A Structural View on the Emergence of a Conception: Conceptual Change as Radical Reconstruction of Contexts

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ABSTRACT: Conceptual change is often described as a causal process in which changes in an embraced system of beliefs result in a new system of beliefs. Here, it is argued that conceptual change is better understood as an intentional activity with regard to the learner, that is, what the learner is doing when trying to understand something. Children were interviewed every year during a period of 3 years from their ages of 4–6 years of age. In the study, there were 37 children participating, of which 29 were followed during all 3 years. They were asked to tell about their beliefs about the earth, and their developing understanding is described. The results show that in the conceptual changes the children's main concern was to restructure the often vast amount of knowledge they possessed. This reconstruction is described as a simultaneous reconstruction of conceptual contexts as well as contexts for their application. This also directs the focus of conceptual change from specific conceptions to structural changes. © 2009 Wiley Periodicals, Inc. *Sci Ed* 1–25, 2009

INTRODUCTION

Conceptual change is often described as some sort of causal process in which changes in, or manipulations of, an embraced system of beliefs result in a new system of beliefs. Here,

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we will argue that the process of conceptual change is better understood as an intentional activity on the part of the learner. This means that the learner is trying to understand something (Marton & Säljö, 1976a, 1976b), and by understanding what the learner is trying to do, we can get at a better grasp of the process of, and what constitutes, conceptual change.

Since the late 1970s, research on learning has had a growing focus on questions about conceptual change (White & Gunstone, 2008). By conceptual change is meant the substantial revision of beliefs that sometimes is required from a learner to understand a scientific explanation, concept, or theory—for example, changing from a commonsense understanding of movement and force into an understanding within the realm of Newtonian dynamics. Carey (1985) characterized conceptual change, or *strong restructuring,* as changes in the understanding of the domain of phenomena to be accounted for by a theory, changes of explanatory pattern, and changes in individual concepts (p. 187).

One common model for describing conceptual change is as a replacement of one conception, A, with another conception, B (e.g., Posner, Strike, Hewson, & Gertzog, 1982). In this linear model of conceptual change, conception B is defined as a conception accepted in our culture or in science. Conception A is viewed as a more primitive conception that, during the process of change, will be replaced by the more potent conception B. Obstacles that might prevent this process from occurring have been described in different ways in the research. For example, Chi (2008) distinguished between three different types of conceptual change. The most difficult change is when the change requires a categorical shift in beliefs. A categorical shift is described as a change between ontological categories (Chi, Slotta, & de Leeuw, 1994). The learner makes categorical mistakes between different ontological trees or between different lateral branches. For example, the learner can misconceive the concept of heat as a kind of entity, whereas scientists view heat as a process, an ontological category distinct from entities.

Conceptions have been described as embedded within larger frameworks (Vosniadou, 1994). For example, initial conceptions coming from experiences in the physical world have been described as a naïve framework theory of physics that constrains the process of conceptual change. A naïve framework consists of certain ontological and epistemological presuppositions and specific theories. Conceptions are embedded within these specific theories. "The process of conceptual change appears to be slow and to proceed through the gradual suspension and revision of the presuppositions of the framework theory and their replacement with a different explanatory framework" (p. 56).

So far we have talked about beliefs as hindrances for conceptual change to occur; there are characteristics in the embraced conceptual framework that hinder a change to the target conception, that is, the concept addressed in instruction. Quite another way of looking at the difficulties inherent in understanding a topic in a radical new way is to identify what is lacking, as opposed to what obstructs. Recently, it has been proposed that there are specific concepts that "open up" a space for new understanding—the so-called *threshold concepts*. Thus, there are concepts that have the effect of organizing knowledge and permitting interpretations in the new way intended in instruction, once they are understood by the learner (Meyer, Land, & Davies, 2008). Such concepts are related to different disciplinary knowledge areas, as for example, *opportunity cost* in economics or *limit* in mathematics. Here, there are not beliefs in the embraced conceptual framework that constitute the obstacles, but rather, a missing piece.

However, a similarity in the different approaches is the focus on specific concepts, on their ontological status, presuppositions that make the new concept untenable, or a missing piece in the desired new conceptual structure, respectively. Also, these approaches conform to a linear process of conceptual change in that by changing one or a few beliefs embraced

by the learner, a process of conceptual change is supposed to be brought about. Furthermore, a common trait is that conceptions are looked upon as embedded in more all-embracing conceptual structures. However, it is not this embeddedness that is dealt with as a question as such, but rather specific conceptions within this web of conceptions. Here, we will argue that there are no specific conceptions that are of primary importance for a conceptual change to occur, but rather that attention should be given to the contexts in which conceptions are embedded.

On the Concept of Context

In their introduction to *Rethinking Context*, Goodwin and Duranti (1992) established that, at that time, the term *context* meant quite different things and was defined by use rather than by formal definition. This probably has not changed much. However, they also recognized that this is "not a situation that necessarily requires a remedy" (p. 2). Nevertheless, without giving a formal definition of context, they discuss the meaning of the concept. In discussing the use of language, they say that context involves "a fundamental juxtaposition of two entities: (1) a focal event; and (2) a field of action within which that event is embedded" (p. 3). They then discuss different dimensions of context. They introduce setting, behavioral environment, and language as different contexts, as well as the extrasituational context. Their focus was on language as an interactive phenomenon. Here, we will only be dealing with language when it comes to the method for the investigation presented, that is, interviewing, and the interpretation of interview data. The focus of the study, however, is on conceptual development and thus we also have to talk about context with regard to this. This means that we also have to delineate dimensions other than those pointed out by Goodwin and Duranti.

In an interview, one dimension is the actual situation as context. This involves the four dimensions identified by Goodwin and Duranti, but also other dimensions related to language and culture. This dimension relates to the interview as an event "inextricably and unavoidably historically, politically, and contextually bound" (Fontana & Frey, 2005, p. 695), and is best described as a "negotiated text" (p. 716), that is, "active interactions between two (or more) people leading to negotiated, contextually based results" (p. 698). However, if an interview is looked upon as a negotiation, the negotiators bring something into the negotiation. With regard to an interviewee, we also claim that that person brings in utterances stemming from a conceptual understanding of what is being talked about. Thus, there is the idiosyncratic or semantic meaning of what that person utters. It is then a question of method of analysis making it possible to elicit the nature of these meanings or this understanding.

Thus, there are also other dimensions of contexts related to what is talked about in an interview. If natural phenomena are talked about in an interview, as in the study presented here, there is the context of the scientific framing of these phenomena. Thus, there is the scientific or culturally established meaning of a phenomenon. Concepts in science gain their meaning from the theoretical context of which they form a part and out of which they simultaneously classify what counts as empirical data in our experiences of the outside world (Wistedt, 1994a, 1994b). The structure of such a context has been pointed out by Tiberghien (1994), who discussed the level of theory, model, and experimental field of reference, respectively. Caravita and Halldén (1994) differentiated between a theoretical context, theoretical concepts, and an empirical context. In understanding a scientific concept, there is a question of coherence between these different levels. Also, they argued that there is a similar three-level organization in commonsense knowledge just as there is in scientific knowledge, that is, a level of worldview and ideology, a level of conceptions and norms

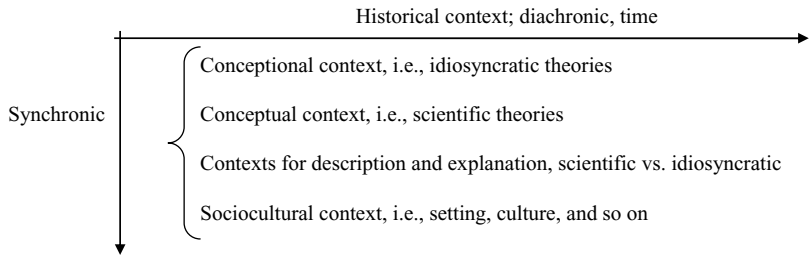


Figure 1. Dimensions of context.

for action, and, finally, a level of practical context constituted by perceptions, experiences, and acting. At the core in conceptual change, then, is to relate the context of commonsense conceptions to the concepts in scientific theories. This actualizes a fourth dimension of context of relevance for our study: the question of applicability.

