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Heavenly Talk: Discourse, Artifacts, and Children's Understanding of Elementary Astronomy

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Key Words

Conceptual change · Cognition and artifacts · Reasoning · Cognitive development · Cognitive tools

Abstract

In the literature on children's understanding of astronomical concepts, such as the shape of the earth and gravitation, the difficulties that children have in conceptualizing these phenomena have been documented in many studies. The purpose of this research is to critically scrutinize these findings by taking a situated and discursive perspective on reasoning (and cognitive development). Instead of viewing understanding as the overt expression of underlying mental models, children's responses in interview studies should be regarded as situated and as dependent on the tools available as resources for reasoning. By modifying the interview situation through the introduction of a globe as a tool for thinking, the outcomes are radically different from those reported earlier. None of the problems that have been reported, where children, for instance, claim that people can fall off the earth, can be detected. Even among the youngest participants gravitation is often invoked as an explanatory concept. It is argued that the globe in this case serves as an efficient prosthetic device for thinking, and this illustrates the tool-dependent nature of human reasoning.

Over the past decades, there has been a growing acceptance of the idea of domain specificity of cognition. One sign of this is the interest in issues of children's conceptions of scientific phenomena, and in the problems of what it takes to bring about conceptual change in the direction of making people adopt scientifically acceptable concepts. Although work of this kind began in relation to learning in the natural sciences, especially in relation to concepts in mechanics such as force and motion [cf., for example, Cle-

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ment, 1982; DiSessa, 1982; McCloskey, 1983], the interest has spread to many other domains including the humanities and social sciences [cf., for instance, Carretero & Voss, 1994; Halldén, 1998].

Research on these issues has been carried out from different theoretical perspectives, most of which belong to cognitive and constructivist traditions. The object of analysis has been referred to as children's 'alternative frameworks', 'naive conceptions', 'misconceptions', 'lay theories', to mention just a few of the terms that have been used. One line of research has been inspired, more or less explicitly, by a Piagetian approach to children's thinking. The point of departure has been the recognition that children are not blank slates when encountering explanations of scientific phenomena in the school setting. Rather, they bring to situations previously acquired notions and intuitions that they use for rendering what they see and hear meaningful. A slightly different approach is grounded in cognitive psychology and cognitive science and focuses on analyzing children's representations and mental models of objects and scientific principles [cf., e.g., Larkin, 1983; Vosniadou, 1996a]. The schema (or scheme), and to some extent the script, concept in this tradition has been one important source of inspiration for inquiries into what is referred to as the cognitive basis of conceptions [Driver, Guesne & Tiberghien, 1985, p. 4ff; Vosniadou, 1996b]. Again the emphasis is on studying the (lack of) compatibility between existing conceptual structures and the concepts that are to be acquired through teaching in formal settings. Yet another line of research is rooted in phenomenologically inspired approaches to describing different conceptions of the world [cf., for instance, Johansson, Marton & Svensson, 1985; Roth, McRobbie, Lucas & Boutonné, 1997]. In such frameworks, the representational view of mind is not accepted as a valid premise for the analysis of conceptual phenomena. What is studied are instead people's (reported) experiences of phenomena as lived and as available to consciousness. The representational intermediary of conceptual structure, schema and/or cognitive processing are not recognized as autonomous entities accessible for study as such [cf. Bolton, 1991].

The work in these fields is very intense at the moment to say the least, and it is clearly one of the areas where psychological research and instructional interests converge. At a very general level, this work on conceptual knowledge in specific domains has confirmed how local and tied to specific areas and circumstances conceptual knowledge appears to be [cf., e.g., Chi, Feltovich & Glaser, 1981]. Furthermore, it often seems difficult for children (or adults, for that matter) to realize the difference between everyday concepts and scientific ones, and to use the latter type of conceptual constructions consistently across problems and situations. Claims to the effect that 'it is often noticed that even after being taught, students have not modified their ideas in spite of attempts by a teacher to challenge them by offering counter-evidence' [Driver, Guesne & Tiberghien, 1985, p. 3], that 'students frequently hold on to misconceptions even after receiving many hours of physics instruction' [Ploetzner & VanLehn, 1997, p. 170] and similar remarks about conceptual inertia appear frequently in the literature.

Constituting the Object of Research

A critical element in research of this kind, as in any research for that matter, is how the research object is constituted. The theoretical differences between traditions commented on above are reflected in the fact that empirical research is organized in such a

manner as to be compatible with a particular theoretical perspective. As Bruner [1990] points out in his elegant analysis of the development of learning theories, 'research on *anything* will yield findings that mirror its procedures for observing or measuring', and in this sense science 'always invents a confirming reality in just that way' [p. 104; italics original]. There is nothing fundamentally flawed in this close relationship between theoretical constructions and methods for generating data, and this, of course, in no way invalidates the results produced. How would we ever learn anything about cognition and learning if we did not coordinate theoretical constructs and empirical observations? However, there is an interesting problem in this context in the sense that one has to be aware of the fact that we tend to organize data collection in such a manner that we find the entities that we are looking for.

