothesized that children would think that gravity operates along an up/down gradient and that the day/night cycle is caused by the movement of the sun and the moon rather than by the movement of the earth. Some support for the view that children conceptualize the earth as flat and gravity as operating in an up/down fashion is found in previous research (Nussbaum & Novak, 1976; Nussbaum, 1979; Sneider & Pulos, 1983).

Such a naive understanding of the cosmos is of course very different from currently accepted views. We were interested in finding out whether children do indeed construct such an naive understanding of the world and, if so, how this understanding changes as children are exposed to the Copernican theory.

### Methodological Issues

We examined children's knowledge of astronomy using an elaborate questionnaire which was developed after extensive pilot work and which consisted of a total of 207 questions. The children were also asked to make models of the solar objects using play dough and to select from a variety of physical models of the earth, sun, moon and stars. We conducted a series of studies using this questionnaire involving preschool, elementary school, and high school students in the United States (Vosniadou, 1987; Vosniadou & Brewer, submitted), in Samoa (Brewer, Hendrich & Vosniadou, submitted), in India (Samarapungavan & Vosniadou, in preparation), and in Greece (Vosniadou & Brewer, in press).

Children's concepts were identified from their responses not to one but to many questions tapping each concept. Crucial to our methodology was the distinction between *factual* and *generative* questions. Factual questions were designed to test children's exposure to certain theoretically important facts. These were questions like "What is the shape of the earth?", "Does the earth move?" Children could answer these questions either on the basis of their underlying conceptual knowledge or by simply repeating information they had obtained from adults. Generative questions were questions to which children had not been previously exposed and which had the potential of revealing whether the children had assimilated the adult information into their underlying conceptual framework. Consider for example the questions "If one were to walk for many days on a straight line would one ever reach the edge of the earth?"," Does the earth have an edge? ". We assumed that in order to answer these questions children would use their existing conceptual knowledge to form a mental model of the earth. If the children had fully understood the information that the earth is a sphere they should form a mental model of a spherical earth. Based on such a model they should come to the conclusion that the earth does not have an edge and that if someone walked for many days in a straight line one would come back to were one started. On the contrary, if the children had not fully incorporated the information that the earth is a sphere into their underlying conceptual structures they should form a mental model of a flat earth. Based on such a model they should come to the conclusion that the earth has an edge.

Follow-up questions and confrontation questions were also used throughout the interview to try to understand children's concepts. The following is an example of our questioning procedure from the protocol of Renae (grade 1).

E: What is the shape of the earth?
C: Round
E: Could you ever reach the edge of the earth?
C: Yes.
E: Could you fall off that edge?
C: No.
E: Why not?
C: Because once you fall off you can't get back on.
E: What if you could get back on, do you think you could fall off then?
C: Yes...and if you took to the edge of the thing, and you had one hand on it, you could fall off easier.

In this protocol we see that Renae starts by saying that the earth is round. Upon further questioning it is, however, revealed that she believes that the earth has an end/edge from which people could potentially fall off, although she is very reluctant to accept this possibility.

### Results

**Consistency.** Children's responses to the individual questions investigating each concept revealed tremendous surface inconsistency. For example, in a study of children's concept of the earth shape (Vosniadou & Brewer, submitted) we found that forty out of sixty children gave responses which did not agree with a consistent use of either a spherical earth concept or a naive concept of a flat earth. Many of these children appeared to have formed an alternative conception regarding the shape of the earth. Here is an example from the protocol of Veronica (grade 3).

E: What is the shape of the earth?
C: Round
E: If you walked for many days in a straight line, where would you end up?
C: Somewhere in the desert.
E. Would you every reach the edge of the earth?
C: No. You would have to have a spaceship if you're going to go to the end of the earth.
E: If there an edge to the earth?
C: No. Only if you go up.
E: Does anyone live here on the bottom of the earth?
C: No because they live in the states up here.
E: But could they live down here?
C: Yes.
E: Why wouldn't they fall off?
C: Because they are inside the earth?
E: What do you mean inside?
C: They don't fall; they have sidewalks, things down like on the bottom.
E: Is the earth round like a ball or round like a thick pancake?
C: Round like a ball.
E: When you say that they live inside the earth, do you mean they live inside the ball?
C: Inside the ball. In the middle of it.

Veronica appears to believe that the earth is round like a ball and that people live deep inside this ball.