Questions asked in common sense are often different from questions asked in science (Halldén, 1993; Österlind, 2005). When scientists look for causal explanations as, for example, in regard to the Darwinian theory of evolution, the layperson is often confined within teleological explanations (cf. Halldén, 1988); when the historian looks for structural explanations, the layperson is confined within explanations referring to individuals (Halldén, 1998); when the statistician is most interested in the stochastic results, the layperson is interested in heuristics (Halldén, 1999; Scheja, 2006), etc. Thus, we also have the context of the applicability of a specific conceptualization (cf. Halldén, Scheja, & Haglund, 2008; Taber, 2000). This is also implied in Carey's description above, as well as in the models by Tiberghien (1994) and Caravita and Halldén (1994). Commonsense frameworks are developed by the individual's project to manage her or his practical world in a pragmatic or ethical way (Driver & Easley, 1978). Contrary to this, scientific frameworks are developed, first and foremost, with the purpose of understanding and explaining the world, and then, if productive, of making it possible to manipulate the world in desirable ways based upon sound knowledge. Also, these two different kinds of descriptive and explanatory fields have to be related to each other to make way for conceptual change; thus, there are also contexts of descriptions and explanation.

To this can be added a historical context—all of the dimensions of context that have been discussed here are also in flux. This means that they all have a history, that is, they have a diachronic dimension in that they have a past, a present, and a future (Mercer, 2008). The different dimensions of context relevant to this study are summarized in Figure 1.

The distinction between a conceptual context and a conceptional one in Figure 1 is intended primarily to follow the distinction between scientific frameworks and alternative frameworks, in the manner pointed out by Driver and Easley (1978). Since then, this has been the traditional way of talking about conceptual change, as a transition from commonsense knowledge to scientific knowledge of a concept within the "alternative framework movement" (Gilbert & Watts, 1983; cf. Vosniadou, Vamvakoussi, & Skopeliti, 2008). This introduces the question of the possibility and fruitfulness of making a distinction between concept and conception.

The Concept of Conception

In this study, we will dwell on the emergence of the conception of earth. In relation to this, a word is needed about the concept of concept. For example, diSessa and Sherin (1998)

argued that the concept of concept is too vague to work as a scientific formulation in explaining conceptual change; it does not identify which mental entities are included and which are excluded. Following Entwistle (2007), we want to make a distinction between concept, which "is most frequently used to describe a grouping of objects or behaviours with the same defining features that has become recognised through research or widespread usage" (p. 2), and conception, which "indicates individuals' different ways of thinking about a particular grouping" (p. 2; cf. White & Gunstone, 2008). Gilbert and Watts (1983) proposed a similar conceptualization by suggesting "that 'conception' be used to focus on the personalized theorizing and hypothesizing of individuals" (p. 69). This is not to make a distinction between different research paradigms, such as the sociocultural and constructivist paradigms for research. Rather, it is a distinction within a constructivist approach, making it possible to talk about "all the knowledge that a person has, and associates with, the concept's name" (White, 1994, p. 118) on the one hand, and the culturally accepted meaning of this concept on the other.

What we are studying in conceptual research, then, is conceptions and the change of conceptions. This means that when we are studying the learning of a scientific concept, we are still studying conceptions. Usually, we are studying the learner's conception of the same entity, or similar entities, as the scientific concept denotes. We will not go on further to discuss the problems with "the same" or "similar" entities. This would take us too far into philosophy. The claim we want to make, however, is that, in accepting this distinction, we always make comparisons between conceptions and concepts when evaluating a learner's knowledge. Thus, we decide on what in a conception is adequate and relevant in accounting for an understanding of what is understood by the concept.

A reasonable question, then, is how to find the concept. If, by asking people, we always find conceptions and, as a matter of course, the researcher also has a conception of the concept, where can the concept be found that should be the norm for the evaluation? Again, we have to constrain the discussion here in order not to get caught up in philosophy. We restrict ourselves to the claim that the meaning of a concept is what is to be found in scientific textbooks, in scientific debates, or in a thesaurus of a language, thus, in authoritative texts regarding the concept in question. However, by making the distinction between conception and concept, we depart from the often-implicit idea that the learner either understands or does not understand a concept. The understanding of a concept is always an individual understanding, that is, a conception, and the quality of this understanding is decided upon by the extent to which the individual can communicate with experts in the field. Saying this implies that it appears inappropriate to talk about the understanding of a concept; an appropriate use of language should be "to understand the same that is understood by a concept." However, for the sake of simplicity, we will in the following still use the expression of understanding a concept.

This does not meet the critique raised by diSessa and Sherin (1998). We have almost exchanged the concept they are criticizing with another word, and thus gained little or no more precision. However, making the distinction above relieves the burden of the definition of conception; what counts as a conception is decided upon in the analysis and based on what seems to be of relevance for the learner or for an interviewee. The conception so described, then, can be compared to what is adequate and of relevance for the scientific concept or the culturally accepted view. In this way, we have tried to capture which meanings children give to the word *earth*, from the age of 4 through 6. The word *earth* has meaning for such young children, and it is reasonable to assume that it is out of these meanings that a conception is formed.

Children's Understanding of the Shape of the Earth

There is now a rather long tradition of studies on children's conceptions of cosmologies, and especially of the shape of the earth. A series of studies have shown that children have difficulties in understanding that the earth is a huge sphere, surrounded by space (see, e.g., Mali & Hove, 1979; Nussbaum, 1979; Nussbaum & Novak, 1976; Vosniadou & Brewer, 1992; for a review, see Brewer, 2008). These studies describe the development from naïve conceptions of the earth into the conception accepted in culture, thus conforming to the scheme A → B.

Sometimes, intermediate conceptions are described that are formed during the transition from A to B. For example, Nussbaum and Novak (1976) discovered five alternative notions, of which the first notion indicated the earth as being flat and the fifth notion was the culturally accepted view of a spherical earth. One conception of the first notion was described as a flat earth on which we live and a spherical earth representing some other planet in the sky. This was discussed as a failure to comprehend the correct meaning of the information presented. Furthermore, the notions intermediate between one and five were described by what was lacking in the children's ideas, for example, ideas of gravity and unlimited space.

In a frequently cited study, Vosniadou and Brewer (1992) found different mental models of the earth in children between the ages of 7 and 12. Their scheme of different models produced by the children during interviews can be regarded as a classic. The authors described an evolving complexity, from an initial conception of the earth as a *flat rectangle* or a *flat disk* into synthetic models. Three synthetic models of the earth were described: the *dual earth* model (two earths, a flat one on which we live and a spherical one, which is a planet up in the sky), the *hollow sphere* model (a sphere within which we live on flat ground deep inside), and the *flattened sphere* model. These synthetic models function as intermediate steps in the change from the initial model of the earth as flat to the normative model.