In research on learning and cognition, this problem, in our opinion, deserves particular attention, since our conceptual entities are not, nor will they ever be, directly observable. Rather, they have to be inferred, and our knowledge of people's thinking is always indirect and mediated by what they say and/or by their actions. So as researchers we have to observe and, in addition, often also create conditions that allow us to elicit data in systematic manners. Most research in this area relies on interviewing as a means of eliciting data. Children (and sometimes adults) are typically asked a series of questions on whatever phenomenon is of interest and they have to produce a reply on the spot. The answers given by interviewees are interpreted by analysts as indicators of 'alternative frameworks', 'misconceptions' or 'conceptions of the world' depending on the theoretical inclinations of the investigators.

The work to be reported here takes as its point of departure the explicit recognition of the interdependence between theorizing and empirical observation. We shall therefore assume a conservative attitude, as it were, with respect to what utterances made by individuals imply in terms of psychological processes that cannot be directly observed in data. In order to refrain from making any premature assumptions of what statements imply, we shall focus on spoken interaction as a situated practice, and treat utterances as first and foremost elements of, an contributions to, concrete discursive practices. Thus, what people say and do will be related to (a) the premises for communication [Rommetveit, 1974] that they assume to be valid in the particular situation they are in, and (b) to the resources for understanding and communicating that a particular practice entails [Gauvain, 2000; Siegal, 1991].

The background of the empirical work is twofold. First, it reflects an interest in the research interview as a concrete discursive practice. In particular, our interest has been one of studying in some detail how children are positioned [Walkerdine, 1988] in a communicative sense in such interactions in which they dialogue with an adult. Second, our interest is focussed on issues of the relationship between reasoning and artifacts, i.e., how people rely on socioculturally meaningful artifacts when thinking.

Some of the most substantial work of this kind on conceptual understanding in a specific domain has been carried out by Vosniadou and her colleagues [cf. Vosniadou, 1996a, b; Vosniadou & Brewer, 1992, 1994; and several others] in a series of thought-provoking studies of children's conceptions of elementary astronomy. In particular, these studies have focussed on children's understandings of the shape of the earth, gravity, and related phenomena. We will use this research as a means of illustrating our point about the discursive and tool-dependent nature of human cognition. We would like to emphasize that our dialoguing with this work reflects a genuine appreciation of the findings.

Children's Conceptions of Elementary Astronomy – A Cognitive Science Interpretation

The work by Vosniadou and her colleagues, very explicitly carried out in a cognitive science tradition, testifies to the difficulties children have in arriving at a scientific understanding of, among other things, the spherical shape of the earth and gravity. In summarizing some of the early work, Vosniadou and Brewer [1992, p. 575] conclude that 'elementary school children have difficulty understanding that the earth is spherical and [they] form various misconceptions regarding its shape'. But before challenging this conclusion by attempting to situate what people say and think in communicative practices, let us look at the results of some of the work in this specific domain carried out during the past 25 years or so.

As far as we have been able to establish, Nussbaum and Novak [1976] were the first to investigate this particular problem. In their study, which was based on interviews with second-grade pupils in the United States, they found that children could not understand how the round earth relates to the flat ground that one can see, nor could they predict how objects would fall at various places on the surface of the earth. The authors also presented an empirical pattern which is described in terms of five different notions about the earth as a cosmic body. There is an initial and naive assumption of the earth as flat, followed by a sequence of more elaborate, intermediate versions, and finally we end up with the accepted view. Nussbaum and Novak argue that children seem to keep quite consistently to one of these notions. A few years later, Nussbaum [1979] reported a study based on data from an Israeli sample. Children in grades four to eight were interviewed about their notions of the shape and gravity of the earth. The results confirmed the assumption of the five different notions of the earth.

Several studies have subsequently confirmed these five notions. Sneider and Pulos [1983] interviewed 159 students aged 9–14 in California. In addition to answering questions, the students had to draw a picture of the earth with themselves standing on the grounds. The interview was then related to this picture. Later on during the interview, the investigators also presented a globe to the pupils. Sneider and Pulos found that 75% of the children in grades three, four, and five believed that there is an absolute down direction in space. As in previous studies, they found a wide distribution of notions at each grade level. Baxter's [1989] survey of children's understanding of basic astronomy also lends further support to these findings. Children, in critical respects, appear primitive in their reasoning.

