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A structural view on conceptual change

Integration, differentiation, and contextualization as fundamental aspects of individual meaning making

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Abstract

Conceptual development and conceptual change processes are described by a longitudinal study on preschool children's conception of the earth. 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. A normative line of research has been dominating the research field of conceptual change. There has been a search for specific conceptions that are missing in the learners' reasoning or that prevent conceptual change from occur. Here, the learner's capacity of reasoning is focused. The children's reasoning is described in its own right (Driver & Easley, 1978). It is argued that conceptual change is to be 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 annually from four to six years of age. There were 37 children participating, of which 29 were followed during all three years. The children were interviewed about their conceptions of the earth.

The results directs the focus of conceptual change from specific conceptions to structural changes. The children processed a lot of conflicting information. However, there does not appear to be any specific conflict that causes the process of conceptual change to occur. Rather, conceptual change is about the reorganization of the sum total of beliefs and to find adequate contexts to which they relate. Conceptual change involves a simultaneous processing of information and complex conception as well as revisions and changes at a model level, and all of this processing is related to contexts for description and explanation. The result also indicates some core stability in reasoning over the course of the investigation.

Keywords: conceptual development, conceptual change, coherence, contextualization

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List of articles:

Article 1
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Article 2
Larsson, Å., & Halldén, O. (submitted for publication). Coherence and contextualization in the process of conceptual change.

Article 3
Larsson, Å., & Halldén, O. (2010). A structural view on the emergence of a conception: Conceptual change as radical reconstruction of contexts. *Science Education, 94*, 640-664.

Contents

Introduction

This thesis is based on a longitudinal study on preschool children's conceptual development and conceptual change. The research field on learning within cognitive developmental psychology and science education has emphasized the learner's difficulties in acquiring scientific knowledge. To learn something is not to be a passive recipient of information. Instead the learner creates meaning out of the information and constructs his or her own knowledge.

Learning is not only restricted to formal education in a school setting. Children make meaning out of their experiences in their daily lives and they develop an understanding of phenomena in the world. Thus, the individual develops commonsense knowledge in order to manage his or her practical world. Sometimes the individual's spontaneously formed understanding, that is, their commonsense knowledge, is incompatible with what is taught in school. For example, the commonsense understanding of movement and force differs substantially from Newtonian dynamics (Watts, 1983).

For several decades there has been a growing interest in how the learners' have to restructure their already existing knowledge (Duit, 1999) in order to arrive at a scientific understanding. This field of research interest is referred to as conceptual change (Vosniadou, 2013). 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).

Numerous studies have focused on identifying the learner's common sense knowledge and how this knowledge differs from and is sometimes incompatible with science taught in educational settings (for a bibliography, see Duit 2009). Less focus has been on the process, that is, what the learner does in order to understand a phenomenon. One explanation for this can perhaps be that most studies have been cross-sectional. To get at a deeper understanding of the process of conceptual change, there is a demand for more longitudinal studies (Brewer, 2008; White & Arzi, 2005; and White & Gunstone, 2008). In recent years, theories on conceptual change "has become more and more sophisticated and the teaching and learning strategies developed have become more and more complex" (Duit & Treagust, 2012, p.683). However, most research effort on conceptual change has focused on obstacles or deviations in

the learners' already embraced beliefs that hindering conceptual change to occur. Thus, a normative line of research has been dominating emphasizing what is hindering a conceptual change from a previously established conception into a scientific conception, that is, conceptual change as desired in educational settings. As early as the 1970s, Driver and Easley (1978) were requesting more focus on understanding the learner's ideas and reasoning in their own right rather than assessing their ideas as being correct or incorrect.

In this thesis, the aim is to describe children's conceptions and conceptional development in their own right, that is how they are reasoning rather than assessing whether their ideas are right or wrong according to a normative view. In order to obtain a deeper understanding of the children's reasoning the focus is on describing their all-embracing conceptional structures, that is, the contexts in which their conceptions are embedded (Caravita & Halldén, 1994; Halldén, 1999; see also the section Conceptual change and contextualization in this thesis). The results of this empirical study are reported in three articles. In the study children were interviewed about their conceptions of the earth over a three-year period of investigation. Within the research field of conceptual change a fruitful and commonly used topic of investigation has been children's conceptions of the earth. In this thesis, the interest thus is on processes involved in conceptual change and the concept earth is used as an example.

Outline of the thesis

The thesis is divided into two parts. The first part begins with an introduction to the field of conceptual change as it relates to the second part, that is the three articles that make up the empirical study. The introduction in the first part is followed by an overview of research on conceptual change. This, in turn, is followed by the objectives of the thesis and methodology of the empirical study. The articles are then summarized and followed by a concluding discussion of the results. In the second part of the thesis, the articles are presented in their entirety.

Research overview of learning as conceptual change

In recent decades there has been an upsurge in research on learning as conceptual change. This overview presents the main features of the different approaches to conceptual change and highlights the central questions within the field relevant for this thesis.

Misconceptions or alternative frameworks

The research field on conceptual development and conceptual change has its roots mainly in the constructivist approach and relies heavily on the work of Piaget. However, some researchers have in addition also been inspired by Kuhn's (1962) concepts of normal science and scientific revolution (e.g. Posner, Strike, Hewson, & Gertzog, 1982). Piaget gave children a voice when he described their conceptions of the world and their moral reasoning (e.g. 1929, 1935). His interest was in how children are reasoning and how they make meaning out of their experiences. He developed the clinical method with the aim of revealing children's naturally formed thoughts about the world. In The *Child's Conception of the World* (1929), he described children's conceptions of the world in their own right. By interviews and observations, he revealed children's conceptions of phenomena such as dreams, thoughts, and the origins of the sun, moon, trees, mountains, the earth, etc. There was also a normative aspect in that he described how children's conceptions change with age into conceptions prevalent in their contemporary society. Piaget's (1935) comprehensive investigations of children's thoughts and reasoning had its origin in his interest in the growth of intelligence.

However, research on conceptual understanding and development has focused on different aspects of Piaget's works. One interest has been in understanding the learner's ideas and reasoning in their own right. Another line of research has focused on the normative aspect of assessing the correctness in the learner's answers. In the late 1970s, it was concluded that the normative line of research was dominating in studies on conceptual development in adoles-

cent science education (Driver & Easley, 1978). The normative line of research identified common 'misconceptions' among the students', that is, their wrong or incorrect ideas that may be developed during the learning process. Hence, there had been a focus on students' difficulties and shortcomings that can be referred to what Rommetveit the same year called a "negative rationalism" (Rommetveit, 1978; see also Halldén, Scheja, & Haglund, 2008). However, Driver and Easley's main point (1978) was that when students give wrong answers to questions at school, these should not always be regarded as misconceptions but as answers from a different point of view, that is, from an alternative framework. Prior to instruction, students form "autonomous frameworks for conceptualizing their experience of the physical world" (Driver & Easley, 1978 p.62). These so called alternative frameworks make the student to describe and explain events in other ways than is done in the sciences. These alternative frameworks also make them to interpret descriptions given in instruction in different ways than those intended. Driver and Easley requested more focus on understanding the student's ideas and reasoning in their own right rather than "as a device for classifying pupils and prescribing programmes for them" (1978 p. 79).

Research aimed at describing these alternative frameworks in their own right would mean exploring their development; the reasons for this development, including how they help the individual to obtain meaning out of the world; and evaluating their explanatory force. This line of work would require determining how descriptions and explanations within this framework solve problems and guide activities within an explanatory field delineated by a commonsense conception of the world and practical action in the world, that is, finding the rationality in laymen's ways of reasoning. A small body of research has attempted to explore alternative frameworks in their own right (as done in, for example, Demastes & Good, 1996; Ehrlén, 2009; Petersson, 2005; Österlind, 2005; Sternäng, 2011). This line of research is based on the assumption that there is a certain amount of stability and scope in alternative frameworks (cf. Vosniadou, 1994).

The normative approach, however, has continued to receive the most attention within the research field. Alternative frameworks or previously established conceptions based on experiences and interpretations of the physical world have been regarded as initial or primitive and described as being very robust and resistant to instruction. Numerous studies have shown how the learner's alternative frameworks differ from scientific thinking and are obstacles in the acquisition of scientific knowledge (for a bibliography see Duit 2009). Thus, there has been a focus on identifying what features in the alternative frameworks are obstacles to bringing about a change from naïve to scientific descriptions and explanations, in other words, the conceptual change as it is de-

sired in educational settings. For example, Watts (1983) identified eight different conceptions of force that deviated from the scientific notion of force. Even if this was done under the assumption that it is productive to look for as much coherence as possible in students' statements, a central aim of Watts' study was to describe how these alternative conceptions differ from "the orthodox physics view" (p. 218) to make them easier to disprove in instruction. Thus, students' alternative frameworks were explored to identify obstacles to conceptual change.

The question of coherence

Coherence has been discussed in different ways within the research field on learning as conceptual change. A central issue is to what extent it is reasonable to ascribe coherent systems of beliefs to individuals. For several decades there has been an ongoing debate between the so called knowledge-as-theory perspectives and knowledge-in-pieces perspectives (for an overview of these different strands of research on conceptual change see Özdemir & Clark, 2007). Thus, there is the question of coherence related to the structure of knowledge. The question of coherence has also been discussed with regard to method for analysis of interviews (Halldén, Haglund, & Strömdahl, 2007; Halldén, Scheja, & Haglund, 2013; cf. also Sherin, Kraowski, & Lee, 2012). In the following, I will give a brief overview of how coherence has been discussed within the research field and how coherence is taken into account in this thesis.

Coherent systems of beliefs or knowledge in pieces

From knowledge-as-theory perspectives, the learner's alternative frameworks have been described as coherent systems of conceptions that form more or less theory-like coherent structures (e.g. Carey, 1985; Chi, 2005). These spontaneously developed conceptual structures have been described in different ways. For example, the learner's conceptions as embedded within intuitive theories have been talked about as children's science (Osborne, Bell & Gilbert, 1983) and have been compared to early concepts in the history of science (e.g. Carey, 1985; Wiser, 1995). A related line of research is the "framework theory" (Vosniadou, 1994; Vosniadou & Skopeliti, 2013). According to this view children develop a so called "naïve framework theory" consisting of ontological and epistemological presuppositions.

A contrasting view is that the learner's initial knowledge rather should be regarded as fragmented and piecemeal with limited systematics and coherence (diSessa, 1993). From this perspective, it is argued that the learner's ideas consist of small knowledge elements called p-prims, *phenomenological primitives* (diSessa, 1988, 1993, diSessa & Sherin, 1998). P-prims are described as

sub-conceptual in that they are of smaller size than can be associated with words (diSessa, 1993). In empirical studies, a large amount of p-prims has been identified, for example, Ohm's p-prim that more effort leads to more effect. A related knowledge element that has similar function as p-prims has been talked about as e-prims, *explanatory primitives* (Kapon & diSessa, 2012).