Vosniadou and Brewer (1992) have argued that children's alternative mental models are constrained by presuppositions within a naïve framework theory of physics as, for example, the presupposition that unsupported things fall in a downward direction. The children's cognitive process is described as a gradual revision of presuppositions. For example, the children with a hollow sphere model of the earth "operate under the constraints of the up/down gravity presupposition when they consider the physical objects located on the earth" (Vosniadou, 1994, pp. 55–56).

The change from a conception of the earth as flat into the accepted conception of the earth as a sphere surrounded by space has been proposed as a radical conceptual change, requiring a categorical shift (Vosniadou & Skopeliti, 2005; Vosniadou et al., 2008; cf. Chi, 2008). According to this view, children place the earth in the ontological category of "physical object," rather than in the category of "astronomical object." For conceptual change to occur, the children have to recategorize the earth from one category to the other.

In a few small-scale studies of children's conceptions of the earth, the question of conceptual change as a problem of contextualizing became apparent (Halldén et al., 2002; cf. also Halldén, 1999). From these studies, it was concluded that contextualization and coherence within different explanatory frameworks seem to be of utmost importance for understanding the process of conceptual change. Out of these findings, a longitudinal study was conducted to further explore contextualization as a crucial factor in conceptual change. The study reported here is about children's understanding of the earth, and how their understanding continuously grows out of rather vague ideas about the earth into increasingly more complex views.

DESIGN OF THE STUDY

The study was designed as a longitudinal investigation of children's conceptions of the earth. Children were interviewed once a year over a 3-year period, from the year they were 4 years of age to the year they were 6.

Participants

In the first year, 37 children (26 girls and 11 boys) born in 2001 were interviewed. At the time of the first set of interviews, the children ranged in age from about 3:5 to 4:5 (4 years and 5 months). In the second year, 35 children (24 girls, 11 boys) were interviewed, and in the third year, 29 children (21 girls, 8 boys). Hence, 29 children were followed with interviews through all 3 years. Eight children dropped out during the 3 years of study.

The children came from five different preschools in two suburban municipalities in the area of Stockholm, Sweden. The children came from different socioeconomic backgrounds. Their parents' educational backgrounds ranged from low educated to high educated, and their positions in the labor market can be roughly divided into employees, workers, and unemployed. In the analysis, we have not considered gender or social background.

The Interviews

The children were interviewed at their respective preschools, in a room where no disturbance occurred from the ordinary activities. All interviews were videotaped using a stationary camera (Sony DCR-HC40E/s). The interviews were semistructured. The interviewer tried to frame the interviews in a dialogical nature. This means that the interviewer did not ask a certain number of questions according to a preestablished questionnaire. Rather, there were some main questions or main themes to be covered in the interviews. In all of the interviews, the main themes were *what is the earth*, *where do people live*, and *what do the artifacts represent*. There were also questions about what a country is, and children who had travel experiences were asked where they had been and how they went there.

Questions about the solar system became more elaborate from year to year. Often it was the children who introduced their travel experiences as well as issues of the solar system in the interviews. The interviewer was open minded with regard to the issues the children talked about, and followed up any issues the children introduced to the conversation insofar as they concerned the subject matter of the interview.

The interviewer used different techniques in the interviews. Three frequently used techniques were *open questions*, *specific and leading questions*, and *silence*. Open questions, such as "Tell me about the earth," were used foremost in the beginning of the interviews to open up the children's meanings of the earth. More specific questions were used to ask the children to explain in more detail what they meant by their utterances; for example, "What do you mean by 'living inside the earth'?" Some of the specific questions were also leading. For example, if the child had expressed the idea of the earth as being situated up in the sky and that there were no people living on earth, the interviewer could ask, "But don't you live on earth, then?" This type of leading question can be regarded as important if we want to understand the child's reasoning, as well as whether their propositions were just an effect of the setting at hand. In several interviews, there were frequently moments of silence; by this the interviewer tried to give the children time to think and to leave it open for the children to be the ones who restarted the dialogue.

In all of the interviews, the children were provided different communicative tools, such as paper and pencils, and different representations of the earth. Table 1 is an overview of the 3 years of interviewing, illustrating what tools were used in each kind of interview. In the interviews, the different representations of the earth were introduced one by one. When presenting a representation, the interviewer always introduced it by the question "What is this?" or "What does this represent?," often followed by questions of what could be recognized in the representations as, for example, "What are the blue parts in this?"

During this first year the children were very young, and about half of them had not yet celebrated their fourth birthday. Even if several children were quite talkative, other children seemed to be rather shy, but also at an early stage in their language acquisition. Hence, four very silent children were interviewed in pairs instead of individually so that they could gain support from each other. The aim with the group interview in the first year was to provide the children an opportunity to communicate with each other, thus trying to reduce the influence of the interviewer. Three children were not available for this interview.

As shown in Table 1, the artifacts used in the first interview, Year 1, were paper and pencils and a colored picture of the earth that, according to ordinary rules for interpretation, illustrated the earth as a sphere. This means that the picture conformed to a circular shape and that some of the continents were indicated. In the second interview, a terrestrial globe was presented (the terrestrial globe had a political structure, was scaled at 1:38,600,000, which creates a diameter of 33 cm, and was produced by Räthgloben Verlag, Leipzig, Germany). In total, 34 children were interviewed in 15 interviews using the terrestrial globe. In the second year, paper and pencil were used, as well as a simplified colored map of Sweden, which also indicated the other Nordic countries in gray (an illustration by Jonsson, in Larsson, 2003): a terrestrial globe (produced by Scanglobe, with a political structure and a diameter of 30 cm): and a satellite photo of the earth. Finally, in the third year, the children were presented with a terrestrial globe and a satellite photo of the earth. These were the same as used in the interviews a year earlier.

In total, the results comprise material from 114 interviews (first year, 50 interviews with 37 children; second year, 35 interviews with 35 children; third year, 29 interviews with 29 children).

All interviews were transcribed by the interviewer by using the program Transana (Chris Fassnacht and David Woods, Wisconsin Center for Education Research, Madison). The transcriptions are a mixture of spoken and written languages but are closer to written language for the sake of readability. In the transcriptions, some actions other than the verbal actions are indicated. These nonverbal actions are seen as important for following the conversations and are taken into account in the analysis. All nonverbal actions are written in italics within slashes in the transcriptions, for example, /*pointing at the terrestrial globe*/.

In the presentation of results, the interviews are labeled by number, indicating the child, with the addition of the letters *a*, *b*, or *c*. The letter *a* indicates the first year of interviews, *b* the second year, and *c* the third year.

In Swedish, we have two words for the earth: *jorden* and *jordklotet*, the latter word indicating the globe shape. In the excerpts in the following presentation of the results, we have translated *jorden* as "earth," and *jordklotet* as "the globe." The artifact representing earth is labeled *jordgloben* in Swedish and is here translated as "the terrestrial globe."