Vosniadou and Brewer [1992, 1994; cf., Vosniadou, 1996a, b for further elaborations] have refined Nussbaum's findings even further, and they have added a concise theoretical interpretation of how to account for children's reasoning. A key assumption in this approach, as in many cognitivist traditions, is that by using interviews we can ascertain children's (and adults') underlying mental constructs that are used when accounting for phenomena in the world. The empirical work is thus conceived as a kind of mapping of cognitive structures or mental models (cf. below). In a study by Vosniadou and Brewer [1992], 60 US pupils (20 from grades 1, 3 and 5, respectively) were interviewed with respect to their understandings of concepts relating to the shape of the earth, its position in space, gravity, and some related matters. Each interview lasted between 30 and 45 minutes, and during this time 48 questions were asked. Of these 48 questions, 15 concerned the shape of the earth, its location in space and gravity:

1 What is the shape of the earth?
2 What way do we look to see the earth?
3 What is above the earth?
4 What is below the earth?
5 What is to the sides of the earth?
6 Can you draw a picture of the earth?
7 Now on this drawing show me where the moon and the stars go. Now draw the sky.
8 Show me where the people live.
9 Here is a picture of a house. This house is on the earth, isn't it? How come here the earth is flat but before you made it round?
10 If you walked for many days in a straight line, where would you end up?
11 Is there an end or an edge of the earth?
12 Can you fall off that end or edge?
13 Where would you fall?
14 Now I want you to show me where Champaign is. Where is China?
15 Now tell me what is down here below the earth.
[Vosniadou & Brewer, 1992, p. 543ff]

Vosniadou and her colleagues have been using basically two different kinds of questions to map children's knowledge and concepts. They refer to these as factual questions and generative questions, respectively. Factual questions can be answered simply by recalling information. Generative questions, on the other hand, confront children with phenomena with which they are unfamiliar. These questions, according to Vosniadou [1994, p. 50] 'have a greater potential than factual questions to unravel the mental model students use during creative problem solving, and [they] provide information about the underlying theoretical structures that constrain them'.

The latter part of this sentence referring to 'underlying theoretical structures' testifies to the cognitivist framework within which the work is carried out. In the analysis, the concept of mental model is used as an indicator of the 'dynamic structure which is created on the spot for the purpose of answering questions, solving problems or dealing with other situations' [Vosniadou & Brewer, 1992, p. 543]. The mental model, in this perspective, thus appears as a situated variant of underlying conceptual structures, and understanding their nature is seen as a very important ingredient in understanding the 'underlying knowledge base' that people have access to. '[M]ental models are generated and constrained by people's underlying conceptual structures', and, thus, 'we think that understanding the mental models individuals use to answer questions or solve problems provides information about the content and structure of their underlying knowledge base' [p. 543].

At the theoretical level, Vosniadou further argues that conceptual structures are embedded in wider theoretical structures. A distinction is made between framework theory and specific theories. A framework theory is built up at an early age and it consists of commonly held beliefs and assumptions about the world. Vosniadou claims to have found two important assumptions of a framework theory that children seem to have: (a) space is organized in terms of the directions up and down, and these relate to a flat ground and (b) unsupported objects fall in a downward direction. This latter assumption makes children claim that objects on the 'bottom' side of the earth fall 'down'.

Specific theories, on the other hand, depict the internal structure and content of a conceptual domain. As examples, assumptions such as the 'ground extends along the same plane over a great distance', the 'sky is located above the ground', and 'there is

Table 1. Results of Vosniadou & Brewer's [1992, p. 572] study of children's mental models of the earth

No.	Earth shape models	Grade 1	Grade 3	Grade 5	Total
1	Sphere	3	8	12	23
2	Flattened sphere	1	3	0	4
3	Hollow sphere	2	4	6	12
4	Dual earth	6	2	0	8
5	Disc earth	0	1	0	1
6	Rectangular earth	1	0	0	1
7	Mixed	7	2	2	11
Total		20	20	20	60

ground and/or water below the earth' [Vosniadou, 1994, p. 55] are given. According to this perspective, children use framework as well as specific theories when they create mental models of the earth. Three different kinds of mental models have been found. These are referred to as: initial, synthetic, and scientific, respectively. Initial models, derived from everyday experiences, imply that the earth is flat and rectangular or like a disc. Synthetic models imply that the interviewee holds that there are two earths – for example, one that is flat where we live and one spherical up in the sky – or in some other way combines models.

Conceptual change in this perspective proceeds through modifications of one's mental models. From the results of the particular study that we have been using as a target here [Vosniadou & Brewer, 1992], it can be seen that 49 of a total of 60 children used one or the other mental model consistently. Twenty-three children used the accepted, scientific model. It is argued that not until the end of elementary school will children have adopted the scientific model. The following table summarizes the results presented by Vosniadou and Brewer (table 1).