Some evidence for the presence of alternative conceptions about the shape of the earth has been provided in previous research on the earth shape and gravity concepts (e.g., Nussbaum & Novak, 1976; Nussbaum, 1979; Sneider & Poulos, 1983). This research has not, however, shown whether children's alternative conceptions about the earth are systematic and are used in a consistent fashion or represent transitory and internally inconsistent problem solving attempts.

In order to determine whether the children were consistent in their use of an alternative conception of the earth we derived from our data and from the previous research in this area as many possible alternative conceptions of the earth as possible. Then, we generated the answers we would expect the children to have given to our individual questions had they made consistent use of that conception. For example, we reasoned that if children believed that the earth is round like a disc, rather than round like a ball, they should think that the earth has an end/edge, that people can fall down from that end/edge, that people live only on top of the earth, and that there is something that supports the earth.

Once the pattern of responses for each alternative earth shape concept was determined we checked children's responses to the relevant questions to see if they agreed with the expected ones. Assigning a concept to a child required no more than one deviation from the expected pattern of responses and only if this deviation occurred in a non-defining item for this category. For example, a child who said that there is an end/edge to the earth could not be assumed to be making consistent use of a spherical earth concept, even in those cases where this response was the child's only deviation from a spherical earth concept response pattern. On the other hand, the response "circle" to the question "What is the shape of the earth?" was considered an acceptable deviation for a child whose responses agreed in all other respects with the spherical earth concept because it could be caused by a linguistic rather than a conceptual confusion (e.g., the child may have used the word "circle" to mean "round").

Using this procedure we were able to determine that the great majority of children in our studies made consistent use of a concept. For example, in the case of the earth shape we were able to determine consistent use of the same concept in 51 out of the 60 children investigated. As is shown in Table 1 most of the children used alternative concepts of the earth which showed a combination naive and scientific views. We have identified three such concepts: The dual earth, the disc earth and the inside-the- sphere concepts. The children who had a dual earth concept believed that there are two earths; a flat one on which people were usually thought to live and a spherical one which was thought to be up in the sky. The children with a disc concept thought that the earth is both flat and round and that it has an end/edge from which people can fall. Finally some children believed that the earth is round like a ball but that people live deep inside this ball. The questionable sphere category included the children who seemed to be making use of a sphere concept but had two or three deviations from the accepted pattern of responses and could not therefore be placed in the sphere category.

Following this procedure we have been able to determine that most children use in a consistent fashion certain concepts of the sun, moon, stars and certain explanations of the day/night cycle. For example, many children believe that the movements of the sun and the moon cause the day/night cycle. Others think that the sun is occluded by clouds or solar objects that move in front of it. One interesting explanation was held by children who knew that the earth rotates around its axis but attributed the day/night cycle to the presence of the moon. These children thought that the moon is fixed in some place in the sky where it is always night; as the earth rotates our part of the earth eventually comes to face the moon and as a result to bring the night.

**Table 1**
**Frequency of Children's Concepts of the Earth's Shape as a Function of Grade**

| Earth Shape Concepts | Grade 1 | Grade 3 | Grade 5 | TOTAL |
|---|---|---|---|---|
| 1. Sphere | 2 | 8 | 10 | 20 |
| 2. Questionable Sphere | 1 | 3 | 6 | 10 |
| 3. Inside-the-Sphere | 2 | 4 | 4 | 10 |
| 4. Disc | 0 | 1 | 0 | 1 |
| 5. Dual Earth | 7 | 2 | 0 | 9 |
| 6. Flat (Rectangle) | 1 | 0 | 0 | 1 |
| 7. Mixed | 7 | 2 | 0 | 9 |
| TOTAL | 20 | 20 | 20 | 60 |

Some children had mixed concepts and for some no consistent concept could be identified. On the whole, however, our results suggested that there was a relatively high degree of internal consistency in children's atomistic concepts about the earth, sun, moon and stars and their explanations of the day/night cycle.

The success in identifying consistent concepts for the great majority of the children in our sample shows that children's conceptual knowledge is not as fragmented as some theorists have argued (e.g., diSessa, 1985; Solomon, 1983), at least at the level of the individual concepts investigated. It appears that children try to synthesize their everyday experience into meaningful and internally consistent conceptual structures.