Analysis

During the interviews, the interviewer attempted to identify and challenge the meanings of the word *earth* as used by the children. In the analysis, we have aimed to provide a

TABLE 1
Overview of the Interviews Conducted in the 3-Years Long Investigation

	First-Year Interviews		Second-Year Interviews	Third-Year Interviews
Kind of interview	Interview 1 (33 individual and a four in pairs)	Interview 2 (small groups)	Individual interview	Individual interview
Artifacts used in the interview	Paper and pencils (to draw the earth), a colored picture of the earth (circular and some continents indicated)	A terrestrial globe	Paper and pencil (to draw the earth), a terrestrial globe, a simple map of Sweden (also indicated other Nordic countries), and a satellite photo of the earth	Paper and pencil (to draw the earth), a terrestrial globe, and a satellite photo of the earth
Participants	37 children (33 were interviewed individually; four were interviewed in pairs)	34 (of total 37) were interviewed in small groups of two or three children	35 children were interviewed individually	29 children were interviewed individually
	The children's age ranged from about 3:5 to 4:5 (4 years and 5 months)		The children's age ranged from about 4:5 to 5:5 (5 years and 5 months)	The children's age ranged from about 5:5 to 6:5 (6 years and 5 months)

description of the ways in which the children tried to find solutions to these challenges. In the analysis, we have tried to identify which problems the children encountered and then to describe how they solved these problems. In short, this means reading through the transcripts of the interview several times to find out what the children are talking about. This also means deciding on which topic their utterances are relevant to. This also included our deciding on the contexts for their explanations.

The reading also involved going back to the videotape several times to utilize the children's gestures and bodily movements as cues for the interpretation. The concept of problem, and which problems the children encountered, is reported in detail in a forthcoming article (Larsson, Haglund, & Halldén, in preparation).

Interpretations of the utterances of such young children as occurred in this study have to been done in a holistic fashion. A strict coding of individual utterances runs the risk of being totally misleading. For example, these young children use prepositions in quite an unpredictable way. Saying that we are living "in" the earth does not unequivocally imply that they believe we are living inside the earth in a hollow sphere. It can simply be the effect of an inappropriate use of the preposition *in*. On the whole, it cannot be taken for granted that these young children always used words as they are commonly understood and, thus, the meaning of individual words used sometimes had to be decided on by a comparison with what had been uttered in an altogether different part of the interview. In this regard, the videotapes proved invaluable. The children often used gestures when communicating, for example, pointing up to the roof when saying "up" to explain the location of the earth, or pointing out through the window when answering "there" to the question of where they lived. Furthermore, they pointed out things on their drawings when explaining them, as well as showing in the representations of the earth where to find, for example, the sky, space, or water. Also, sometimes greater parts of the interviews had to be taken into consideration to eliminate instances of romancing, that is when the child, "without further reflection" invented "an answer in which he does not really believe, or in which he believes merely by force of saying it" (Piaget, 1929/1973, p. 21).

Thus, by reading through the transcripts several times, forming hypotheses of what the children are talking about, and by constantly modifying these hypotheses, a conclusion was reached as to what the children were talking about. Three persons, involving the two authors, were involved in this analytic process, and the final hypothesis was not settled until all three were in agreement. The children's meanings so described are regarded as conceptions held by the children.

The main criterion for deciding on a hypothesis was that it had to ascribe coherence to what was uttered by the children. This meant that an interpretation that made a greater part of the children's utterances coherent was favored over another hypothesis that made them less coherent (cf. Davidson, 2001). This was to adhere to what we have elsewhere extensively discussed as the intentional analysis of utterances (Halldén, Haglund, & Strömdahl, 2007; cf. also Halldén, 1999; and Halldén et al., 2008).

In presenting our results, we give short excerpts from the interviews as examples and in illustration of what is claimed.

RESULTS

The results are presented in the order of development as revealed during the 3-year longitudinal study. This means that we found this order of development within the individual child as well as on the group level. This does not mean that we found every developmental step in the interviews with each individual child. However, no individual child was found to develop in a way other than the order we present here.

In some of the first- and second-year interviews, we could not find any expressions of ideas of the *earth*, or we found only vague expressions from which we could not decide on any interpretation of the children's conceptions or ideas of the earth (for frequencies, see Table 2 later in the paper). There were also a few other children who talked about the earth in the sense of soil during the entire interview. However, most children expressed some ideas of the meaning of the word earth as a cosmic body and had no problems distinguishing this meaning of the word earth from the meaning of soil (see also Siegal, Butterworth, & Newcombe, 2004).

Two Different Contexts

In several interviews, the children expressed ideas of two different places: the ground where we live, and the spherical earth as a cosmic body up in space. At first, these two places had nothing to do with each other. The cosmic earth up in space and the ground where we live had no common features in the children's descriptions, thus forming two distinct conceptions.

These children's meaning of the earth as a cosmic body seems to have been assimilated to an already established knowledge of astronomy. Hence, their meanings of the cosmic body earth were intimately connected to other astronomical concepts such as space, moon, planets, and so on. The location of the earth and other astronomical bodies was interpreted from the perspective of the ground, where space is always above us. When the interviewer then asked questions about human beings and where we live on earth, many children declared that we do not live on earth and maintained this during the entire interview.

These children's descriptions of the earth up there in the sky or space were sometimes quite diffuse and differed markedly between children. Some children were relatively knowledgeable about the solar system. Some other children talked about the earth as being "space," or the "sky" or "planets." However, the most common way of describing the earth among these children was as a planet or moon up there in the sky.

Some of these children described the earth with the features of the moon, but without mentioning the word moon. From their point of view, they were talking about the earth, describing it as an object you can see at night—white, and situated up in the sky. Other children compared the earth with other planets such as Pluto and Saturn. Thus, these children classified the earth as an astronomical phenomenon and the difference between the earth and other cosmic bodies such as the moon was often blurred and indistinct.

During these interviews, when the children were asked questions about people on earth, they stated that there are no people on earth. For example, girl 15b drew the earth as a circle and stated that this is "up in heaven." When asked whether there are people on earth, she denied this and drew a human being on another sheet of paper. The interviewer pointed at the man and asked,

I: Does this person live on Earth?/*points at the man on the girl's drawing*/
15a: No: o/*laughs*/
I: Do you and I live on earth?
15a: No::o
I: Where do we live then?
15a: In a house.

As in the above example, several of the children laughed at the interviewer's questions about living on earth, suggesting that they thought the interviewer was kidding them. Some other children who refused to talk about people on earth up in the sky did talk about the place

where we live as the "ground" or, in a few cases, as the "map." However, they consequently used different words for the object earth up in the sky and the place down here where we live. When these children talked during the interviews about where we live, they described their immediate environment—their house, their street, and their neighbors. When they talked about other places they had experiences of, for example, from holiday travels, they described the hotel and the beach or the specific house, street, and people they had visited. Hence, they expressed ideas of a limited tract of flat ground, the house, and the street.

Often the representations of the earth (the picture, the terrestrial globe, and the satellite photo) were interpreted according to the children's expressed ideas of the earth. This means that they talked about the representations as the earth up there in the sky without human beings. But some children showed remarkable knowledge of how to use and talk about the terrestrial globe in particular. Before the terrestrial globe was presented, they expressed the above-described ideas of the earth as a cosmic body up there clearly distinct from the place where we live. However, in front of the terrestrial globe they could start talking about different countries or continents. They asked the interviewer to point out different countries on the terrestrial globe. Hence, they used the terrestrial globe and sometimes the pictures as a map, identifying different countries. Then, when the interviewer tried to make these children relate the terrestrial globe to what it represents, that is, the real earth, they switched and explained the earth as being "up there" distinct from where we live down here in our houses on the ground. In the actual interview setting, the cultural tool thus did not help them in an unambiguous way (cf. Wertsch, 1998; for the problem of using artifacts in instruction, see Ehrlén, 2008; Ivarsson & Säljö, 2005). However, it seems reasonable to look at their cultural knowledge, that is, how to use these representations as a driving force in their development while gradually taking this knowledge into account in their reasoning.