Two points are emphasized by Vosniadou in relation to this outcome. First, 'there is a developmental progression of models held by these children' [Vosniadou & Brewer, 1992, p. 572]. First-graders hold a dual or mixed model, third-graders are distributed across the range of possible models, and fifth-graders cluster on the spherical or hollow sphere model. Second, it is argued that these findings 'agree with the results of previous research', which show that children have difficulties understanding that the earth is spherical, and that they 'form various misconceptions regarding its shape' [p. 575].

As we have already indicated, the purpose of our study is to study this problem from a discursive perspective, analyzing communication as a practice. In such a perspective it is obvious that what is being analyzed in the work commented on are communicative encounters in which two partners, varying in their background knowledge, status, and, possibly, interest in what is being addressed, exchange questions and answers in a very particular, and in many respects atypical, communicative situation. We have no reason to doubt the empirical results produced by Vosniadou and her colleagues, but we will argue that the outcome cannot be accounted for unless one carefully attends to the communicative conditions under which the answers by children have

been produced. To return to the problem mentioned at the beginning of the article about the problems of correspondence of theoretical concepts and empirical observation, our claim will be that the theoretical perspective employed in these studies gives undue preference to unobservable entities of a rather dubious ontological status, and a corresponding disregard of the situated nature of children's reasoning.

Cognition and Discourse – Mental Models or Discursive Resources

Several implications follow from adopting a discursive perspective on cognition [Edwards, 1997; Harré & Gillett, 1994; Säljö, 1996]. An obvious feature is a focus on talk as concrete social action. Talk will be treated as a significant element of situated practices, and it fulfils different aims: expressing opinions, attitudes, understandings, managing social situations, creating and maintaining social relationships, fulfilling communicative obligations (such as answering a question when being asked) and so on. We shall not favor the assumption that what is said in an interview situation is a reflection of conceptual content in the mind of the individual, although we by no means deny that it is reasonable to make assumptions that there are beliefs that lead people to perceive objects and events in consistent manners.

An essential feature of a discursive and sociocultural [Rogoff, 1990; Wertsch, 1998] approach to cognition and communication is the focus on the constitutive nature of language. Thus, any kind of human interaction presupposes that objects and events are constituted in a particular manner of relevance for the purposes at hand. In the concrete instance of studying children's conceptions of elementary astronomical concepts, this feature of language use is obvious. The earth, the moon, and other phenomena can be constituted in very different manners. The poet can focus on the beauty and mystical qualities of heavenly bodies, the science fiction writer will oscillate between fact and fiction when writing a story about invaders from space, the laymen observing a comet will use still another mode of constituting such phenomena, and so on. Thus, there are many discourses in which astronomical phenomena can be accounted for in a meaningful manner. A significant problem in this context is what resources so-called novices are given to ascertain what is the relevant contextualization in a particular setting.

We will also assume that the positioning of a person in relationship to what she/he is talking about is an essential feature of what is being said. The interview situation, as exemplified in the work by Vosniadou and her colleagues, has some interesting features that make it a rather special communicative encounter. It is highly asymmetrical [Linell, 1998] in the sense that the interviewer is the dominant communicative partner, who controls the floor and who makes other powerful communicative moves, including asking the questions that direct the interaction. We must also recognize, as has been forcefully argued by Siegal [1991] that 'since children know less about adults' use of the rules of conversation and less about language generally, they may be more easily misled and their capacity for understanding left unrecognised. They are less likely to share an adult's intentions and goals for communication and the 'implicatures' in adult conversation' [p. 132]. The interview might also be an abstract exercise for the child in the sense that institutional forms of talk are foregrounded through a set of questions asked at a high pace. Handling questions such as 'what is the shape of the earth?', 'what way do we look to see the earth?' and so on at a pace of more than one a minute can most likely be a very taxing exercise for a child. And if one's understanding of these phenomena is –

as the research shows – somewhat vague, it must be assumed that there might be considerable problems in keeping up with such a flow of questions.

The Study: Adding a Globe to the Interview

The most concrete difference between our study and the one reported by Vosniadou and Brewer [1992] is the positioning of the child in a communicative sense. To counteract the need of the interviewees to orientate themselves in an abstract, verbal framework only, the discussion in our case was carried out using a globe as a point of departure. The globe was placed in front of the child and the interviewer, and the initial question was if the child knew what the object was. The participant thus at the beginning of the encounter had to identify this particular artifact and name it. The interview that followed was of a semistructured character. A number of questions were formulated in advance (cf. Appendix), and the interviewer introduced follow-up questions in order to clarify what the interviewee had said in the conventional manner characteristics of what Piaget [1926/1973] referred to as the 'méthode clinique'.