The debate also involves the question of transfer, that is, consistency and/or inconsistency of answers across questions and situations (Sherin et al., 2012). According to knowledge-as-theory perspectives, there is a certain amount of stability in alternative frameworks that is relatively independent of the situation (e.g. Carey, 1985; Chi, 2005). From knowledge-in-pieces perspectives, however, the novices' knowledge structures are regarded as much more contextually sensitive (Özdemir & Clark, 2007). What p-prims the novice uses shifts from situation to situation, and the process of learning involves reorganization of p-prims into increasing coherence and consistency (diSessa & Sherin, 1998). On the other hand, from the framework theory it has been argued that "fragmentation and inconsistency can be the product of instruction, in cases when a rather coherent, but incompatible structure is already established" (Vosniadou, 2013, p. 22).

However, it has been claimed that if we regard the scientific or culturally accepted framework as the norm for coherence and consistency we run the risk of underestimating the learner's resources (Säljö, 1991). Thus, if we want to describe the learner's alternative framework in its own right, we have to allow for other standards than the scientific ones (Halldén et al., 2002; Halldén et al., 2013). The perspectives mentioned above take their departure from a Piagetian constructivist perspective on learning. However, from a sociocultural perspective, or so called situated cognition perspectives (Resnick, 1991), it is argued that the individual's reasoning is always situated and thus a result of what the situation requires. According to this view, the individual's conceptions are always put into play in specific situations and it is irrelevant what place the conceptions might have in an individual's thinking.

Coherence and the question of grain size

It has been argued that the question of coherence should concern at what grain size and level of detail it is appropriate to describe conceptual change (diSessa, 2008; 2013). According to diSessa (2013), the only grain size of mental entities in describing "the building of naïve elements into normative concepts " (p. 34) is at a sub-conceptual level. From this knowledge-in-pieces perspective, the structure of knowledge, and thus coherence, is a question of the relations among these small sub-conceptual elements.

In this thesis, the question of grain size is not decided upon theoretical grounds. Rather, grain size is regarded as an empirical question decided on by detailed analysis of the interviews (as extensively described in Article 2 in this thesis). Thus, grain size is looked upon as a question of the level of detail in the analysis of the interviews. By detailed analysis of what the children were trying to accomplish in the interviews, it is possible to describe what issues the children were struggling with and, thus, at what grain sizes incoherencies appeared. This actualizes the question of coherence with regard to methodology.

Coherence has been discussed as a prerequisite for interpretation of an individual's actions (Halldén, et. al., 2013). In this thesis, coherence is regarded as an analytical tool in trying to understand the rationality in the learner's reasoning. The process of analysis adopted in this thesis is what has been described elsewhere as intentional analysis or good reason assay analysis (Halldén et al., 2007; Halldén et al., 2013) and involves systematically looking for coherence in the individual's conceptualizations. Thus, in this thesis coherence is discussed in two different ways; with regard to conceptual structures as well as with regard to methodology.

The concept of conception

The distinction between concept and conception, as well as the distinction between having and possessing a concept, are issues discussed in philosophy. In this thesis, the aim is not to delve too deeply into a discussion of philosophical questions but rather to discussion how we use the terms concept and conception within research on conceptual change and how these terms are used in this thesis (see also Article 3).

It has been claimed that the concept of concept is too vague and imprecise as used in research on conceptual change (diSessa & Sherin, 1998). However, White (1994) argued that we within the research field should talk about conceptional change rather than conceptual change when talking about alternations of conceptual frameworks. Concept concerns classification, and conceptual change would then mean learning to classify objects in accord with authority (White, 1994). However, concept can also mean "the set of knowledge that a person associates with the name" [of the concept] (White & Gunstone, 2008, p. 622). This meaning is closer to the term conception. Conceptions are systems of explanations, and when we talk about restructuring of conceptual systems we would talk about conceptional change (White, 1994). Hence, in research on conceptual change we are studying conceptions and the change of conceptions. A conception "indicates individuals' different ways of thinking

about a particular grouping" (Entwistle, 2007 p. 2). This means that an individual understanding is always a conception regardless of whether talking about novice understanding or about expert understanding. Then, a reasonable question to ask, is in what sense there actually are any concepts. This is commented upon in Article 3 in this thesis.

Thus, evaluating learner's conceptual knowledge is always a matter of degree of similarity between the idiosyncratic conception and the scientific concept (as illustrated in Figure 1).

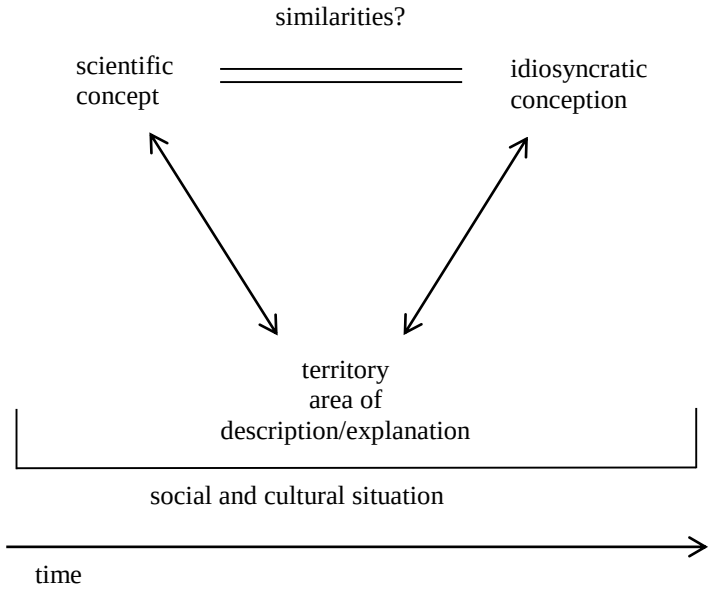

Figure 1. The distinction between concept and conception (from Larsson & Halldén, 2010a).

The scientific concept in the figure is a concept of something in a territory or area of description and explanation. Also, the idiosyncratic conception is a conception of something in a territory or area of description and explanation. Thus, knowing has also to do with similarities between territories of description and explanation; there must be some overlap between what is described and explained by the concept and the conception, respectively. All of this is also related to and adjusted to a social and cultural setting, and, furthermore, all of this changes during time, as indicated by the time arrow. Looking at concept and conception in this way actualizes the different contexts (Halldén, 1999) that are taken into account in this thesis in order to describe the learner's

all-embracing conceptual structures. These contexts will be further elaborated on in the section on Conceptual change and contextualization.

The process of conceptual change

Different questions has been discussed with regard to the process of conceptual change. Conceptual change has been discussed as a replacement of conceptions, as using cognitive conflict as a way to induce conceptual change, and factors hindering conceptual change from occur.

Conceptual change as replacement

A classical model of conceptual change describes the process as a replacement of conceptions (Posner, Strike, Hewson, & Gertzog, 1982; and Strike and Posner, 1992). In this model, an initial or naïve conception, A, is replaced with a more potent or scientific conception, B. Thus, the model implies that the learner abandons his or her commonsense frames of reference in favour of a scientific one. This linear model is influenced by Piaget's developmental psychology and on theory formation and revision in science (Kuhn, 1962). Posner et al. (1982) described accommodation as a radical conceptual change and listed four conditions for conceptual change to occur in the learner; 1) there must be dissatisfaction with existing conceptions, 2) a new conception must be intelligible, 3) a new conception must appear initially plausible, and 4) a new concept should suggest the possibility of a fruitful research program (p. 214). Hence, the learner was regarded as a little scientist and the process of change was regarded as a shift of paradigm. The source of dissatisfaction with existing conceptions was described as the learner's experience of anomaly and the instructional implications were to create cognitive conflicts in the learner.

This model of the conceptual change process has been met with severe criticism. First, learning a scientific explanation or theory seems not to require an abandoning of a commonsense view of the world. Rather, the process appears to be an enrichment of the repertoire of ways to describe and explain the world (Solomon, 1983). Halldén (1999) discussed three different aspects of replacement; abandonment, enrichment, and the emergence of a new conception in which case there is no question of conceptual change at all. Second, it does not appear reasonable to compare the learner with a scientist (e.g. Caravita & Halldén, 1994). Third, rather than a suddenly and direct replacement conceptual change seems to be a slow and gradual process (e.g. Vosniadou, 1994).

A perspective that can be related to the theory of replacement from a naïve to a scientific conception is the theory of categorical shift (Chi, 2008). It has been

argued that the learner assigns scientific concepts to an ontological category to which they do not belong (e.g. Chi, Slotta, Leeuw, 1994). The learners make categorical mistakes either because they do not know to what category the concept belongs or because they lack the category to which the concept correctly belongs (Chi, 2008). For example, it has been argued that the learners categorize scientific concepts such as heat and light as entities, but scientists categorize these concepts as processes (Chi, Slotta, Leeuw, 1994; Chi, 2008). Conceptual change, thus, requires categorical shifts or, if the learner lacks the category, an ability to create a new category.

The use of cognitive conflict

Within the research field there has been a search for the crucial event that makes conceptual change to come about. Replacement models of conceptual change propose that the source of dissatisfaction with existing conceptions is the learner's experience of anomaly. The instructional implication is to create cognitive conflicts in the learner (e.g. Posner et al., 1982). Consequently, the use of cognitive conflict became a leading paradigm in research and instruction (Shnotz, Vosniadou, & Carretero, 1999, p xiv). The cognitive conflict approach to conceptual change relies on the work of Piaget and the interplay between assimilation and accommodation (Duit et al., 2008; Limón & Carretero, 1999). Piaget talked about equilibration between the individual and the environment, as well as about equilibration within a conceptual structure.

> Equilibration is achieved in…three forms: between the subject and the objects, between schemes or subschemes on the same hierarchic level, and between their differentiations and their integrations into superior totalities. (Piaget, 1977, p. 30.)

The cognitive conflict approach in research and instruction has mainly focused on equilibration between the subject and the object, that is, between the individual and the world (Hewson & Hewson 1984). Experimental research has been carried out attempting to create cognitive conflict in the learner by introducing information that contradicts the learner's supposed conceptions. Such information has been referred to as, for example, anomalous data (e.g. Chinn & Malhotra, 2002), discrepant events (e.g. Baddock & Bucat, 2008; Nussbaum & Novick, 1982), and refutational texts (e.g. Mason, Gava, & Boldrin, 2008). However, efforts to induce cognitive conflict rarely result in conceptual change (Limón & Carretero, 1999). A review of studies in science education (Guzzetti, 2000) concluded that learners often fail to realize a state of cognitive conflict. For example, it has been shown that learners often use strategies to avoid engaging in a cognitive conflict (Chinn & Brewer,1993; 1998) or that only weak restructuring is achieved (e.g. Limón & Carretero, 1999). Limón

(2001) pointed at the problem of a lack of meaningfulness, and discussed different variables to make the cognitive conflict meaningful for the students. However, Lee and Yi (2012) have shown that cognitive conflict is not as simple as a conflict between two entities. Rather cognitive conflict is a complex event involving relations among different kinds of resources within a conceptual structure (see Article 2 in this thesis). Students' cognitive conflicts arise from relations among, for example, different types of knowledge such as conceptual, procedural, and contextual knowledge (Lee & Yi, 2012). In this thesis, the focus is on conflicts or incoherencies that arise within a conceptual structure and how this relates to contexts for description and explanation (the main focus in Article 2).