In a sense, these children might have a coherent conception of the earth attributed to them. The earth has the shape of something circular or spherical, and it is an astronomical object situated far up in the sky without human beings. They can also be assigned another coherent conception of the nearby place where we live on the ground. Of course, further discussion is needed to gauge whether these ideas qualify as conceptions of the earth at all. Nevertheless, there are ideas that can be looked upon as the very emergence of nascent conceptions of the earth. Thus, for these children, unrelated conceptions or ideas can be illustrated as an A and B conception, respectively (see Figure 2).

Thus, we can perhaps talk about two distinct models: one model of the spherical planet earth in space, and another model of the experienced nearby environment, that is, a little bit of flat ground. There is no incoherence between these two models or conceptions, as long as there are no people on earth up there and therefore no need for relations between the two places. Hence, these young children's ideas should not be regarded as a conception of the dual earth model as given by Vosniadou and Brewer (1992) and Vosniadou (1994), that is, "a flat one on which people live and a spherical one which is a planet up in the sky" (Vosniadou, 1994, p. 54). From the young children's point of view in our study, earth up in heaven has no relation or common features with the ground where we live. Hence, if we mean by model a pattern by which something can be described or explained, we should not ascribe to these children a conception of a dual earth model. Rather, they are using two distinct models, one for the astronomical object up in the sky and another one for the place down here where people are living. These findings seem to be more in line with these of Nakashima (1998): "there were many children who could not make any relation between everyday experiences and the scientific concept of the earth" (p. 2). The requirement of a single model of the earth, which comprises the place where we live and the astronomical earth in space, seems to emerge for the children out of the growing knowledge of people living on earth.

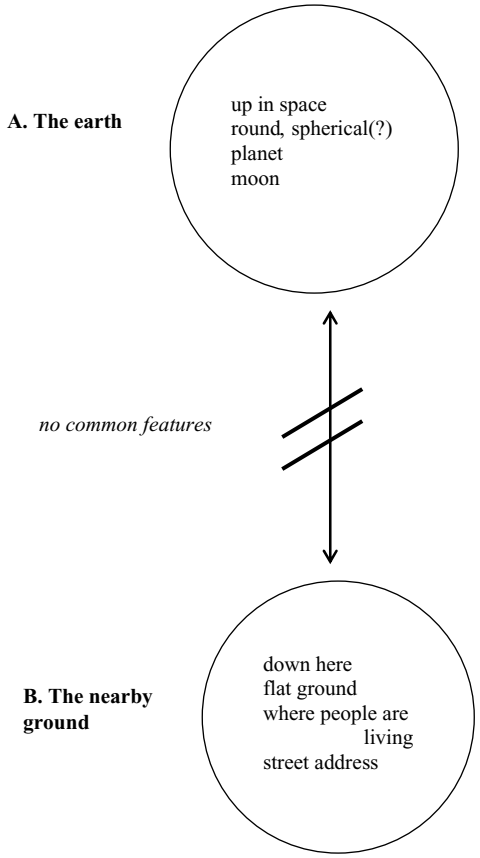


Figure 2. Two distinct conceptions, A and B, with no common features.

Intimately related to the children's meanings of earth are their efforts to understand the meaning of *country*. Their ideas of earth up there in space were sometimes associated with their experiences of other countries "far away." The children's conceptions of countries as naturally bounded entities often made the distinction between planets and countries fuzzy (cf. Wiegand, 1995; see also Jahoda, 1963, 1964, on children's understanding of relations between country and town, and so on). In a way, this uncertain conceptualization of countries seems also to be connected with their occasionally interchangeable use of space and water during the interviews. Hence, they sometimes contextualized the map into the solar system or universe. Then, when taking into account the new information of people on earth up in space, they sometimes took advantage of that possibility to locate other countries up there in the sky or space as well.

Oscillating Between Contexts

During the 3-year interview period, there was a drastic increase of awareness that we live on earth and that earth is a planet in space. Several of these children vacillated between explanations of the earth within these two different conceptual contexts. This means that during one and the same interview, they changed between descriptions of a sphere surrounded by space on which we human beings live in different countries and descriptions of the nearby flat ground from which one looks up at the stars. When the interviewer

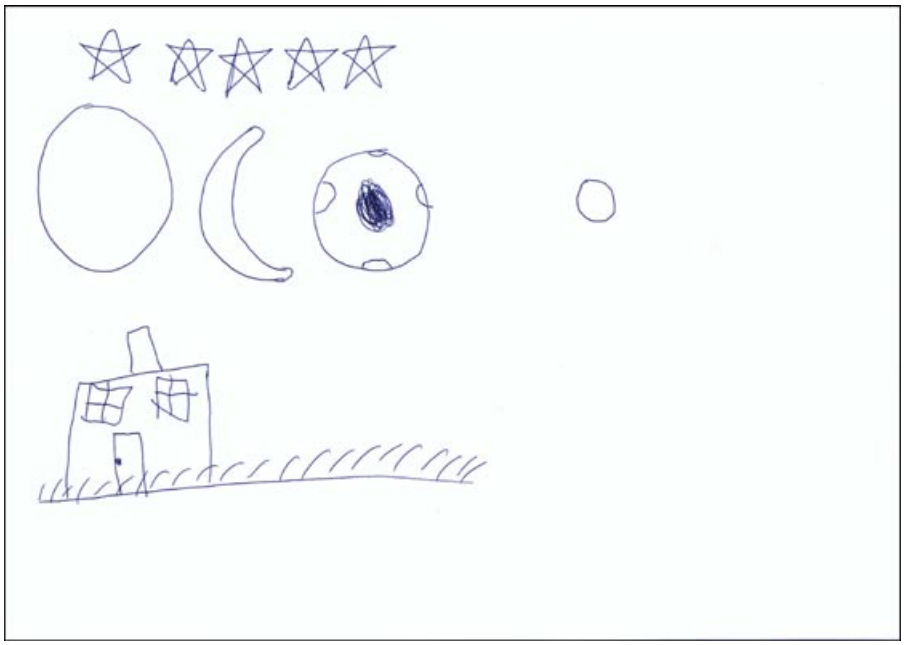


Figure 3. Drawing by girl 36c. The spherical globe where people live, the moon and the sun on the left-hand side of the globe, and stars above the house on a bit of flat ground. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

asked questions about the relationship between these different descriptions, the children usually chose one of them and denied the other. When, for example, they talked about the nearby ground, they denied for a moment what they had said about the planet and other astronomical aspects of the earth. However, in some interviews the children seemed to alternate rapidly between explanations of the astronomical planet and the nearby ground when pushed by the interviewer to explain the relationship between these contexts.

When asked what the earth is, one child (36c) answered "where we are" and also said it is spherical. She also had an idea of people living all around this sphere, and she mentioned different countries on earth. Later in the interview, she located the earth up in the sky. Then, the interviewer asked her to draw the earth. She drew a circle, with spots inside the circle depicting Sweden and other countries. She said there is water between countries (Figure 3).