The 25 participants were recruited from grades 1 (aged 6–7), 2 (aged 7–8), and 5 (aged 10–11) in a Swedish comprehensive school. Eight of the participants came from grade 1, 8 from grade 2 and 9 from grade 5. All interviews took place in the schools attended by these children. They lasted between 20 and 45 minutes with a median of 30 minutes.

The results of this study are – to put it mildly – dramatically different from those reported by Vosniadou and her colleagues. All children recognize the artifact in front of them. The prototypical answer to the initial question of what the object is, is that it is a globe. In Swedish the object is called 'jordglob', which literally translates into 'earth globe'. Thus, the connection between the earth and the globe is represented in the expression the children spontaneously use. The following except, taken from the interview with Madeleine, grade 2, illustrates how the children responded to the initial question and how they relate to the globe.

Excerpt 1, Madeleine, grade 2

I (interviewer)	What's this?
Madeleine	It's a globe
I	What is a globe?
Madeleine	It's where you can see all countries, India, Japan and so on
I	Does it really exist?
Madeleine	Yes, it's the whole... Sweden and all the countries
I	So it is
Madeleine	America and USA, that's where my penpal lives (...)
I	What are the green and brown areas on the globe supposed to be?
Madeleine	The green areas are forests and the brown areas are mountains
I	The blue ones?
Madeleine	They are lakes

The general idea of the globe as a representation of the earth appears obvious to the children, and they have no problems in engaging in a discussion of what one can see by looking at it, what the different colours imply and so on.

The spherical appearance of the earth also seems evident to the children (cf. below). There were only two children in this group of 25 who showed some initial uncertainty as

to whether the earth was spherical. Erik, grade 1, is one of them. Notice, however, that his uncertainty seems to concern whether he really *knows* that the earth is spherical.

Excerpt 2, Erik, grade 1

I	Does the earth look like this [the globe]?
Erik	Yees ...maybe it does...
I	You are not sure?
Erik	I have never seen the earth, really I haven't. I have only seen very small pictures. I have an atlas, but I can't see it so close in this manner
I	No, there are not that many who have seen the earth in this way. Where do you think you should be if you wanted to see it in this way?
Erik	Yes ... maybe ... on the moon
I	Yes, I think so, too, to see the earth in this way. Do you think that the earth looks like this?
Erik	You mean round? Yes, I think so.

Thus, Erik's problem seems to be whether he can prove in some manner that the earth is spherical (or in his terminology, round). None of the interviewees introduces any other model of the earth, nor do they seem to have any problems in talking on the basis of the idea that the earth is – in their terminology – round.

How do the children deal with the problems observed in Vosniadou's studies of people being able to live in the southern hemisphere? Vosniadou explicitly claims that as a result of their crude mental models, and the misconceptions they entertain, children 'cannot understand how it is possible for the people and objects on the Earth to stand on the outside of this sphere without falling "down"'. Thus, 'in order to solve this problem, they create a model according to which the spherical Earth is hollow and people live on the flat ground inside it' [Vosniadou, 1994, p. 56].

The idea of a hollow spherical earth does not appear in our material at all. No child even hints at this possibility. How do the children then cope with this problem of why people in the southern hemisphere do not 'fall down'? Again, our results are dramatically different than those reported by previous research. Let us look at some of the explanations produced starting with Cecilia in grade 2.

Excerpt 3, Cecilia, grade 2

I	Can people live all over the world?
Cecilia	Not in the sea
I	Somewhere else where it is difficult to live?
Cecilia	Where there is war going on
I	Do people live in Argentina? (pointing at Argentina on the globe)
Cecilia	Yes
I	In Australia? (pointing at Australia on the globe)
Cecilia	Yes they do
I	Isn't it peculiar that you can live on this side of the earth?
Cecilia	No, 'cos there is no up and down on the earth

As all the children in our material realized that people can live almost everywhere on the earth, the general impression we get from our findings gives a very different background to children's replies. It seems as if they have never thought about this problem but rather take it for granted that one can live in both hemispheres. But, when asked explicitly, they are able to produce explanations that are relevant, as in the case of Cecilia saying that people cannot 'live in the sea' or where 'there is a war going on'. In fact, the

excerpt illustrates that the interviewer has to be quite pushy before he can make Cecilia understand what the question is all about, namely, whether people can live in the southern hemisphere without falling off. When moved on to interpreting the question in this manner – which thus takes some discursive work on the part of the interviewer – Cecilia simply claims that there is 'no up and down on the earth'. In a sociohistorical perspective, this is quite a remarkable comment from a child of 8 years.