Conceptual change as caused by a single factor

Research within the field of conceptual change has developed what Perkins (2007) called "theories of difficulty". The dominating research effort has focused on identifying what makes conceptual change difficult or even impossible to achieve. The emphasis has been on identifying obstacles in the learner's alternative frameworks that hinder the conceptual change from occurring or identifying what is lacking in the learner's reasoning. The occurrence of underlying presuppositions in the learner's alternative frameworks is one way to explain difficulties in achieving conceptual change (e.g. Vosniadou, 1994). According to this view, children develop coherent structures that can be regarded as theory-like, a so called "naïve framework theory". The naïve framework theory consists of ontological and epistemological presuppositions that prevent conceptual change from occurring and give rise to misconceptions. Thus, the focus is on presuppositions within the framework and the process of conceptual change is about a gradual revision of these presuppositions. For example, it is argued that children's conceptions of the earth are constrained by presuppositions that space is organized in an up and down direction with respect to a flat ground and that unsupported objects fall in a downward direction (Vosniadou, 1994). Conceptual change is achieved by a gradually abandoning of these presuppositions leading to a scientific understanding of the earth (Vosniadou & Brewer, 1992).

Another emphasis in research has been on the learner's difficulties in grasping specific threshold concepts within a subject area (Meyer, Land, & Davies, 2008; Cousin, 2010). A threshold concept can, for example, be opportunity cost in economics or limit in mathematics. Threshold concepts have been characterized as opening up for a new way of thinking, and then, according to what is appropriate within the discipline. The educational implication of this has been to in instruction concentrate on threshold concepts. However, for the learner a threshold concept is probably troublesome in that this very concept

is difficult to master because of the learner's intuitive understanding of the subject matter in question. (Cousin, 2006).

A common theme in the above theories is a focus in identifying deficiencies in a naïve conception, A, that hinder the conceptual change into a scientific conception, B. Trying to understand the learner's alternative framework in its own right (Driver & Easley, 1978), however, would instead mean focusing on what learners are doing when trying to understand something, or as Halldén, Scheja, and Haglund (2013) phrased it:

> If we view learners as individuals who intentionally try to realize certain goals, the shortcomings observed in A do not become antecedents in a causal relationship. Rather, they become arguments in a *teleological* explanation of why learners explain things as they do. (p. 78 f).

Furthermore, conceptions have been regarded as being embedded into larger conceptual structures (Vosniadou, 1994). Nevertheless, the focus has been on specific conceptions within this web of conceptions. There has been a search for specific presuppositions (Vosniadou, 1994), the delineation of ontological categories (Chi, Slotta, & De Leeuw, 1994), and the identification of particular threshold concepts (Meyer et al., 2008). Contrary to this, it has been argued that learning should be regarded as a systemic shift rather than caused by a single factor (Caravita & Halldén, 1994). One way to consider conceptual change as a systemic shift has been proposed from knowledge-in-pieces perspectives. From this line of research, the process of change is regarded as a reorganization of relations among small knowledge entities, p-prims (e.g. diSessa & Sherin, 1998; diSessa, 1993). An alternative is to focus on the reconstruction of previously established conceptional structures as pointed out by Lee and Yi (2012) and in Article 2 in this thesis.

Conceptual change and contextualization

Another way to consider a structural view of the process of learning and conceptual change is to look at the learner's contextualization of knowledge (Halldén, 1999; Halldén et al., 2013). It has been shown that how knowledge is contextualized is a crucial factor in considering the leaner's challenges in understanding scientific concepts (e.g. Halldén et al., 2002; Österlind, 2005). Rather than a linear process caused by a single factor, the process of conceptual change has been described as the ability to differentiate between different contexts and to relate new information to adequate contexts for interpretation (Halldén et al., 2002; Halldén, 1999; Halldén et al., 2013).

There are different contexts to take into account in research on learning and conceptual change (Halldén, 1999). Conceptions are embedded in a web of conceptions. This web of conceptions constitutes a context for the focal conception (Goodwin & Duranti, 1992). In science, concepts gain their meaning from the theoretical context in which they form a part. Thus, the normative way of understanding, that is the scientific one, can be considered a conceptual context. In a similar way, the learner's idiosyncratic conceptions are embedded in larger conceptual structures, that is, conceptional contexts (cf. Caravita & Halldén, 2004). Thus, the conceptional context refers to the structure of what is understood, this means how idiosyncratic ideas cohere to one another.

The assimilation of information into already embraced conceptional structures is a central issue in learning and conceptual change. Empirical studies have shown how learners' integrate information from a range of different sources into coherent wholes. For example, children's construction of a hollow sphere model of the earth has been discussed as a compounded model (Halldén et al., 2002). The children integrated their experiences of the nearby ground and information of the spherical earth surrounded by space into one single model, the hollow sphere. In a similar way this was shown in a study on students' conceptions of climate change and the intensified greenhouse effect (Sternäng & Halldén, 2011). The students integrated different kinds of information belonging to different problem areas about the depletion of the ozone layer and the intensified greenhouse effect into one single coherent model.

There is also research that has brought to the fore the relations between conceptional structures and fields of application (Halldén, 1999). Thus there are also contexts for description and explanation, that is, applicability. Questions asked in commonsense are often different from questions asked in science (Halldén, 1993; Österlind, 2005). Research has shown that students apply different ways of reasoning depending on what they consider to be relevant to explain in the situation at hand (e.g. Halldén, 1999; Scheja, 2006; Wistedt, 1994). For example, it has been shown that children, presented real life problems in mathematics, engage in solving problems such as tiredness of the runners in a race rather than applying the intended mathematical calculus (Wistedt, 1994). In another study it was shown that depending on the student's interpretation of the task they applied either real life explanations or theory of probability (Halldén, 1999; Scheja, 2006). Thus, in these cases the problem seems not to be a lack of conceptual understanding but rather a question of contextualization. When students situate a problem in an everyday context "they find the scientific explanation inappropriate" (Halldén, 1999, p. 64). But there can also be the question of what counts as a scientific explanation. For example, when students learned about the Darwinian theory of evolution they almost added the Darwinian explanation into their already established Lamarckian view (Halldén, 1988b). Thus, they did not differentiate between a

teleological explanation and an explanation based on cause and randomness or chance.

In addition, there is a situational and cultural context, that is, conceptions of the specific situation and of sociocultural norms such as communication and language (Halldén et al., 2013). Social and cultural norms also involve the conventionalized use of artefacts such as different kinds of maps (Halldén, 1999), and conventions of drawings (Ehrlén, 2009).

Out of empirical studies on learners' contextualization of knowledge, it has been argued that the process of conceptual change involves to

> 1) combine information of the conceptions provided into a single compounded model and 2) differentiate between available contexts for interpretation and use ways of conceptualizing the information that correspond to these different contexts and to the current situation (Halldén et al., 2013, p. 89).

In this thesis the learners' contextualization of knowledge as a crucial factor in conceptual change is further explored. In order to describe the children's all-embracing conceptional structure and the process of conceptual change a synchronic dimension of contexts as well as a diachronic dimension of contexts is considered. These dimensions of contexts are shown in figure 2.

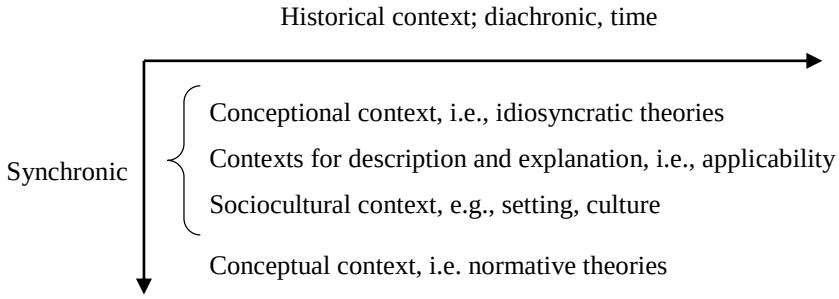

Figure 2. Dimensions of contexts (from Article 2, Figure 1. There slightly modified from Larsson & Halldén, 2010.)

First, there is a conceptional context, that is, idiosyncratic conceptions. Second, there are contexts for description and explanation, that is, applicability. Third, there is a social and cultural context that includes language and cultural conventions. Thus, the all-embracing conceptional structure can be regarded as constituted by these different contexts (as indicated by the vertical bracket

in Figure 2). There is also a diachronic dimension (as indicated by the horizontal arrow in the figure) in that these contexts have a past, a present, and a future (Mercer, 2008). There is also a conceptual context, that is, scientific theories and, thus, the normative way of understanding. This context differs from the others in that it describes what is often intended in an educational setting. Thus, it is the comparison of this context with the others that has been discussed the most in research as pointed out above in the previous section on Misconceptions or alternative frameworks.

Children's conceptions of the earth

Investigations into children's understanding of astronomy have been shown to be a fruitful area of research for discussing issues on conceptual change. Within the field there is now a long tradition of investigating children's conceptions of the earth (for a review, see Brewer, 2008).

Alternative models of the earth

It has been shown that children have difficulties in understanding that the earth is a huge sphere surrounded by space. Nussbaum and Novak (1976) and Nussbaum (1979) discovered several alternative ideas of the earth in children. These ideas ranged from a first notion in which the earth is flat to a fifth notion in which the earth takes on the culturally accepted view of the earth as a solid sphere. One conception of the first notion was described as a belief that the earth we live on is flat and that the globe represents some other planet in the sky. Another notion was about the flatness of the earth; either that the earth has flat spots on the top of the earth or that it has flat ground in the middle inside the earth. In later studies, similar alternative models of the earth as described by Nussbaum and Novak (1976) and Nussbaum (1979) were found among children in different countries (Klein, 1982; Mali & Howe, 1979; Sneider & Pulos, 1983; Vosniadou & Brewer, 1992).

In the often-cited study by Vosniadou and Brewer (1992), their scheme of different mental 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 disc into synthetic models such as the dual earth model, the hollow sphere model, and the model of the earth as a flattened sphere. In these models, aspects from the initial model are combined and synthesized with aspects from the culturally accepted model. The dual earth model was described as two earths, a flat one on which we live and a spherical one that is a planet up in the sky. The hollow sphere model was described as a sphere in which we live on flat ground deep inside.

The third synthetic model was described as a flattened sphere. The fifth model was the scientific model of the earth as a solid sphere.

The children's difficulties in grasping the culturally accepted conception of the earth have been described by what is lacking in the children's reasoning, such as ideas of gravity and unlimited space (Nussbaum & Novak, 1976), or by constraining presuppositions, such as that the ground is flat and that unsupported things fall (Vosniadou & Brewer, 1992; Vosniadou, 1994). These presuppositions are regarded to be based on interpretations of everyday experience, and embedded within a more general theory of naïve physics. The process of conceptual change from alternative models of the earth into the culturally accepted model has been described as a slow process of gradually reinterpreting and abandoning presuppositions (Vosniadou & Brewer, 1992; Brewer, 2008). It has also been argued that children categorize the earth in the ontological category of "physical object" rather than in the category of "astronomical object" (Vosniadou & Skopeliti, 2005). In this case, the process of conceptual change involves a categorical shift that is regarded as a radical conceptual change (Vosniadou, Vamvakoussi & Skopeliti, 2008; cf. Chi, 2008).