The interviewer pointed to the circle and asked whether people were living everywhere on earth. The girl nodded. Asked where to find space on the picture, she said "up here" and drew stars on the top of the paper (the sky and stars located from a ground perspective within the nearby ground context). She drew the sun and the moon next to the earth (the astronomical context). The interviewer pointed below the earth and asked what would be found there. The girl answered "ground" and drew flat ground (the nearby ground context). Then the interviewer asked,

I: Nice. Where do we live in this picture?
36c: On the ground.
I: Where? Can you show me?
36c: Err/*drawing a house on the ground under the circles*/
I: This is where we live. Don't we live on the globe then?/*points to the circle*/
36c: Ahh, but down here on the ground./*points at the ground and the house*/
I: Mhm, is this the globe?/*points at the ground and the house*/

36c: /*nods*/
I: What's this then?/*points at the circle*/
36c: It's the globe as well.
I: Are there two?/*holding up two fingers*/
36c: /*nods*/
I: Well?
36c: No, this is the ground and here's a house./*points at the ground and then at the house*/

In our material, the above-presented interview is the nearest one to being a dual earth model of the earth as described by Vosniadou and Brewer (1992) and Vosniadou (1994). An alternative interpretation would be to look at this as an oscillation between contexts, and at a model level, there are still two models: one of a spherical planet in space, and one of the nearby flat ground. Girl 36c, when forced by the interviewer to explain the relationship between the nearby ground and the spherical planet, made rapid shifts between her explanations within the two different contexts. For a moment, the girl accepted that there are two earths but that appeared first and foremost to be a conclusion from what was just mentioned. She almost immediately returned to a nearby ground context in saying "No, this is the ground and here's a house."

Several other children realized the incoherence between explanations within these different contexts as, for example, girl 1b. She had stated that the earth is up in the sky and was asked whether we then live up there:

1b: Ehhhh, no we live down on... we do. We live down /*points down to the floor*/. Down, down, down /*looks out through the window*/I haven't said that it is up in the sky or something like that.
I: What did you say? What did you say?
1b: We are up in the sky really.

This girl seemed to try choosing one of the two locations for the earth to establish coherence. However, such incoherencies for the children eventually resulted in an integration of these two contexts into one single coherent model.

The Integration of Contexts Into One Single Model of the Earth

In the later interviews, several of the children integrated the planet in space and the nearby ground into one single model. Many of these children placed the nearby flat ground and houses inside the spherical planet, surrounded by space. They located other cosmic bodies in space outside the earth, but often talked about the sky as high up inside the earth and the ground at the bottom or in the middle inside the planet. This model of the earth as a hollow sphere has been found in a series of other studies (e.g., Nussbaum, 1979; Vosniadou & Brewer, 1992).

In the very beginning of the interview with boy 27c, the interviewer asked "What's the globe?," and the boy answered,

27c: It's here where we are now.
I: Yes, we live on the globe, right?
27c: Yes, but inside but outside. But we are inside the globe.
I: Where did you say we live?
27c: Err, down here but we don't live up there. Up, that is up there in space.

The boy answered that the globe is "where we are now." From the point where we are now, space is above us and we are "down here" on the ground. This is not an adequate description in an astronomical context of a planet surrounded by space. But if "down here" is inside the sphere, space can still be explained as above us and at the same time as surrounding the spherical earth, thus making the hollow sphere into a coherent model of the earth. The hollow sphere can then be looked upon as two models compoundeded into one single model: the model of the nearby environment with houses on flat ground and the sky above us, and the model of the astronomical planet surrounded by space. Hence, the hollow sphere made it possible for the children to give explanations within different contexts by the use of one single model.

These children who expressed ideas of living inside a hollow sphere seemed to be knowledgeable about a lot of astronomical facts. For example, several of them expressed the idea that we cannot live on the surface of the earth because human beings cannot breathe in space. Furthermore, most of these children mentioned that we are weightless in space. When the interviewer asked these children why we do not in fact fall off the earth, some of them just answered that we live inside the earth. But there were also other explanations. Some children said that we cannot fall off because the earth rotates or, as in one case, the earth does not rotate.

Other children explained how we would fall if we lived on the surface of the earth. They talked about falling down into a country inside earth, or that we would fly out in space. For example, in front of the satellite photo, girl 15c was asked whether we could walk around the surface of the earth. She answered,

15c: No, you can't do that.
I: Why not?
15c: Because then you will fall down down here/*points to the bottom of the circle on the satellite photo and out towards the black background*/
I: mm
15c: and up there then you would fly up there.

For her, it looks like being weightless in space is what stands out as a salient feature of space and that allows one to "fall" in any direction whatsoever. She also expressed, during the entire interview, the idea of living inside a hollow sphere. This, together with a lot of other experiences and beliefs, makes the hollow sphere appear to be the most coherent model if one wishes to join the nearby context and the astronomical into one single context. As already mentioned, there is the question of oxygen, and the problem with falling off. Thus, there were a huge number of beliefs that had to be integrated into one coherent conceptual context.

It seems reasonable to conclude that the relationship between the nearby flat ground and the spherical earth, and the relationship between up and down directions on earth and features of space, are some of the many relationships between the astronomical context and the context of people on the ground. This makes the hollow sphere into a quite complex model. Also, some of these children were still working with the conceptualization of country. This means that sometimes during the interviews they occasionally described countries in the sense of planets, in a rather uncertain and changeable way.

Thus, when the children integrated the two earlier distinct conceptions of the planet in space and the nearby place where we live, several children created a coherent hollow sphere model of the earth. This makes up the pattern of conceptual change in our model (Figure 4). The hollow sphere model can then be looked at as a compounded model of the earth that functions as a container for various explanations in different contexts.

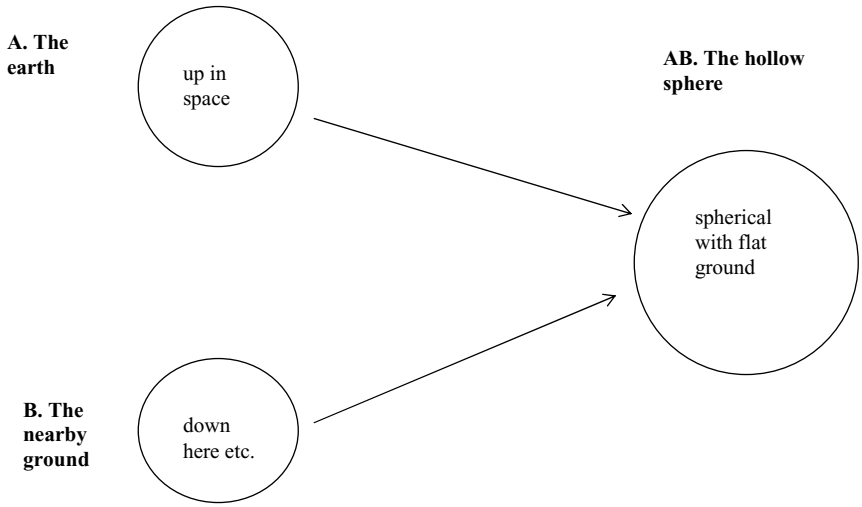


Figure 4. Conceptual change as the integration of two conceptions, A and B, into one compound conception AB.

Differentiation Within a Conception

There are children in our sample, primarily in the third year of interviewing, who expressed a conception of living all around the spherical earth surrounded by space. When these children talked about the planet earth, they gave astronomical descriptions and managed to differentiate these descriptions from descriptions of the nearby environment where we walk on a flat ground. For example, when the interviewer asked girl 35c to draw the sun on her picture of the spherical earth, she said,

35c: But when I draw pictures I usually just draw a half sun just like this./*shows a triangle in higher left hand corner of the picture with the pen on top of the paper*/
I: That's right. You can do that.
35c: But now you can draw a whole because now you're drawing out in space.