In the interviews, an explicit focus was placed on Australia and Argentina which would appear to be 'down under' when looking at the globe. Our intention was thus provocative in the sense that this could lead children into arguing that people would be likely to fall off. However, even at these points during the interviews, participants would not resort to this kind of reasoning but rather maintained an account which supports the idea that one can live everywhere. Johan, grade 2, exemplifies one way of doing this.

Excerpt 4, Johan, grade 2

I	Do people live in Australia? (pointing)
Johan	Yes
I	Mm. Isn't that strange?
Johan	Yes
I	Why is it strange
Johan	They talk in a strange way
I	Anything else, if they live down there? Is it possible to live here?
Johan	No, yes
I	But isn't strange that they don't fall off?
Johan	No
I	Look at Argentina, it's even worse there. Why don't they fall off?
Johan	It is that gravity

This excerpt is interesting. Johan obviously knows that people live in Australia, and when being asked, 'Isn't that strange?' by the interviewer, he agrees. However, his agreement is in no way connected with the fact that Australia is 'down under'. Instead, he claims that 'they talk in a strange way'. In our opinion, and from an interactional perspective, this illustrates how people contribute to dialogues by agreeing with the premise provided by the interlocutor ('Isn't that strange?') by trying to find something in what is being talked about that would qualify as 'strange'. However, Johan in no way relates the strangeness to the fact that Australia is located on bottom of the globe in front of him. The whole idea of people falling down appears to be a nonissue for him, and, like Cecilia, he has problems in realizing that this is what the question is aiming at. When coming under further pressure with a new example (Argentina), he argues that the explanation for this phenomenon is gravity. However, it should be noted that it takes considerable time and many interactive turns for Johan to understand the interviewer's point and come up with this reply, and we might therefore assume that there is no guarantee that this is the answer he would spontaneously have produced in an interview situation in which questions were being posed at a high pace.

A similar impression is given in the following two excerpts. Kristofer has no problems in accepting that people live in Australia, nor does he seem to understand what is strange about that. So, when being questioned, he assumes that the interviewer is suggesting that it is very cold (possibly since Australia appears to be not too far away from the Antarctic region on the globe).

Excerpt 5, Kristofer, grade 5

I	Do people live in Australia?
Kristofer	Yes
I	Isn't it strange that people can live down there?
Kristofer	No, it isn't so cold cause they live rather close to the equator
I	But don't they fall off?
Kristofer	No, what's it called ... it is pull-axis
I	What does it do?
Kristofer	It makes everything stay on the earth

Kristofer is interesting also in the sense that he does not remember the term he is looking for ('what's it called?'). So he invents a new, and rather funny, term (which is difficult to translate): pull-axis (in Swedish: 'dragaxel'). This implies that he does not consider the possibility of falling down from the earth a realistic one, in spite of the fact that he does not remember the name of the concept that would account for this.

Erica, grade 2, is a further case in point. She sees nothing problematic about the fact that people live in Australia, nor does she see anything realistic in the idea that people would fall off the earth. But in order to comply with her obligation as a contributor to an ongoing conversation, she tries to find something that is strange in the situation when the interviewer insists.

Excepted 6, Erica, grade 2

I	Isn't it strange that people can live down there?
Erica	Yes
I	Why do you think it is strange?
Erica	Well, 'cos there has been a lot of fires there

Even when the interviewer somewhat later again pushes her towards considering the idea that people in the southern hemisphere would fall down, Erica seems to have difficulties in understanding this as a serious claim.

Kristina in Excerpt 7 is an illustration of an interviewee who knows the concrete details but who cannot come up with an explanation. She is also obviously puzzled by the problem and perceives the dilemma but in spite of this she does not accept the idea that they might fall down.

Excerpt 7, Kristina, grade 5

Kristina	How do they [the Australians] walk? They must walk like this (feet on the earth, head pointing from the globe, illustrating by using her fingers)
I	With their heads down. But think if they fall off
Kristina	No they don't
I	Why not?
Kristina	It's as flat thee as it is here
I	It is as flat as we have it
Kristina	Sweden, it is flat and so it must be
I	Does it look like this on the earth? They must fall like this. Don't they fall off then?
Kristina	No

To sum up, with the globe as a concrete point of reference for the interaction, we find that all children can identify the globe and they know that it is a representation of the earth. They find it completely natural that people can live in the southern hemisphere without falling off. In fact, they have some problems in understanding this very question. In the explanations, 17 of the 25 children (77%) use the term gravity (or some

Table 2. Children's conceptions of the earth, with access to a globe

Outcome	Grade 1 (age 7)		Grade 2 (age 8)		Grade 5 (age 11)		Total %
	n	%	n	%	n	%	
Is able to identify countries on the globe	8	100	8	100	9	100	100
Considers the earth as a sphere	7	84	8	100	8	89	92
Considers that once can live all across the earth without falling off	8	100	8	100	9	100	100
Uses some kind of concept that refers to gravity as explanatory resource	3	38	6	75	8	89	77

modified version of it such as the one created by Kristofer). But even in the instances where they are not familiar with the terminology, they show no inclination to say that people living in the southern hemisphere will fall off the earth. Table 2 gives a summary of these results.