Critique of the alternative model approach

In a series of studies it has been argued that children neither have alternative models of the earth nor have constraints in understanding the scientific or culturally accepted model (e.g. Nobes, Martin, & Panagiotaki, 2005; Panagiotaki, Nobes, & Potton, 2009; Schoultz, Säljö & Wyndhamn, 2001; Siegal, Butterworth, & Newcombe, 2004).

From a situated and discursive perspective it is argued that instead of looking at children's answers in interview studies as mirroring their mental models the answers should be regarded as situated and dependent on the tools available to the children as resources for reasoning (Schoultz et al., 2001). In a replicating study, Schoultz et al., (2001) modified the interview situation and used a globe as a resource for the children's reasoning. All children accepted the globe as a model of the earth, and there were no other models of the earth introduced by the children.

Also, in other investigations into children's conceptions of the earth, it has been found that even young children can benefit from scientific information and can express the scientific model of the earth as a sphere surrounded by space (Siegal et al., 2004; Nobes et al., 2005; Panagiotaki et al., 2009). From these results, it has been argued that earlier studies on children's alternative models of the earth have underestimated the children's knowledge (e.g. Siegal

et al., 2004). It has also been argued that before the children acquire the scientific model of the earth their knowledge is at best described as fragmented and inconsistent (e.g. Hannust & Kikas, 2010; Nobes et al., 2005; Panagiotaki et al., 2009; cf. diSessa, 2008). The different results in studies on children's conceptions of the earth have been suggested to be an effect of methodological issues (e.g. Nobes et al., 2005; Panagiotaki et al., 2009; see also Brewer, 2008). It has been argued that children's alternative models of the earth are methodological artefacts affected by ambiguous open questions and drawing tasks (e.g. Nobes et al., 2005; Panagiotaki et al., 2009). Therefore, other interview methods have been used such as three-dimensional model tasks and forced-choice questions (Nobes et al 2003; Siegal et al., 2004). However, there are also rules for how different artefacts should be interpreted. The interpretation of, for example, a three-dimensional model relies on culturally accepted norms for interpretation (Ehrlén, 2008; 2009).

In the majority of studies the focus has been on searching for settled consistent models. With this purpose, answers to interview questions have been coded by predetermined categories assessing consistency in answers. Children who changed their minds during the interview have been coded as inconsistent (e.g. Hannust & Kikas, 2010; Vosniadou & Brewer, 1992). For example, Vosniadou and Brewer (1992) categorized some interviews as mixed models. Hannust and Kikas (2010) suggested that the inconsistency was partly the result of ambiguous questions.

To recap so far, there has been a long tradition of investigating children's conceptions of the earth. In several studies it has been shown that children construct other coherent models of the earth than the scientific or culturally accepted model of the earth as a sphere surrounded by space (e.g. Nussbaum, 1979; Vosniadou & Brewer, 1992). These studies have focused on specific conceptions that are missing or constraining the children's understanding. From other strands of research it has been argued that children's alternative models are methodological artefacts (e.g. Nobes et al., 2005; Panagiotaki et al., 2009). It has also been argued that children's knowledge, rather, is fragmented and inconsistent before they acquire the scientific model of the earth (e.g. Hannust & Kikas, 2010; Panagiotaki et al., 2009). Most studies within the field have used predetermined questionnaires and assessed the degree of consistency and correctness by classifying the answers into predetermined categories.

Compounded models and differentiation

In a small-scale study, children between six and eight years of age were interviewed about their conceptions of the earth (Halldén et al., 2002). In the inter-

views, different communicative tools were used such as clay, pictures, a pancake, and drawings. The hollow-sphere model of the earth was discussed in terms of a compounded model. The children brought together their experiences of the nearby ground and information of the spherical earth surrounded by space into one single model, the hollow sphere. Thus, they constructed a single model that was applicable to different contexts. The hypothesized development was a differentiation within the compounded model leading to new models. It was argued that the culturally accepted view of the earth is a differentiated model, that is, we use different models, depending on context. Thus, rather than a linear abandoning of one model in favour of another, the process of conceptual change was regarded as differentiating within compounded models. A conclusion was that the process of conceptual change is about the ability to differentiate between contexts and to relate new information to adequate contexts (Halldén et al., 2002; see also Halldén, 1999; Halldén et al., 2013). Based on this prior research, the empirical study reported in this thesis was conducted to further explore contextualization in the process of conceptual change.

Aim and research questions

The overall aim is to describe children's conceptions and conceptional development in its own right. In specific the aim is to investigate processes involved in conceptual change with the purpose of further exploring contextualization as a crucial factor in conceptual change. The questions addressed, are how children's models relate to contextualization; how incoherence relates to contextualization; and how continuity in reasoning relates to contextualization.

Research questions:

Which models of the earth do the children construct? (The main focus in Article 3)

How are the children's models developed by processes of integration and differentiation? (The main focus in Article 3)

How do the children restructure and reorganize their already embraced beliefs by processing incoherencies within conceptional structures? (The main focus in Article 2)

To what extent is there continuity and/or discontinuity in the processes of conceptual change? (The main focus in Article 1)

Method

In order to grasp the process of conceptual change, the empirical study was designed as a longitudinal investigation over a period of three years. Preschool children were chosen to participate in the study. The choice to focus on preschoolers was to catch as early a conceptual understanding as possible. The children were interviewed from the year they turned four years old. Younger children than that would probably have been difficult to interview. The children were interviewed about their conceptions of the earth every spring-time over three years. Since several decades, as pointed out above, it has been shown fruitful to investigate children's conceptions of the earth within the research field of conceptual change. It can be noted that in this study the choice of the concept 'earth' is intended as an example of a concept in order to develop a better understanding of processes involved in conceptual change.

Participants

The children participating in this study came from five different preschools in two municipalities in the area of Stockholm, Sweden. During the first year of investigation, 37 children participated in interviews; in the second year, 35 children were interviewed; and in the third year, 29 out of the original 37 children were interviewed. Thus, from the first to the second year two children dropped out, and from the second to the third year an additional six children dropped out. In all cases, the children who dropped out did so because they had left the preschools involved in the study. Also, other children changed preschool during the period but then between the preschools involved in the study and therefore they were followed with interviews all three years.

The children were interviewed from the year they turned four years old to the year they turned six years old. When the first year interviews were conducted the children's ages ranged from 3:5 to 4:5 (four years and five month). It is worth mentioning that at the time for the first interview 19 children (of the total of 37) had not yet reached their fourth birthday. The children were interviewed at about the same time every year. Thus, the second year the children's ages ranged from 4:5 to 5:5, and in the third year from 5:5 to 6:5.

A greater number of girls than boys participated in the study (see Table 1). The children came from different socioeconomic backgrounds. Their parents' backgrounds ranged from unemployed to employees and from minimally educated to high trained. Gender and social background are not considered in the analysis because focus is on general considerations regarding conceptual development and conceptual change.

The interviews

Table 1 presents a year-by-year overview of the participants, the kinds of interviews, and the artefacts used in the interviews. All interviews were conducted in a secluded room at the children's respective preschools. The interviews were videotaped by a stationary camera (Sony DCR-HC40E/s). All interviews were conducted by the same interviewer (the author). The framings of the interviews each year are described in detail in article 1, 2, and 3. However, in the following I will give a brief description of how the interviews were conducted.

In the first year of the investigation, the children were interviewed twice with two different kinds of interviews. In the first interview session, 33 children were interviewed individually and four children were interviewed in pairs. The four children who were interviewed in pairs instead of individually were very reticent and it was believed that interviewing them in pairs would allow the children to support each other. In the other interview session, the children were interviewed in small groups of two or three children. In the second and third year of the investigation, each child was interviewed individually.

When Piaget (1929) developed the clinical method, his focus concerned both how to conduct interviews and how to analyse them. Piaget was clear in his statements that interviews with the purpose of revealing children's conceptions could not be based on highly structured and predetermined questionnaires and each answer could not be related to a scale or a schedule.

In this study, all of the interviews were broadly framed in the same manner with regard to main themes such as what the earth is and where people live on the earth. The interviews were semi structured. There were no certain number of questions based on a predetermined questionnaire. The intention was to conduct the interviews in a manner as close to a natural dialogue as possible. This required the interviewer to try to understand the child's meanings during the interview, that is, what he or she was talking about as we do in an ordinary conversation. This involved trying to be an attentive listener, posing clarifying questions, and challenging and probing the children with further questions depending on what they had expressed. Silence was an important feature in the

interviews in order to give the child time to think, but also in order to give the child the possibility to be the one who resumed the conversation (cf. Doverborg & Pramling, 1993). This turned out to be rewarding in the sense that the children sometimes introduced new information or topics of conversation. However, for the interviewer this is a balancing act between allowing the child to talk freely and maintaining the focus of the interview.

No artefacts were used in the introductory portion of each year's individual interviews. This part of the interviews became longer and more elaborate each year. However, different artefacts were then introduced in order to offer the children a variety of communicative tools. Every year the children were asked to draw the earth, and a terrestrial globe was used in interviews each year. In addition to those artefacts, a coloured picture of the earth (circular, with some continents indicated) was used the first year. The second year a simple coloured map of Sweden was used that also indicated the other Nordic countries in grey (an illustration by Jonsson in Larsson, 2003), and the second and third year there was also a satellite photo of the earth used (photographed by Apollo 17 en route to the moon).

When the children were asked to draw the earth, the conversation continued during the drawing and the interviewer asked questions about the drawing. The different artefacts representing the earth were introduced one by one and almost always by the question "What is this?". The conversation continued with a focus on the representation. In front of the terrestrial globe, common questions concerned whether the terrestrial globe represents something that exists for real, and, if so, where to find it, and where people and the children themselves live on earth. In front of the terrestrial globe and the other representations, the conversation often also concerned countries and the children's travel experiences. Sometimes these subjects were introduced into the interview by the interviewer and sometimes by the child. The satellite photo supported the child in talking about the surroundings of the earth.

The videotaped sessions were transcribed by the interviewer using the program Transana (Chris Fassnacht and David Woods, Wisconsin Center for Education Research, Madison).

TABLE 1: Overview of participants and interviews, year by year

	Year 1	Year 2	Year 3
Participants	37 (26 girls, 11 boys)	35 (24 girls, 11 boys)	29 (21 girls, 8 boys)
Age range (year: months)	About 3:5 to 4:5	About 4:5 to 5:5	About 5:5 to 6:5
Kind of interview	Interview 1: 33 children were interviewed individually and four children were interviewed in pairs Interview 2: 34 children were interviewed in small groups of two or three children	35 children were interviewed individually	29 children were interviewed individually
Artefacts used in the interviews	Interview 1: Drawing, a coloured picture of the earth Interview 2: A terrestrial globe	Drawing, a terrestrial globe, a simple map of Sweden, and a satellite photo of the earth	Drawing, a terrestrial globe, and a satellite photo of the earth

Ethical considerations

Participation in the study was, of course, voluntary. However, the children in the study were too young to take a position on the study's purpose and on what the interviews would be used for. Accountable in the municipalities as well as the responsible leaders at the preschools gave their consent to conduct the study in the respective preschool. The parents were informed about the aim of the study and received a brief description of the design of the study. The parents who were interested had to submit a written consent that their children had permission to participate in the study. Those who chose not to participate could do so without it being known to anyone other than the researcher. Participation could, of course, be aborted at any time during the ongoing investigation. At the time of the first interview, it turned out that one child did not want to be interviewed. This child was left out of the study. There was no other child who withdrew participation.