This child took into account how she was accustomed to drawing pictures according to children's cultural conventions of drawing. It is reasonable that she used to draw the sun up in the corner of her drawings in relation to a flat ground on the bottom of the paper. However, she had drawn the spherical planet earth and realized that, in relation to this, she could not draw the sun as she had been accustomed to. Hence, she drew the sun as a big circle beside the earth. She distinguished the astronomical context from the nearby ground, and furthermore, she managed to relate this to different ways of depicting in drawings (Ehrlén, 2009).

The children who now gave culturally accepted descriptions of living all around the spherical planet surrounded by space had developed understandings of when it is appropriate to describe the nearby ground and in what situations it is appropriate to give descriptions of the planet and its surroundings in space. Furthermore, they also figured out new ways to relate these different contexts to each other.

Some of the children were quite aware of some kind of gravitational force making it possible to live all around earth. But there was also an awareness of the big distances and the huge size of the earth that made it possible to grasp the idea of the earth. For example, while facing her own picture of the earth as a circle, girl 31c said,

31c: . . . the globe is big. That's why it is so flat.
I: Is that why it looks flat?
31c: Yes, it's like it's flat but really round and big. Now I know why it feels like it's flat.
I: mm
31c: Because it's so big./*makes large circular movements with arms*/

Several children who figured out these new relations between the nearby flat ground and the spherical planet managed to reflect on the small distances on earth in relation to the enormous distances in space. For example, girl 20c was asked about the surroundings of earth in front of the satellite photo and told the interviewer that once upon a time, her father had seen another planet. She explained that, "He saw a planet but it looked like a star. But stars are so. . . they are big in space but little when you're far away." This girl and some other children showed a remarkable understanding of how other cosmic bodies can appear to be small from the point of view where we are, but in space they are big.

One child, 35c, went further than that when asked about the surroundings of earth. She had drawn the earth as a circle and talked about different countries on earth. Then the interviewer pointed outside the circle and asked,

I: What's around the globe?/*points around the circle on the drawing*/
35c: Err, its space.
I: mm
35c: And the universe never ends.
I: no
35c: Because what would there be, what would there be like on the other side.
I: That's strange.
35c: Mm, it can only get higher and higher and higher. It can never end.
I: But can something which never ends exist?
35c: Yes, of course it can.
I: mm
35c: Space never ends.

This girl, 35c, reasoned about eternity on the day of her sixth birthday. This was occasioned by the question about the earth's surroundings.

In our model for conceptual change, the processes of differentiation within earlier compounded conceptions described here can be illustrated as shown in Figure 5.

It seems reasonable to look at these children's conceptions of the earth as differentiated conceptions, which means that they now use different models of the earth depending on context. However, this means that they have found new ways to relate these models to one another as indicated by the lowercased letters in the figure.

Summary of Results

What we have described is a process of conceptual change in which beliefs emanating from different sources, conceptions A and B, respectively, are integrated into compounded conceptions, AB, at the same time becoming differentiated into new conceptions A_B and B_A. However, these are ascribed to different contexts that are now related to each other in the sense that these contextualizations are made explicit (cf. Lundholm, 2004). The pattern is illustrated in Figure 6.

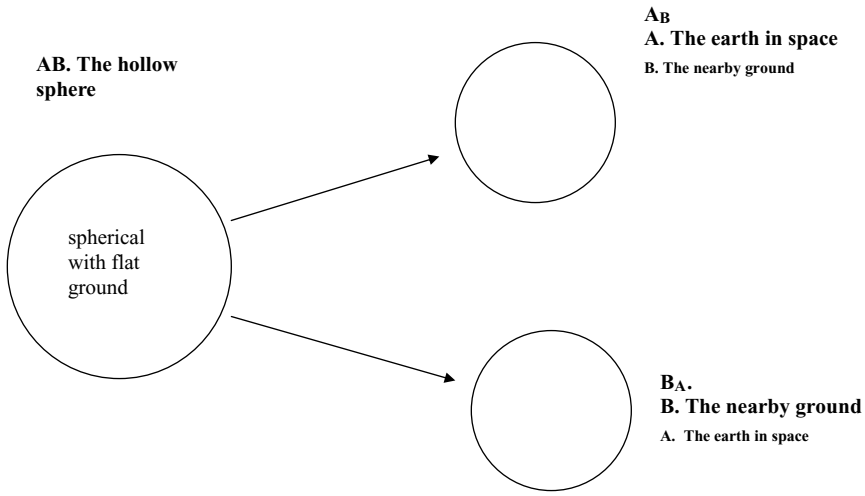


Figure 5. Conceptual change as a differentiation within one compound conception or model, AB, into two or several new conceptions, A_B and B_A.

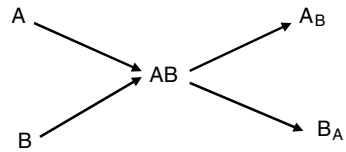


Figure 6. Two conceptions, A and B, integrated into one compound conception, AB, that is differentiated into two or several new conceptions A_B and B_A but now related to each other.

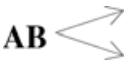
Over the course of the 3 years, we found a drastic increase in children who expressed ideas of the near-experienced ground and the astronomical planet as being one and the same object, with one and the same location, as well as an increase in the number of children expressing ideas conforming to the normative view of the earth. However, there were also children oscillating between models, and children who made utterances that could be interpreted as anticipating a more complex model or a model closer to the normative one. Here, in making a quantification, we are giving the numbers of children expressing A and B models as well as indications of transitions from A and B to AB, or who are expressing an AB model and/or indicating a transition to A_B and B_A (Table 2).

The quantification presented in Table 2 is intended to show that all models described in the results are well represented among the children and that there is an increase of children conforming to more complex models over the years. This is also why, in the above presentation of the results, there are more excerpts from the third year of interviewing than from the earlier years.

CONCLUDING DISCUSSION

This study is about conceptual change, that is, a radical or strong restructuring of conceptions held by an individual, as was pointed out in the Introduction. A reasonable question, then, is what should qualify as being a conception. It can be argued that when the youngest children in our study stated that the earth is something up in the sky, this should not be regarded as a conception; such an idea is too vague and fragmented. On the other hand,

TABLE 2
Frequency and Percentage of the Children's Conceptions of the Earth Over 3 Years

	Year 1	Year 2	Year 3
No identified meaning or something vague round, or in the meaning of soil	15/37 (41%)	6/35 (17%)	–
Two different contexts and initial transition into integration 	20/37 (54%)	18/35 (51%)	9/29 (31%)
Integration of contexts and initial differentiation 	2/37 (5%)	8/35 (23%)	13/29 (45%)
Differentiation 	–	3/35 (9%)	7/29 (24%)

the idea of a hollow sphere intuitively qualifies for being regarded as a conception. That is because the idea is complex in that it puts several characteristics of the earth in relation to each other into some sort of coherent whole. Thus, it is more than an ostensive designation. Also, it makes it possible for the children to explain that we live on an apparently flat ground that at the same time is spherical in shape. Thus, the hollow sphere does not only qualify as a conception but perhaps also as a rudimentary theory or model. Here, we have decided to call it a model.

Finding a clear demarcation between knowing the name of something on the one hand, and complex of interrelated ideas on the other to define the meaning of conception does not seem to be a very fruitful enterprise; this, at least as long as we are interested in learning and conceptual change. The learner always enters the learning setting with some ideas about the learning target, or ideas that can be related to the learning target. If not, communication within the instructional setting is made impossible. Whether these more or less vague ideas should be regarded as conceptions or not did not seem to influence our understanding of the learning process. Thus, we have talked about conceptions regardless of whether they indicate the name of an object up in the sky or knowing that we live within a hollow sphere situated in space. Furthermore, ostensive designations are made within a frame of reference that allows for specific propositions but not for others; in our study, for example, that we live on earth (cf. Halldén, 1990, and the metalevel in conceptual structures).