There is a clear ceiling effect already at the age of seven, with the notable exception of using gravity as an explanatory concept. Here we find an increase from 38 to 89% from grade 1 to grade 5. This is more of an observation, since the limited nature of our study does not permit making any claims about developmental patterns.

Reasoning from a Discursive, Situated Point of View, as a Tool-Dependent Activity

There are, of course, many reasons why the results between the two studies deviate. The presence of the globe, the concrete circumstances of the interviews, the nature of the questions and other aspects of the concrete situation. A simple explanation would be that Swedish children are much more well-informed than those of other countries where these studies have been carried out. However, there is no reason to assume that this is the case (though we cannot disprove this idea). In order to understand the good performance in our study, and the much poorer one in the work of Vosniadou and her colleagues, it is, in our opinion, necessary to consider reasoning from a discursive and situated point of view and as a tool-dependent activity.

Our main claim, thus, is that the variation in outcomes between the studies illustrates that the object of analysis must be construed in terms of a situated practice with people interacting using particular linguistic and physical resources [Lemke, 1990; Wertsch, 1998]. Thus, to understand what happens, we can disregard neither the context and its affordances/constraints, nor the individuals and the cognitive resources they bring to the situation. But, even more importantly we would hold that these elements have to be described within a discursive understanding of cognition and communication. Consequently, we would challenge the feasibility of using a model of explanation that infers 'mental models [that] are generated and constrained by people's underlying conceptual structures' [Vosniadou & Brewer, 1992, p. 543]. Thinking and communication should be accounted for in commensurable terms. We think that the poor results in those studies, as well as the much better ones in ours, seem reasonable when using a

discursive approach to cognition and when situating what people say in the concrete encounters in which it was produced.

In both studies, the tangible subject of research is utterances made by people in a concrete setting and for particular purposes. Even though this is not explicitly recognized in the studies by Vosniadou and her colleagues, where the interview is regarded as a method and not as a concrete social practice, the fundamentally interactive and discursive nature of the data collected is evident. Any inferences regarding cognitive processes, thus, must be grounded in an analysis which gives considerable attention to the manner in which utterances are produced in context and what resources that are available to the interlocutors.

Following this line of thinking, our claim is that the main difference in the two studies is that in our case, the utterances are grounded with the presence of the globe as a shared object of attention. When students talk and produce their utterances, they have a resource to which they can relate. This physical tool allows them to reflect while talking by serving as a prosthetic device for thinking. The tool also in a very concrete manner invokes knowledge. For instance, all the participants in our study know that people live in Australia and South America. They know this through personal experiences of different kinds and very obviously through the mass media as can be seen in Erica's awareness of the problem of bushfires in Australia. The concrete nature of this knowledge implies that they have no inclination to say that people would fall off the earth if living in the southern hemisphere. Thus, their positioning in relation to this particular question is one of knowing what is the case, but maybe lacking the tool for explaining why this is so (even though a clear majority in fact produced an answer which implies, or is close to ,the notion of gravity).

The work reported by Vosniadou and her colleagues is also, we would claim, a study of how people talk rather than directly of their cognitive processing. In fact, due to the lack of a concrete object to refer to while talking, these kinds of studies are even more of a talking event than is ours, and, in addition, they must be rather abstract for the participants. But, again, what is studied is how children use words according to certain rules. The apparently simple introductory question, 'what is the shape of the earth?', is in all likelihood quite abstract to someone who may have had no reason to see this as an interesting problem. The very question itself has as a premise that people think in terms of shapes of celestial objects and that they can reproduce their reflections on the spot. But in the absence of something concrete in which to ground the discussion, answering questions like this is indeed an abstract activity. Behind every question, there is a perspective from which that question is being raised. Our guess is that the interviewees might have some problems in discerning what this position is, and, as a consequence, they probably feel somewhat uncertain at times.

So, instead of considering the answers as indicators of mental models or underlying constructs, our suggestion is to look at the manner in which they were produced. Our claim is that many of the answers produced by children in Vosniadou's study can be understood as children fulfilling their communicative obligations by answering something when being asked. The replies are thus occasioned as much by the concrete situation as by their thinking. Furthermore, when looking somewhat more in detail at the interview data presented, it would seem as if the line of 15 questions (cf. above) already implies a certain model of thinking and in a sense suggests a way of reasoning. For instance, consider the first four questions as they appear in the following extract taken from Vosniadou and Brewer [1992, p. 557].