It could be objected here that some of the alternative conceptions we have identified may not be precompiled but may be constructed by the children on the spot as they are trying to answer our questions. In our view this issue is not critical for our position. Whether precompiled or not the use of relative stable and internally consistent knowledge structures shows that many if not all children are both sensitive to and capable of connecting their knowledge fragments into internally consistent wholes. In that particular respect children's synthetic attempts are not different in kind from scientists' attempts to construct theories.

**The robustness of naive conceptions.** It appears that one reason why children may construct alternative concepts is because they find it very difficult to give up their naive conceptions. Indeed, all the alternative conceptions of the earth shape we have identified can be seen as attempts to assimilate the scientific concept of a spherical earth to the naive concept of a flat earth. For example, the children with a dual earth concept believe that there are two earths one round and one flat. The children with the disc model interpret round to mean flat. Finally, the children with the inside-the-sphere concept believe that the earth is a sphere but that people live on flat ground inside it. The presence of these alternative concepts shows that naive conceptions are rather robust.

**Naive concepts consist of several discrete ontological beliefs.** A close examination of the alternative concepts we have identified reveals that these concepts are attempts from the part of the children to synthesize a number of discrete ontological beliefs about the nature of the earth, sun, moon and stars. Let's examine the earth shape concept once more. This concept appears to be composed not only of the belief that the ground is flat but also (among others ) of the beliefs that the earth has some kind of an end/edge, that people can fall down from that edge, that there is ground or water underneath the earth, and that people live only on top of the earth.

In forming alternative concepts children change their naive concepts in a way that allows them to retain all or some of their ontological beliefs without contradicting adult teachings. The detailed examination of children's responses reveals that there is a progression of more and more advanced alternative concepts depending on how many ontological beliefs children have given up. For example, the inside-the-sphere view is a more advanced concept than the disc concept. The children who hold the inside-the-sphere concept have given up their ontological belief that the earth is flat, that there is ground all the way down and that the sky is only on top of the earth. These children conceptualize the earth as a sphere suspended in space but still believe that people live on flat ground inside the earth, and that things fall downward rather than toward the center of the earth.

This does not happen only in the case of the earth shape concept. Consider, for example, the children who have constructed an explanation of the day/night cycle according to which the rotation of the earth allows our side of the earth to face the stationary moon. These children have changed their ontological beliefs that the moon moves and the earth does not

but have not yet given up on the idea that night is associated with the presence of the moon.

**Naive concepts are embedded within global theories.** We think that ontological beliefs are constructed by children on the basis of their everyday experience under the constraints of their global theories. Naive concepts are generated by synthesizing these discrete ontological beliefs. In addition, two epistemological constraints appear to further constrain children's concepts: (a) the belief that ontological beliefs represent the true state of affairs about the world, and (b) the belief that adults are usually right. If children did not believe that their ontological beliefs represent the way the world really is there would be no reason to form alternative concepts. They would simply change their beliefs and adopt the adult models. The formation of alternative concepts, especially in cases like the earth shape where the culture provides such massive exposure to the idea that the earth is a sphere, strongly suggests that children are operating under the epistemological constraint that their ontological beliefs are fundamentally true.

The construction of alternative concepts also presupposes the belief that adults are right. If children did not believe that adults are right they would have no difficulty rejecting the adult information and retaining their original naive views. When children construct an alternative concept they try to retain as many of their ontological beliefs as possible without contradicting adult teachings.

In short, the genesis of an alternative concept can be conceptualized in the following way. When children read in a book or hear from an adult that the earth is a sphere they do not want to believe that the adult information is wrong but find it hard to reconcile it with their ontological beliefs. Because children believe that their ontological beliefs represent the true state of affairs about the world they are not likely to question them. Rather, they believe that they have misunderstood what the adults really mean when they say that the earth is round. In trying to interpret the adult information in a way that does not contradict their ontological beliefs children construct alternative concepts or develop unassimilated internally inconsistent concepts.

## CONCLUSIONS

Our investigations of the process of knowledge acquisition in the domain of observational astronomy have shown that children start by constructing a naive understanding of the world which is based on their everyday experience. This naive understanding can be decomposed into a number of discrete ontological beliefs such as that the ground is flat, that things fall down when you drop them, that stars are small objects, and that the day/night cycle is caused by the movement of the sun and the moon. Children try to synthesize these ontological beliefs into relatively consistent conceptual structures which are, however, constrained by different epistemological frameworks than those of adult scientists. The process of knowledge acquisition requires the rejection of these ontological and epistemological beliefs and their replacement with a different explanatory framework.

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