Looking at conception in this way has made it possible to describe a general pattern for conceptual change. It seems reasonable to conclude that children begin with two distinct and different conceptions of the earth. In the model presented in Figure 6, this is indicated by A and B, respectively, meaning one conception of the earth as a cosmic body up in space without human beings, and another conception of the nearby environment or the ground where we live. The cosmic body earth up in space and the ground where we live had no common features in the children's descriptions, and they never used the same word for the two places. However, these two models can be regarded as coherent descriptions within different contexts, that is, the context of living and an astronomical context, respectively.

Several children in our study managed to *integrate* the two earlier distinct conceptions of the earth into one single conception, the AB in our model (Figure 6). Several of these children constructed a model of the earth as a hollow sphere inside of which we live. Out of the hollow sphere, the children were able to give explanations of the nearby flat ground with the sky above us, and explanations of the spherical planet surrounded by space in one and the same model. This also makes a coherent model in that it embraces the astronomical context as well as the flat ground. Hence, the hollow sphere can be looked upon as a compounded model. In short, the hollow sphere model solves a lot of the problems that stand out for the children in everyday life and, inter alia, allows them to make sense of a lot of the "scientific" information presented at school and in other settings (an elaborated discussion of problem solving as a key factor in conceptual change is to be found in Larsson et al., in preparation). Thus, the hollow sphere model makes it possible for the children to remain within the context of a commonsense framework of conceptions. Nevertheless, with the help of this model they also managed to incorporate a substantial amount of information belonging to a normative view of the earth.

By way of a *differentiation* within the compounded conception or model, it then became possible for some children to express the normative conception of the earth as a sphere surrounded by space with people living all around the surface of the earth. These children distinguished the astronomical context from the context of the nearby ground in a new way and also found innovative ways to relate both contexts to each other, as indicated by the lowercased letters in our model (Figure 6). They expressed a differentiated, culturally accepted conception of the earth, using different models depending on context.

Thus, during the years in which we followed the children in this study, two conceptual changes were occurring. These two observed conceptual changes are best described as radical reconstructions of already embraced ideas. The first conceptual change was the integration of two different conceptions into one. For the children, bringing these conceptions together involved taking into account a lot of information that they already possessed as, for example, questions of up and down directions, oxygen at hand, weightlessness in space, and so on. However, it seems not to have been misconceptions about these single beliefs per se that caused them to construct a hollow sphere model rather than the normative one. In fact, there were children who did adhere to the normative meaning of these ideas as, for example, a relational view of up and down gravity directions, yet still got stuck at the idea of a hollow sphere. Thus, it does not appear that any single, specific belief, or lack of such belief, was preventing conceptual change from occurring.

The second conceptual change was about differentiation. In order to conform to the normative model, or models, of the earth, two different contexts for the same object, that is, the earth, were created. One set of models is related to the terrestrial context and the other set is related to the astronomical context. The children's idea of one all-embracing model for different aspects of the earth was now differentiated into different models for different aspects, but also these different models were set in relationship to each other. This is a radical reconstruction of their already embraced information. This means that the reconstruction of already embraced ideas is of decisive importance for conceptual change to occur, rather than it being an abundance of already embraced ideas or the acquisition of certain beliefs that is lacking. The reconstruction is made within conceptual contexts as well as between different contexts, that is, conceptual contexts on the one hand and contexts for description and explanation on the other.

Looking at the children's developing conceptions of the earth, it seems fruitful to look upon this development as a process of how to relate different objects to one another, how to distinguish between them, and how to find adequate contexts to which they relate. Rather than regarding the process of conceptual change as a categorical shift from a naïve

conception of the earth as a "physical object" to a conception of the earth as a "solar object" (Vosniadou & Skopeliti, 2005; cf. Chi, 2008, Chi et al., 1994), it can be looked upon as a search for adequate conceptions adapted to relevant contexts. Neither do there seem to be specific presuppositions (Vosniadou, 1994) that create obstacles, nor is the organization of particular p-prims (diSessa, 1988; diSessa & Sherin, 1998) at stake. Rather, the conceptual change was in bringing single beliefs into relationship to each other and thus bringing them together into a coherent conceptual structure, or forming an all embracing conceptual context. Thus, we argue that conceptual change is about the reorganization of the sum total of beliefs rather than a process primarily involving specific presuppositions or p-prims. This is not to deny the existence of presuppositions or p-prims just to question there function for conceptual change.

In sum, so far our results indicate that at the core of conceptual change is the reorganization of already acquired knowledge, rather than changing certain beliefs or acquiring specific new information. New information can often be assimilated into already established conceptual structures (for another example in the understanding of the Darwinian theory of evolution, see Pedersen & Halldén, 1994), and a revision of these structures does not necessarily result in the desired conceptual structure. Thus, it looks like we should be much more engaged in the reorganization processes of the conceptual structures than in the learner's understanding of specific concepts (cf. Scheja & Bonnevier, in press). In our studies of these reorganization processes, a great deal of emphasis must be placed on the contextuality of the learner's knowledge, or, as diSessa phrased it, "a smaller grain size and a greater number of elements means that *contextuality*—exactly when elements are used and how such context/knowledge links change in learning—becomes much more important theoretically and empirically" (diSessa, 2008, p. 55, emphasis in original; cf. also Halldén, 1999).

As has already been pointed out, there is also a context within which descriptions and explanations occur. When we state that scientific concepts are more powerful than are commonsense conceptions, we are referring to their greater inner consistency and their greater explanatory power. But this explanatory power only holds for the specific context for the explanations, as is delineated within the discipline. If the learner does not delineate the context of the explanation, as the scientist does, then the learner has no possibility of appreciating the increased explanatory power of the scientific concept (Halldén, 1993; cf. Österlind, 2005). Learners discover interpretations of new information and concepts presented in instruction, for example, which are applicable to the contexts for description and explanation that seem relevant for themselves (e.g., the hollow sphere as a functional context for the location of houses). In doing so, reinterpretations of the contexts for description and explanation are also actualized. Thus, for the learner, there are two contexts that have to be negotiated: one with regard to the conceptual structure, that is, coherence, and another with regard to the explanatory field. There are thus not only conceptual contexts but also contexts at an empirical or experiential level that have to be negotiated. It can be noted that these processes come quite close to Piaget's description of development as an assimilation of features in the world, that is, interpretations of new experiences, reinterpretations of earlier ones, and accommodation, that is, restructuring of conceptual schemes (Piaget, 1935/1970). So far, we are inclined to pretend that the pattern for conceptual change presented here is a general pattern. However, which specific beliefs that will be reorganized is dependent on the subject area under consideration and must be investigated by small grain size empirical studies.

The implication for teaching, then, seems to be to encourage our students to continuously meditate upon and attempt to reorganize the beliefs that they already rely on. Furthermore, in doing this also encourage them in doing their own reflections by our stimulating the

formulation of different ways of looking at and describing reality. The presentation of more information, or the effort to eradicate inadequate beliefs, then, does not present itself as being among our main concerns in trying to bring about conceptual change. Conceptual change does not appear as a totally rational process relying first and foremost on causal chains. Conceptual change seems to be a process of tentative reorganizations within different conceptual structures and within different explanatory contexts and, when these tentative reorganizations within different contexts take the form of a new gestalt, a conceptual change is in the process of occurring.

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