E: What is the shape of the earth?
C: It's the shape of a ball
E: Which way do we look to see the earth?
C: Down
E: What is above the earth?
C: Space
E: What is below the earth?
C: Space

As can be seen, most of the talking in this sequence is done by the interviewer (E). And the questions seem to suggest the very model that is being ascribed to the child. In her assumption regarding the existence of a so-called framework theory that children allegedly have, Vosniadou claims that children think that space is organized in terms of directions up and down compared to flat ground. If sequences such as this are read as indicators of children holding this view (which none of our children did), there is cause for some concern. It is very obvious from this piece of interaction that the interviewer in fact might be interpreted as suggesting this model by asking 'what is above the earth?' and 'what is below the earth?'. It is very likely that the person responding assumes that this is a valid perspective from which to put a question (when it is, in fact, very problematic). Furthermore, the second question is quite ambiguous. In one sense we look down to see the earth (when looking in everyday life), in another sense we do not (when taking the position of an astronomer looking at the earth as a celestial body in the universe). Which is the relevant contextualization in this particular setting? This might be very difficult for a child to realize when bombarded with abstract questions.

The main point of our work has been to illustrate that there is no neutral ground on which children's understandings of concepts can be studied. The interview is certainly no privileged context in which the mind can be tapped of its conceptual content in a straightforward manner. Rather, it is a concrete social encounter, and it occasions talk which makes people appear competent or incompetent. In one line of study, children appear to have great problems realizing certain fundamentals about the shape of the earth and gravity, while in the setting that we arranged, involving the use of an additional cultural artifact (besides language), they appear to be surprisingly competent and sophisticated.

So, what is the bottom line? We would argue that there is no such thing as a neutral point from which children's conceptions of phenomena such as these can be studied. The unfortunate point is that psychology and cognitive science, at least until recently, seem to prefer to study people when their thinking is up for inspection rather than when it is used in situated practices. Thus, the interview is arranged in such a manner that what is allegedly studied is the thinking of the individual in some kind of pure fashion. But, the idea of studying thinking outside situated practices is very problematic, even though it has been the dominant approach in the behavioral sciences. The interview is simply another social practice, and a highly problematic one as well, we might add.

In order to understand why studies of conceptual development and conceptual change investigate thinking without the support of culturally meaningful artifacts that are present in society and that children encounter, one has to go back a long way in the history of the human sciences when the psyche was separated from the body and from social action in concrete settings. Cartesian dualism paved the way for an abstract conception of cognition, in which thinking became an autonomous domain of inquiry, accessible as such and outside social practices. But our study illustrates, we claim, the

continuity between cognition, discourse, and cultural artifacts [Gauvain, 2000; Säljö, 1996]. The globe is a cultural artifact and an external representation that embodies and represents a particular conception of the earth. Children as young as the age of 7 in the particular social context in which we made our observations seem to have no problem identifying this object and carrying out a surprisingly informed discussion of what it represents. In addition, they seem quite competent at recreating many of the conceptual distinctions that are relevant when discussing issues about its shape, behavior, where people can live, etc. So, the interesting question becomes one of trying to understand why we study children without giving them access to one of the cultural tools by means of which they have obviously learned to reason in such sophisticated manners.

When considering the outcomes of our study in terms of what they tell us about children's cognitive and communicative capacities, the main conclusion seems to be that when children's reasoning is supported by a cultural artifact such as the globe, they appear to be familiar with highly sophisticated modes of reasoning. What is appropriated is simultaneously a mode of reasoning and a mode of thinking. In a very practical manner, the globe seems to be doing concrete discursive work and it serves as a point of departure for the discussion that keeps the children within a certain discursive framework. Once there, they appear surprisingly competent and informed. If we compare our results to those previously obtained, we would argue that children seem to have been exposed to, and they seem to partially master, some of the features of the sophisticated, and historically quite recent, conceptual constructions of scientific reasoning that construe the earth as a planet in space with a particular set of characteristics that conflict with everyday experiences. We consider this a rather strong argument for a sociocultural interpretation of mind.

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Appendix

Interview Questions

(1) What is this [the globe]?
(2) Does the earth look like this?
(3) Do you know where Sweden is on the globe?
(4) Have you been to some other countries? Can you find them on the globe?
(5) Do you think you can find more countries or places?
(6) What are the green/blue/brown areas on the globe?
(7) Can people live all over the world?
(8) Do people live in Argentina?
(9) Do people live in Australia?
(10) Isn't it strange that people can live in Australia?
(11) Don't they fall off?

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