All participants were guaranteed anonymity. When the focus of the research interest is not on the individual but on separated processes in an individual's thinking, anonymity was relatively easy to achieve. In the transcription the children were labelled with numbers. In all reporting of results the children are labelled with these numbers or when using names these have been fictitious. When the children have mentioned names, addresses, or other kinds of private information these have been left out or made anonymous by fictitious names.

Analysis

The same process of analysis was used to produce the results in all three articles. The procedure for interpretation and analysis is described in detail in the articles. In the following section, the framing of the method for interpretation will be described followed by the procedure of analysis of the data material.

Method of interpretation

The method of interpretation used in analysing the data material in this thesis has been developed in a series of previous studies and is referred to as intentional analysis or good-reason assay analysis (for a detailed description, see Halldén, 1999; Halldén et al., 2007; Halldén et al., 2013). The method has been developed for qualitative analysis in a constructivist perspective. Thus, the object, and the focus of the analysis, is the acting individual. The method

takes its departure from the assumption that human action should be understood intentionally (von Wright, 1971). In order to understand why an individual acts the way he or she does in various situations, it is necessary to ascribe meaning to his or her behaviour, that is, to regard it as intentional (Halldén et al., 2013).

According to von Wright (1971), the action has an internal and an external dimension. The internal dimension consists of what von Wright called internal and external determinants, which together can be seen as the individual's intention in action (Searle, 1983). In intentional analysis, these determinants are considered in what are called competence oriented and discourse oriented resources, respectively. Competence oriented resources refer to individual beliefs, abilities, and wants or desires. Discourse oriented resources refer to how the individual apprehends the situation and includes conceptions of duties, norms, and opportunities. In the interpretation of an individual's actions, the method makes it possible to take into account factors pertaining to the individual's cognitive structure as well as factors pertaining to culture and situation. In individual action also speech acts are included. Thus, in the interpretation of individual action, we can assign actions to competence oriented resources, that is, cognitive contexts, and to discourse oriented resources, that is, cultural and situational contexts (Halldén, 1999; Halldén et al., 2007).

This method of interpretation is of relevance for interpretation of interviews as well as for interpretation of data obtained in educational settings. Halldén (1988a) stated that "if we are to understand a learning outcome, we have to take into consideration the learner's conceptions of the learning task" (p. 123). To understand the student's interpretation of a learning task in school, we can look at the student's action as solving problems or fulfilling projects. In a series of studies (e.g. Halldén, 1988b; Halldén, 1999; Österlind, 2005; Scheja, 2006), it has been shown that students' different interpretations of a task in an educational setting often make them engage in problems other than those the teacher had intended by presenting the task. This distinction between task and problem can effectively describe what a learner is trying to achieve in an educational setting (Halldén et al., 2013). In an interview, in a similar manner, the problem or issue is what the interviewee is trying to accomplish. The issue stems from the interviewee's interpretation of the interviewer's questions or the interviewee's interpretation of the discussed subjects. Thus, in order to understand individuals' ways of reasoning, the focus in the analysis is on examining what the individual is trying to achieve. This means looking for which problems or issues utterances are relevant to and deciding on an interpretation that makes the utterances most reasonable and coherent (cf. Davidson, 2001; see also Article 2 in this thesis).

The procedure of analysis

The analytical process began during the interviews when trying to understand the children's meanings as we do in ordinary conversations. In ordinary conversations we regard individual's utterances as a means to achieve something (cf. Halldén, 1988a). This means that we ascribe an intention to the individual that makes the utterances meaningful. Trying to understand an individual is to ascribe coherence to him or her. During the interviews, the interviewer looked for the children's coherence and in a similar way the children tried to understand the interviewer's questions, and out of this the conversation could continue. This can be regarded as a negotiating process (Fontana & Frey, 2005). The analysis then proceeded by using the transcripts and videotapes of the interviews.

In order to detect the children's conceptions of the earth and their reasoning about this phenomenon, the analysis progressed by identifying the children's problems or issues and how these were solved. In the articles constituting this thesis, the word 'problem' is sometimes replaced by the word 'issue'. However, there is no significant difference between the uses of these words. The main problem to solve in the interviews was how to answer the question "What is the earth?" (See Article 3 for a more detailed description). Trying to solve this problem can be regarded as constructing a conception of the earth. However, in analysing the utterances there appeared to be a web of problems that were relevant to the main problem. Deciding on which subjects the children's utterances were relevant to, and what problems they tried to solve, required reading through the transcriptions numerous times. This process of analysis also involved going back to the videotapes of the interviews to look for the children's and the interviewer's gestures. For example, it was sometimes important for deciding on an interpretation to scrutinize where they were pointing at the drawings and other representations of the earth used in the interviews.

Trying to understand the rationality and coherence in the children's reasoning required examining how problems were solved in regard to different contexts. Thus, the analysis involved deciding on the children's contextualization of knowledge (Halldén, 1999; Halldén et al. 2013). The dimensions of the contexts relevant to this study are extensively described in Article three. Conceptual understanding is looked upon as a synchronic processing of different interdependent contexts. There is an overall context constituted by three interrelated contexts. There is a conceptional context, that is, idiosyncratic theories, there is contexts for description and explanation, that is, field of application, and there is these two contexts adjusted to a sociocultural context. These analytical distinctions made it possible to identify incoherencies with regard to the different contexts.

In understanding the process of change over time in the children's reasoning a diachronic dimension of the different contexts was also taken into account in the analysis. In the analysis, the diachronic dimension was considered by examining the order in which the children developed different models of the earth and the process of their reasoning leading away from one model into another. In Article 1, the analysis of an individual child's reasoning also involved to examining the degree of continuity in the child's reasoning. This was done by identifying seeds of ideas in one interview that were more clearly articulated in a later interview, as well as traces of ideas in later interviews that had been more clearly articulated earlier.

In the analysis, a conceptual context, that is, scientific theories, was then also taken into account. This means that there was a normative aspect to the analysis in that the children's idiosyncratic conceptions were evaluated according to their degree of similarity with the scientific or culturally accepted concept of the earth.

Summary of the articles

The thesis is based on an empirical study presented in three articles.

The overall aim of the study is to describe children's conceptions and conceptional development in its own right. The purpose of investigating the processes involved in conceptual change is to further explore contextualization as a crucial factor in conceptual change.

In Article 1, an individual child's conceptions and conceptional development is described. The focus in this article is on continuity and/or discontinuity in this development process.

In Article 2, the children's restructuring and reorganization of already embraced beliefs is described. The focus is on the children's processing of incoherencies within conceptional structures.

In Article 3, the children's constructions of models of the earth, and the development of the models is described. The process of conceptual change is described as processes of integration and differentiation.

In the following a short summary of each article is presented. The articles are included in their entirety at the end of this thesis.

Article 1: A longitudinal study on the processes of conceptual change in a four- to six- years old child

The article describes an individual child's conceptual development of the earth over a three year period. The overall aim is to describe how a child understands a complex phenomenon like the earth. To understand the process of changing ideas about this phenomenon, the focus is on a detailed description of the child's reasoning and the information involved in her reasoning.

The results show that there was continuity in the child's reasoning over time. At a model level, the child began with a model of the earth as "another moon"

far up in the sky. This model then led into a model of a hollow sphere, and finally to a model of a sphere more similar to the normative or culturally accepted model. A fine grain size analysis of the individual child's conceptual development made it possible to identify continuity in her reasoning that was not only related to well-defined models but could also be seen in the form of seeds of upcoming models and in traces of earlier conceptions. For example, in the first- and second- year interviews there were occasional indications of reasoning about living inside the spherical earth. However, the hollow sphere model of the earth was clearly expressed in the third year interview. There were also seeds of the normative model in the second year interview that were elaborated on to a greater extent in the third year interview. In the same manner, there were indications of traces of models in later interviews that had been emphasized in the first year interview.

The continuity was related to different kinds of contexts. The development of conceptions within the web of conceptions, that is the conceptional context, enabled the transition from one model to another. For example, in the first-year interview, when the child was four years old, she had a conception of her house as too big for a cosmic body far up in the sky. The continuously growing understanding of relational concepts made new models possible, and even necessary. Interwoven with this were also a lot of information of different kinds such as the spinning of the earth and that we cannot breathe in space.

The continuity in the child's reasoning was also related to contexts of applicability, that is, contexts for description and explanations. For example, the child consistently equated the earth with the moon when relating the earth to an astronomical context for description and explanation. This was the case the first and second year of investigation. There was also a situational and cultural context involved. For example, during the course of the investigation the child developed her understanding of how to interpret artefacts such as different representations of the earth as well as her ability to draw pictures (cf. Ehrlén, 2008; 2009).

A conclusion in the article is that conceptual change is a complex process. There is a web of conceptions composed of at least three entities that interact with one another: the target conception, the conceptions scaffolding the target conception, and contexts for description and explanation. These entities are interrelated in that they presuppose each other and are dependent on each other. Thus, the restructuring of already embraced beliefs in the process of conceptual change is made within a conceptional context as well as between different contexts. In the process, each context develops over time, but, also, in this development each context is dependent on the development of the other contexts.

The result indicates a degree of core stability in the child's reasoning regardless of when different well-defined models became possible or impossible. The result also indicates that the child's reasoning was not entirely related to the situation.

Article 2: Coherence and contextualization in the process of conceptual change

In the article conceptual change is described as a multifaceted process involving the restructuring and reorganization of already embraced beliefs. The focus is on conflicts or incoherencies that arise within a conceptional system when a learner tries to use it for description and explanation.

The aim of the article is to present evidence for the claim that restructuring and reorganizing within already embraced beliefs, that is, conflicts or incoherencies within conceptional structures, is a motor for the process of conceptual change.

Preschool children were interviewed about their conceptions of the earth annually from four to six years of age. The children's ideas about the earth changed as they realized the incoherencies of the model of the earth they advocated. The children processed a lot of conflicting information. However, there does not appear to be any specific conflict that causes a process of conceptual change to occur. The children brought together information that concerned knowledge of facts, as for example lava inside the earth. They also actualized highly theorized concepts, as for example gravity, atmosphere, production of oxygen, and country. In addition, they were concerned with issues related to concepts such as distance, size, inclusion, and scale. These ideas were interwoven with occasional ideas like fear of darkness, fear of being hit in the head by other planets, etc. Thus, all of these interwoven ideas had to fit together simultaneously. However, some bits and pieces came into conflict with the models being tested. For example, facts that do well in an existing model may not fit into models that are tried out to account for information that does not suit the previously articulated model. Oxygen, or air, required for breathing is accounted for in the hollow sphere model but is difficult to account for in the normative model without additional information about some kind of atmosphere or similar entity. At the same time, living on the surface of the earth solves the problem of lava being inside the earth, which is not accounted for in the hollow sphere model.

The conceptual understanding is described as being related to contexts of applicability. As far as an astronomical and a terrestrial context for application

could be separated from each other, there was no problem for the children to account for where people live. On the other hand, when it became apparent to the children that where people are living has to be accounted for in the same context for application, that is, the astronomical context, this challenged their conceptional context; how to account for the fact that we can live all over the earth and get air despite the fact that the earth in space.

It is concluded that conceptual change is affected by the incoherencies that are revealed in the relation between three entities, that is, two or more different facts or conceptions that conflict when related to one specific context of applicability. Conceptual change involves a simultaneous processing of information and complex conceptions as well as revisions and changes at a model level, and all of this processing is related to contexts for description and explanation.

Article 3: A structural view on the emergence of a conception: Conceptual change as radical reconstruction of contexts

The aim of the article is to describe the children's conceptions of the earth and their conceptional development, as well as how these are related to contexts for applicability. The children's conceptual development over the three years of investigation is described as a process of reorganization of already embraced knowledge.

The results showed that the children began with two different and unrelated conceptions. One conception was of a spherical earth far up in the sky or space without human beings, and the other conceptions was of the nearby ground where we live down here. Several children kept these conceptions apart and never used the same word for the 'earth' up there and the 'ground' down here. At a model level, the earth up in the sky and the ground down here can be regarded as two distinct and coherent models. It is also argued that these two models are coherent descriptions within different contexts, that is, a terrestrial context and an astronomical context, respectively.

Several children later integrated these two earlier distinct conceptions into one single conception of the earth that they often expressed as a hollow sphere model of the earth. The model of the earth as a hollow sphere in which we live on flat ground has also been found in several other studies (e.g. Nussbaum, 1979; Vosniadou & Brewer, 1992). However, rather than looking at the hollow sphere as a misconception that is constrained by certain presuppositions (Vosniadou & Brewer, 1992), the model can be looked upon as a rather good

invention for accounting for explanations within different contexts by the use of one single model.

Some children, especially during the last year of the investigation, differentiated within the compounded conception or model. These children expressed the normative conception of the earth as a sphere surrounded by space with people living all over the surface of the earth. They 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. From these results it was possible to propose a general pattern for conceptual change as a process of integration and differentiation as illustrated in the figure below (Figure 3):

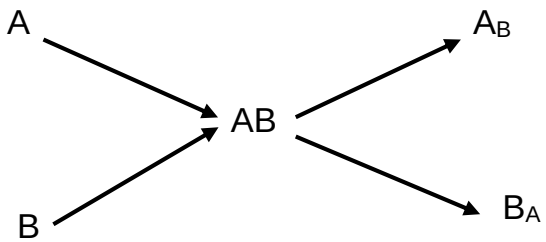

Figure 3. Two conceptions, A and B, integrated into one compounded conception, AB, that is differentiated into two or several new conceptions, A_B and B_A, but now related to each other (Article 3, figure 6, Larsson & Halldén, 2010b).

The order of development, from two distinct conceptions, A and B, into one compounded conception, AB, differentiated into two new conceptions, A_B and B_A, was found within the individual child as well as on group level. This does not mean that each developmental step was found in the interviews with each individual child, but no child was found to develop in another order than this.

In figure 1, the A and B indicate two distinct conceptions, that is, a conception of an earth up in the sky (A), and a conception of the nearby ground (B). These conceptions are related to two distinct contexts for applicability, an astronomical context and a nearby, or terrestrial context, respectively. The AB indicates the integration of the two earlier distinct conceptions into one single conception that the children often expressed as a hollow sphere model of the earth.

Within the hollow sphere model, the astronomical context and the nearby/terrestrial context were accounted for simultaneously. The A_B and B_A indicate the differentiation into two or several new conceptions. The astronomical context and the nearby/terrestrial context were now distinguished but also related to one another (as indicated by subscript letters in Figure 3). This means that different models were used depending on context.

A conclusion drawn in the article is that the process of conceptual change is best understood as radical reconstructions of already embraced ideas. The results direct the focus of conceptual change from specific conceptions to structural changes. The reconstruction is made within conceptional contexts as well as between different contexts, that is, conceptional contexts on the one hand and contexts for description and explanation on the other. Thus, there is a simultaneous processing of conceptions, that is, conceptional contexts and the adjustments within these and these adjustments are made in relation to different contexts for applicability.

Summary of results

Children's models of the earth

It has been shown that children construct alternative models of the earth. The models found among the children are almost similar to those found in a series of earlier studies (e.g. Nussbaum & Novak, 1976; Nussbaum, 1979; Sneider & Pulos, 1983; Vosniadou & Brewer, 1992). However, the results diverge from earlier studies in that no dual model of the earth was found. Thus, there were three well-defined models of the earth identified; an earth up in the sky, a hollow sphere, and a model more similar to the normative one, that is a sphere in space with people living all-around the surface. However, the results support the order of model development hypothesized earlier by Vosniadou and Brewer (1992).

Coherence regarding conceptional structure

It appeared that there were a range of interdependent conceptions of different dignity involved in the children's reasoning that they brought into a coherent whole. There were simple facts, ideas that can be related to theorized concepts, and logical and metrical relations such as distance, size, inclusion, and scale. The children used their existing knowledge to handle incoherencies within conceptional structures in order to re-establish coherence and construct another reasonable model of the earth. They handled logical incoherencies as well as contradictory beliefs. However, there does not seem to be any specific conflict that caused conceptual change to occur.

The interdependence of involved conceptions enabled certain models of the earth and made other models untenable. The interdependence of involved conceptions also made certain concepts insignificant to consider at a certain time during the process. There are conceptions that does not have to be considered until other interdependent conceptions within the web of conceptions are developed. The results show that for the children in the study their conceptional coherence was promoted by their resources to find adequate contexts for description and explanation, that is, applicability.

Synchronic interdependence of contexts

Coherence and consistency in the children's reasoning was related to different kinds of interdependent contexts. The children's conceptional contexts were related to their contexts of description and explanation. The children sometimes oscillated between different contexts for description and explanation. This was done in a quite consistent way. Conceptional contexts and contexts for description and explanation were interdependent in the following ways:

1) The astronomical context for description and explanation and the nearby/terrestrial context were kept apart by two different, unrelated, conceptional contexts, one of the earth and another of the nearby ground. This means that two different coherent models were used depending on contexts for description and explanation. The two conceptional contexts were not related to each other and were adjusted to two unrelated contexts for description and explanation. In addition, the children occasionally dismissed or avoided one of these contexts for description and explanation to ensure coherence.

2) The astronomical context and the nearby/terrestrial context were accounted for simultaneously, by the use of one single conceptional context. This means that the two earlier unrelated models were integrated into one single model, a hollow sphere model of the earth, which is functional for explanations of the astronomical context as well as the nearby/terrestrial context.

3) The astronomical context and the nearby/terrestrial context were distinguished but also related to one another. This means that different conceptional contexts or models were applied depending on the contexts for description and explanation.

A diachronic dimension and stability

At a model level, the pattern of development indicates that there is a certain amount of stability in that the different models of the earth were not suggested in a totally haphazard way. The order of model development found in the study was from the earth up in the sky into a model of a hollow sphere. Some children ended up with a model of the earth that can be regarded as the culturally accepted model. During the three year period of investigation, some children expressed all three models in the order described here. Other children only expressed one or two models, but the order of model development can be regarded as linear in that no child in the study developed in any order.

Furthermore, it has been shown that there was continuity in the children's reasoning not only with regard to the development of well-defined models of the

earth but also in the form of seeds of upcoming conceptions and in traces of earlier conceptions. However, this does not mean that the models should be regarded as completely stable models, but that there seems to be some core stability in the children's reasoning that is not entirely related to situation. Rather, there seems to be a gradual development of models in which later models are an effect of earlier ones, which, in turn, provide seeds for later models.

Concluding discussion

The focus in this thesis has been on the learner's resources in the process of conceptual change rather than on what is missing or constraining her or his reasoning. The learner's resources were original emphasised by Driver and Easley (1978) who talked about alternative frameworks and who requested more focus on learners' ideas and reasoning in their own right rather than on the learners' "misconceptions" or incorrect ideas.

Thus, the overall aim has been to describe the learner's alternative frameworks in its own right, that is, to find the rationality in the learner's ways of reasoning. In doing so, contextualisation has presented itself as a prominent factor. There is the setting in which a conversation occurs. Every setting wears cultural tools and conventions that invite those involved in the conversation to perform in different ways. In an interview setting, the interviewee thus is invited to answer questions within the frames and affordances decided on by the interviewer. However, these frames and affordances have to be interpreted and understood by the interviewee. To this end, the interviewee has at her or his disposal a set of values, a conceptional structure, and a repertoire of questions that are to be answered or a set of issues that have to be explained. Out of this, as an interviewee, I have to decide on what question I am supposed to answer or what issue I am supposed to comment upon.

Thus, in order to understand students in their own right, we have to account for three different contexts. First, there is the sociocultural context. Second, there is the conceptional context, and, third, there is the context for description and explanation. The sociocultural context restricts and affords what can be talked about. But, within this framework, the students make choices and these choices are enabled as well as constrained by their repertoire of conceptional contexts and their ideas of contexts for description and explanation. Thus, it can be concluded that the process of conceptual change consists to a large extent of a restructuring and a reorganization of already embraced beliefs. These reconstructions and reorganizations are made within conceptional contexts as well as between different contexts, that is, conceptional contexts on the one hand and contexts for description and explanation on the other, and all of this is framed by a social and cultural context.

Of course, the different contexts discussed here have already been paid attention to in contemporary research. However, the results from this study underline the interdependence of these contexts, and the simultaneous development within and between contexts and how this constitutes an overall embracing context. Thus, the results of this study direct the focus of conceptual change from specific conceptions to structural changes.

Mainstream research within the field of conceptual change has focused on what is hindering a conceptual change from coming about. The dominant normative line of research has primarily been focused on how idiosyncratic conceptions differ from scientific concepts. The search has been for what is missing in the learner's reasoning, or what in the learner's conceptions that are constraining. Although there is an agreement within the research field that conceptions are embedded in larger conceptual structures (e.g. Vosniadou, 1994) a significant amount of effort has focused on specific conceptions within this web of conceptions. For example, there has been the identification of specific threshold concepts (e.g. Meyer, Land, & Davies, 2008), specific presuppositions (Vosniadou, 1994; Vosniadou & Brewer, 1992), and so forth. Another agreement within the field seems to be that "conceptual change has to do with major restructuring of already existing knowledge" (Duit, 1999 p. 263). This restructuring process has been described as the changing of ontological categories (Chi, 2008), the abandoning of presuppositions (Vosniadou, 1994), the experience of anomalous data (Mason, 2001), etc. A similarity in these approaches is thus implying that conceptual change is a linear process caused by a single factor.

From this study, it appears that there are no single factors hampering a conceptual change to occur. Rather, there are continuous reconstructions of embraced ideas to make them constitute meaningful wholes. This actualizes modelling processes, questions of coherence and stability in the learner's reasoning, and questions about how, in research, we try to understand learning.

Children's modelling of the earth

In contrast to earlier studies (e.g. Vosniadou & Brewer, 1992), we found no dual earth model among the children (cf. Juuti, 2013). Rather, it was found that children have an unequivocal conception of the earth as an astronomical entity up in the sky and another unequivocal conception of the ground down here. Thus, in these children's minds there was no model that had to be abandoned in favour of a new one. Rather, their problem was how to relate the two models to each another. This gives rise to the claim that conceptual change is a process of integration. For several of the children, this integration resulted

in a hollow sphere model, similar to the one that has been reported in several studies of children's conceptions of the earth.

Moving from a hollow sphere model to a normative model also does not presents itself as an abandoning of one idea in favour of another. Of course, the idea that we live inside a hollow sphere has to be abandoned but the abandoning appears to be contingent on realizing that we are talking about the same thing but from different perspectives, or different contexts for description and explanation as it is worded in this thesis. Thus, it seems more appropriate to talk about this specific conceptual change as a process of differentiation, that is, using appropriate models for different contexts for description and explanation.

The conceptual changes demonstrated by the children in this study lend to a description of conceptual change as a process in which integration and differentiation are the core processes. How far this claim is valid in other instances of conceptual change is a question for further research. Is it a reasonable description for conceptual change in other age groups and is it a common feature of conceptual change irrespective of subject matter?

Thus, in this thesis there are radical differences in the theorizing of model construction and the process of development compared to those proposed in earlier studies. The process of model change in earlier studies has been described as gradual revisions of presuppositions (Vosniadou & Brewer, 1992; Vosniadou, 1994), and as a shift from one ontological category into another (Vosniadou & Skopeliti, 2005; Vosniadou et al., 2008; cf. Chi, 2008). Thus, these studies have described a linear abandoning of one model in favour of another and this conforms to the model of conceptual change as a replacement of one conception in favour of another conception (Posner et al., 1982; and Strike & Posner, 1992).

Rather than a linear process caused by a single factor, the results from this thesis present evidence for a structural view on the process of conceptual change. The results suggest that it might be fruitful to look at the process of conceptual change as a restructuring and reorganization within and between different contexts. These results confirm earlier arguments that stressed that contextualization and coherence within different explanatory frameworks are of utmost importance in the process of conceptual change (Halldén, 1999; Halldén et al., 2013; Halldén et al., 2002). In this thesis, contextualization as a crucial factor in conceptual change has been evaluated by fine grain size analysis describing the interdependence of contexts in a synchronic dimension as well as in a diachronic dimension.

The question of coherence in conceptional contexts

The debate between knowledge-as-theory perspectives and knowledge-in-pieces perspectives concerns questions of coherence and consistency in the learners' knowledge structure.

Most studies on children's conceptions of the earth have searched for established and consistent models of the earth. The results from these studies are conflicting. On the one hand, it has been shown that children construct coherent alternative models of the earth (Vosniadou & Brewer, 1992). On the other hand, it has been argued that children's knowledge rather is fragmented and inconsistent before they acquire the scientific model of the earth (e.g. Hannust & Kikas, 2010; Panagiotaki et al., 2009). This might be an effect of methodology in that coherence in thinking has been related to well-defined models. Thus, these studies conform to the normative line of research assessing degree of correctness in answers rather than understanding the reasoning in its own right (Driver & Easley, 1978). Here, it is argued that if we want to understand the reasoning in its own right we have to realize that consistency and "coherence in answers given can follow other rules for coherence than those that are scientifically or culturally accepted" (Halldén et al., 2007, p.37). Thus, we have to look for coherence from the learner's point of view and try to find the learner's rationality in what he or she is proposing. In this study, coherent models has been described, but then by taking the individual's contexts of description and explanation into account. Not running the risk of underestimating the learner's resources, coherence has to be looked upon in relation to coherence with regard to different kinds of contexts.

Most of the research on cognitive conflict has focused on conflicts between the individual and the world (e.g. Chinn and Brewer, 1993; 1998; Chinn & Malhotra, 2002; Hewson & Hewson, 1984). Here, more emphasis has been put on conflicts or incoherencies within conceptual structures. Lee and Yi (2012) have stressed that cognitive conflict rather than being a conflict between what is right or wrong is a complex event involving relations among different kinds of resources within a conceptual structure. Thus, they confirm the results in this thesis. Furthermore, it has been shown that incoherencies are revealed in the relation between three entities, that is, two or more different facts or conceptions that conflict when related to one specific context of applicability.

Identifying what issues or problems the children were trying to solve involved deciding on their contexts for description and explanation. In the material, there are mainly two different contexts of description and explanation actualized in the interviews, an astronomical context for description and explanation and a nearby or terrestrial context, respectively. The children's solutions to

incoherencies were intimately related to these two contexts for description and explanation. Coherence could be maintained by keeping different contexts for description and explanation apart as being unrelated, or by accounting for different contexts simultaneously, or by differentiating between contexts. This can be one explanation for why efforts at inducing cognitive conflict rarely result in conceptual change (Limón & Carretero, 1999). If the learner is to realize a state of cognitive conflict, contradictory facts or conceptions have to be related to one specific context for description and explanation

The question of stability in conceptional contexts

When different contexts are considered, a kind of stability in the children's thinking can be revealed. The fixed order of development of models as well as the seeds of later ideas and traces of earlier ideas both speak for a kind of stability. Even if there are no fixed models that endure over time, there appears to be issues that afford long-lasting processing. These issues are actualized by bits and pieces of information that need to be brought into coherence and related to contexts for description and explanation. Thus, stability seems to have more to do with issues emerging from structural circumstances than with the entertainment of specific models or conceptions. Consequently, it looks like the issues and problems have a certain amount of stability rather than their solutions expressed as specific models and conceptions. Thus in research we have to face the paradox of looking for stability in cognitive structures that, at the same time, are almost totally in flux.

Grain size in research on conceptual change

The question of grain size in analysis within research on conceptual change has been raised (diSessa, 2008: 2013; diSessa & Sherin. 1998). The question discussed is at what grain size the object of analysis is to be performed. It has been argued that conceptual structures and conceptions or preconceptions are too complex to account for the processes involved in conceptual change. Rather, the object of analysis should be looked for at a sub conceptional level (diSessa, 2013). Thus, that is to ask for the level of analysis on a theoretical basis.

According to what is argued in this thesis, the concept of conception is a construct that can range from simple ideas to complex structures of ideas (Article 2). It is argued that for the purpose of studying conceptual change, it is arbitrary when the complexity of ideas turns into a conception. If accepting this

line of reasoning, there are no theoretical grounds for deciding on a particular grain size.

Grain size can also be discussed, however, in terms of at what level of detail an interview protocol should be analysed. Here, the conclusions from this study are that this ought to be done much more thoroughly than is often the case. Probably, we have to go as far into the details as possible to determine what an interviewee is trying to accomplish in an interview. This also means to gather rich data sets in order to do justice to an individual learner's struggle in understanding something entirely new. More indebt studies of single individuals are needed.

In a way, the main conclusion from this study is a triviality. In effect, it has been argued that in order to understand another human being we have to come to terms about what we are talking about. However, it appears that such coming to terms is a difficult commitment. This difficulty is probably due to an overabundant interest in what is right or wrong in thinking, which is the normative line of research on conceptual change. By focusing too much on what is right or wrong according to a normative view, we run the risk of overlooking the rationality in the learner's own reasoning. Or as Davidson phrased it, "To see too much unreason on the part of others is simply to undermine our ability to understand what it is they are so unreasonable about," (Davidson, 2001, p.153). Thus, in research as well as in teaching we should be more curious about how people think and what they are thinking about rather than what is right or wrong in their thinking.

So as not to underestimate our interlocutors and to do justice to their thinking we have to engage in what are they thinking about, that is, what issues they are engaged in, and how they navigate in order to find a solution to their problems. In this we are to search for the learner's contexts for description and explanation. It is probably also by this that we can find a stability in the learner's reasoning, that is a stability in the patterns of reasoning related to issues. There was a pattern in the children's reasoning when confronted with the issue of the shape of the earth. Probably, it is possible to discern enduring patterns of reasoning also with regard to other issues. Being confronted with what in the student's view is a specific issue, in interpretation actualizes specific contexts for description and explanation, specific conceptional resources, and sociocultural resources. Thus, rather than looking for stability in conceptions, it appears fruitful to look for what kind of reasoning is evoked in relation to the apprehended issue.

Sammanfattning

Ett strukturellt perspektiv på begreppsförändring

Integrering, differentiering, och skapande av sammanhang som centrala aspekter i individens meningsskapande

Avhandlingen bygger på en longitudinell studie om förskolebarns begreppsutveckling och begreppsförändring. Resultaten från denna empiriska studie presenteras i tre artiklar som binds samman i en kappa. Avhandlingen rör centrala frågor inom forskningsområdet begreppsförändring (*conceptual change*). Barnen i studien intervjuades om sina föreställningar om jorden. Inom forskningsfältet har det visat sig fruktbart att studera barns föreställningar om jorden för att förklara centrala delar i begreppsförändringsprocessen. I avhandlingen är fokus på processer involverade i begreppsförändring och begreppet jorden används som ett exempel för att beskriva begreppsförändring.

Bakgrund

Forskning om lärande har i allt större utsträckning kommit att handla om den lärandes svårigheter att tillägna sig vetenskapliga begrepp och förklaringar som presenteras i undervisning. Redan på 70-talet konstaterade Driver och Easley (1978) att den dominerande forskningen om studenters begreppsutveckling var normativ. Driver och Easleys (1978) huvudpoäng var att det i undervisningssituationer kan vara så att studenterna resonerar inom ramen för andra begreppssystem så kallade alternativa referensramar (*alternative frameworks*). De menade att vi spontant utvecklar sammanhängande system av föreställningar som skiljer sig från de begreppssystem vetenskapen arbetar med. De efterfrågade mer fokus på att förstå hur den lärande resonerar i sin egen rätt snarare än att bedöma om resonemangen är rätt eller fel enligt någon gängse norm. Den normativa forskningen har fortsatt att dominera. I en mängd studier de senaste decennierna har det visats hur den lärandes alternativa referensramar, som bygger på commonsense tänkande, skiljer sig från ett vetenskapligt tänkande (för en bibliografi se Duit, 2009). Att den lärande resonerar inom ramen för commonsense tänkande har beskrivits som ett hinder för den

lärande att tillägna sig vetenskaplig förståelse. Därmed har forskningen kommit att handla om vad som krävs för att en begreppsförändring ska komma till stånd hos den lärande.
Inom forskningsområdet har fokus främst varit vad som hindrar begreppsförändring att komma till stånd och vilken kunskap som saknas hos individen och därmed leder till att individen har så kallade missuppfattningar eller en naiv begreppsförståelse. Man har försökt att hitta specifika och avgörande företeelser som leder till begreppsförändring. Svårigheterna i att få begreppsförändring att komma till stånd har beskrivits som presuppositioner som står i vägen för förändring (Vosniadou, 1994), som en fråga om byte av ontologiska kategorier (Chi, Slotta, & De Leeuw, 1994), och man har försökt identifiera anomalier (Chinn & Malhotra, 2002; Mason, Gava, & Boldrin, 2008), och tröskelbegrepp (Meyer et al., 2008). Även om det finns en enighet om att det är ett system som förändras beskrivs förändringen som orsakad av en specifik faktor.

Den klassiska modellen för begreppsförändring har varit ett övergivande av primitiva föreställningar till förmån för mer vetenskapliga föreställningar (Posner, Strike, Hewson, & Gertzog, 1982; och Strike & Posner, 1992). En nyckelfaktor för att begreppsförändring ska komma till stånd har setts som att skapa kognitiv konflikt hos den lärande (t ex Strike & Posner, 1992). Experimentell forskning har dock visat att försök att skapa kognitiv konflikt hos den lärande sällan resulterar i begreppsförändring (Limón & Carretero, 1999).

Begreppsförändring som innebär att man överger en uppfattning till förmån för en annan och mer potent uppfattning har mött hård kritik. Snarare än ett direkt övergivande verkar begreppsförändring vara en långsam och gradvis process (t ex Vosniadou, 1994). Att tillägna sig en vetenskaplig förklaring eller teori verkar inte kräva ett övergivande av commonsense tänkande utan snarare att utveckla en repertoar av sätt att beskriva och förklara världen (Solomon, 1983; Caravita & Halldén, 1994), och det har hävdats att mer uppmärksamhet borde ges åt olika former av kontextualisering (Halldén, 1999). Begreppsförändring har beskrivits som en ökad förmåga till kontextualisering, det vill säga en ökad förmåga att kunna skilja mellan olika sammanhang och relatera ny information till adekvata sammanhang (Halldén, 1999; Halldén m.fl., 2002).

En central fråga är i vilken utsträckning det är rimligt att tillskriva individer sammanhängande system av föreställningar. Alternativa referensramar som sammanhängande system har ifrågasatts och det har hävdats att den lärandes föreställningsvärld snarare ska ses som fragmentarisk med begränsad systematik och koherens (diSessa, 1993). Enligt denna syn är det så kallade fenomenologiska förgivettaganden, *p-prims*, som styr lekmannens sätt att tänka

och vilka p-prims som används växlar från situation till situation (diSessa, 1993; diSessa & Sherin, 1998).

Barns föreställningar om jorden

I en serie tidigare studier om barns föreställningar om jorden har det visat sig att barn konstruerar andra modeller av jorden än som en sfär i rymden på vilken vi lever (t ex., Nussbaum, 1979; Nussbaum & Novak, 1976; Mali & Hove, 1979; Vosniadou & Brewer, 1992). Till exempel identifierade Vosniadou och Brewer (1992) fem modeller av jorden: en initial *platt rektangel* eller *rund skiva*, en *dual jordmodell*, en *ihålig sfär*, en *tillplattad sfär*, och den kulturellt accepterade modellen som en *sfär*. I en serie andra studier har det ifrågasatts om barn konstruerar koherenta alternativa modeller av jorden. Snarare än koherenta modeller av jorden har det hävdats att barnen har inkonsistenta och fragmenterade idéer om jorden (t ex. Hannust & Kikas, 2010; Nobes m fl., 2005; Panagiotaki m fl., 2009; cf. diSessa, 2013). I en pilotstudie om barns föreställningar om jorden (Halldén m fl., 2002) diskuterades modellen av jorden som en ihålig sfär som en *sammansatt modell*, det vill säga en modell funktionell i olika förklaringssammanhang. Den sammansatta modellen kunde förklara både ett astronomiskt och ett marknära sammanhang. En hypotes var att begreppsförändring från en sammansatt modell sker genom en differentiering inom den sammansatta modellen, det vill säga en ökad förmåga att kunna använda olika modeller beroende på sammanhang.

Syfte och frågeställningar

Ett övergripande syfte med avhandlingen är att beskriva barnens föreställningar i sin egen rätt (Driver & Easley, 1978) och försöka förstå rationaliteten i deras sätt att resonera. Detta för att i ett mer specifikt syfte få en ökad förståelse för sammanhang som en avgörande faktor i begreppsförändring (Halldén m fl., 2002). Det innebär att undersöka hur barnens modeller av jorden relaterar till sammanhang, hur inkoherens relaterar till sammanhang och hur kontinuitet i hur barnen resonerar relaterar till sammanhang.

Frågeställningar:

Vilka modeller av jorden konstruerar barnen? (Huvudfokus i artikel 3)

Hur kan barnens modellutveckling beskrivas i termer av integrering och differentiering? (Huvudfokus i artikel 3)

Hur omstrukturerar och omorganiserar barnen sina redan etablerade föreställningar, det vill säga, hur processar de inkoherens inom begreppsliga strukturer? (Huvudfokus i artikel 2)

I vilken utsträckning finns det kontinuitet och/eller diskontinuitet i begreppsförändringen? (Huvudfokus i artikel 1)

Metod

Under tre år intervjuades 29 förskolebarn varje år (37 barn år 1, 35 år 2 och 29 år 3). Barnen intervjuades om sina föreställningar om jorden. De intervjuades varje år från det år de fyllde fyra till det år de fyllde sex. Barnen intervjuades individuellt en gång per år i ett ostört rum på respektive förskola. Första året intervjuades de även i grupper om 2-4 barn med en jordglob placerad framför dem. De flesta individuella intervjuer inleddes med frågor utan artefakter. Barnen fick sedan rita jorden, och under intervjuerna tog intervjuaren sedan fram olika representationer av jorden som samtalet fortsatte kring. Första året var det en bild av jorden. Andra året användes en enkel Sverigekarta, ett satellitfoto av jorden och en jordglob. Tredje året användes samma satellitfoto och jordglob som året före.
Alla intervjuer har filmats.

I analysen har barnens innebörder av ordet jorden identifierats liksom de problem barnen stöter på och hur de löser dessa. Med en sådan analys, så kallad intentionell analys (Halldén m. fl, 2007; Halldén m fl., 2013), beskrivs vad *barnen gör* d v s hur barnen skapar sammanhang när de försöker förstå ny information och hur de organiserar olika informationsenheter. Analysmetoden tar i beaktande såväl faktorer som hänför sig till individens kognitiva struktur som till situationella faktorer.

Resultat

Resultaten visar att barnen konstruerade olika modeller av jorden som till stor del liknar modeller som identifierats i tidigare studier (t ex., Nussbaum & Novak, 1976; Vosniadou & Brewer, 1992). Tre väl definierade modeller av jorden identifierades: jorden som en himlakropp långt uppe i rymden skild från marken som vi bor på här nere, en ihålig sfär d v s vi lever inuti sfären som är omgiven av rymd, och slutligen en modell av jorden mer lik den normativa där människor lever runtom hela sfären. Främst de två första åren av studien uttryckte många barn en föreställning om jorden långt uppe i himlen eller rymden och en annan föreställning om den nära marken som vi lever på. Till skillnad från den nära marken som vi lever på relaterade barnen jorden till ett astronomiskt sammanhang. Många barn beskrev jorden som en måne eller ”en annan måne”, ”långt uppe i luften” eller rymden. Andra barn talade om jorden där uppe som en ”planet” och jämförde den med andra planeter de kände till. Jorden verkade från en början inte ha något med var människor bor att göra. Barnen förnekade att de bor på jorden och beskrev platsen de bor på som den nära omgivningen ”här nere”. Barnen verkar alltså inte ha en föreställning om två jordar d v s en dual modell av jorden som beskrivits i tidigare studier (t ex Vosniadou & Brewer, 1992) utan snarare två olika modeller, en av jorden och en annan av marken vi lever på. Den här tolkningen utgör utgångspunkten för en beskrivning av processen i termer av integrering och differentiering. De två

orelaterade föreställningarna, den nära marken respektive jorden som astronomisk kropp uppe i himlen, *integrerades* senare i *en* modell av jorden, en ihålig sfär. Utifrån jorden som en modell av en ihålig sfär kunde barnen förklara både den nära marken och det astronomiska sammanhanget. *Differentiering* inom den ihåliga sfären gjorde det senare möjligt för barnen att använda olika modeller av jorden beroende på förklaringssammanhang. Den kulturellt accepterade föreställningen av jorden kan ses som differentierad, det vill säga vi använder olika modeller beroende på sammanhang.

I artikel 2 beskrivs hur barnen processade en mängd information när de resonerade om jorden. De skapade en sammanhängande helhet genom att ta hänsyn till en mängd informationsenheter av olika slag. Dessa informationsenheter rörde bland annat faktakunskap till exempel att det finns lava i jorden och att jorden roterar. Annan information rörde mer teoretiserade begrepp till exempel gravitation, atmosfär och länder. Dessutom var relationell förståelse involverad till exempel skala, avstånd och inklusion. Barnen använde sin redan omfattande kunskap för att handskas med inkoherens och konflikter för att sedan konstruera nya modeller. Deras lösningar av inkoherens var intimt relaterade till förklaringssammanhang. Koherens kunde upprätthållas genom att hålla isär olika förklaringssammanhang (till exempel ett astronomiskt respektive ett marknära sammanhang) eller genom att förklara flera sammanhang samtidigt (som till exempel i modellen av jorden som en ihålig sfär) eller genom att skilja mellan olika sammanhang och kunna relatera dem till varandra (till exempel att använda olika modeller av jorden beroende på sammanhang).

Barnen handskades med såväl logisk inkoherens som motsägelser men det verkar inte vara någon specifik konflikt som orsakar begreppsförändring. Begreppsförändring verkar snarare vara omorganisering av summan av föreställningar och att hitta lämpliga förklaringssammanhang som de kan relateras till.

Resultaten visar även på en kontinuitet i barnens resonerande över tid. Kontinuiteten är relaterad inte endast till väldefinierade modeller av jorden. I artikel 1 beskrivs hur det hos ett enskilt barn gick att identifiera spår av idéer som uttryckts tydligt i tidigare års intervjuer liksom frön till idéer som tydligt uttrycktes i senare års intervjuer. Detta tyder på att barnens resonemang inte är helt relaterat till situationen utan att det finns en kärna av stabilitet i resonemangen. Kontinuiteten i resonemangen relaterar även till förklaringssammanhang. Även om det inte alltid är väldefinierade modeller av jorden som uttrycks finns alltså en stabilitet i resonemangen som kan relateras till de frågor barnen är engagerade i.

Diskussion och slutsatser

Snarare än en linjär process orsakad av en specifik företeelse presenterar den här studien evidens för en strukturell syn på begreppsförändring. Det verkar fruktbart att se på begreppsförändring som omstrukturering och omorganisering inom och mellan olika sammanhang, d v s begreppsliga sammanhang relaterade till förklaringssammanhang. Resultaten från studien stödjer tidigare argument för att den lärandes skapande av sammanhang är av yttersta vikt för förståelsen av processer som är involverade i begreppsförändring (Halldén, 1999; Halldén et al., 2013; Halldén et al., 2002).

Även om inkoherens eller konflikter i den lärandes begreppsstruktur är viktiga för att åstadkomma förändring verkar det inte vara någon specifik konflikt eller föreställning som leder till förändring. En slutsats är att om den lärande ska uppleva en konflikt måste två motsägande fakta eller föreställningar relateras till ett och samma förklaringssammanhang. Det här kan förklara varför tidigare forskning visat att försök att försätta den lärande i kognitiv konflikt sällan har resulterat i begreppsförändring (Limón & Carretero, 1999).

En annan slutsats är att den påstådda bristen på konsistens och koherens i den lärandes begreppsliga struktur (diSessa, 1993;2013) snarare verkar vara en metodologisk effekt av att man inte har tagit hänsyn till den lärandes förklaringssammanhang. Resultaten från den här studien visar att frågan om koherens måste ses i relation till olika typer av sammanhang.

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