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RESEARCH REPORT

Examining young children's conceptual change process in floating and sinking from a social constructivist perspective

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This paper presents a case study of the process of conceptual change in six-year-old children. The process of conceptual change in learning about floating and sinking is described from two different viewpoints: how the children's conceptions change during the instructional process, and how the social discussion during the experimental exploration can be seen in terms of the cognitive changes in the children. Based on qualitative analysis of verbal data, changes in the children's conceptions were mostly epistemological and the children's theories of flotation became more complete with respect to the scientific view. From the viewpoint of the conceptual change, conceptually orientated teacher–child interactions seemed to support the children's cognitive progress in cognitive skills and guided the children to consider the reasons for the flotation.

Introduction

The literature on research concerning children's conceptions in science commonly describes both children's conceptual understanding and the cognitive processes involved in learning. These studies have described a large range of children's alternative or inadequate conceptions of scientific knowledge. At the different stages of schooling, the scientific concepts and the relationships between these concepts are not deeply understood by children. In addition, in the work on children's understanding, the epistemological and ontological principles of knowledge often remain undefined. These results have stimulated many researchers considering science learning as a process of conceptual change, which considers learning as a process in which children reorganize their existing knowledge in order to understand concepts and processes of science more completely.

The tradition of research concerning conceptual change is rooted in developmental psychology, considering conceptual change only as a cognitive function and seeing conceptual change mostly depending on individual skills. In addition, the main interest has focused on older students; and young children's conceptual change has not been so widely studied. However, conceptual change as a part of the learning process should be seen as a lifelong process, which beings before children enter school. Young children have acquired a common-sense understanding of their immediate environment and its phenomena, based on their experiences and everyday routines. Because these experiences are often embedded in culture (Halldén 1999) and are emotionally stimulated (Pintrich et al. 1993), the older children become, the

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more complex the process of change becomes. Recent learning theories see this process as one of construction. They discuss the processes and changes in conceptions at a more holistic level, taking a more multidimensional view of the process of conceptual change (see, for example, Duit and Treagust 2003, Tyson et al. 1997). The aim here is therefore to describe the changes in six-year-old children's conceptions of floating and sinking, and how social discourse during the process of knowledge construction is linked to the change in children's concepts.

Conceptual change: from the cognitive to social constructivist view

The conceptual change approach to learning has been under intense discussion for many years, and several different views have been presented by researchers in cognitive psychology and science education. Although there has been much discussion in the field of conceptual change (see table 1), a common characteristic of researchers (for example, Carey 1985, Posner et al. 1982, Thagard 1992) has been to take a very theoretical view of the process of conceptual change and to stress the perspective of rational learning. They have considered conceptual change mostly as a polarization of low and high levels. More detailed analysis can be found only in the work of Thagard (1992). whose understanding is based on the strength of different rules of explanation. It seems a relevant way to analyse young children's conceptual change processes because of the gradual, slow and complex nature of conceptual change (see, for example, Dekkers and Thijs 1998, Hynd et al. 1997, Palmer and Flanagan 1997). This detailed analysis probably will do more for the understanding of the construction or reconstruction process of knowledge than a bipartite (low and high levels) view of changes would.

In the case of young children, Carey (1985) argues that conceptual change is essentially a process of theory change caused by increasing domain-specific knowledge. In addition, one of her findings refers to developmental changes in the child's judgements. Changes occur in the types of reasoning available to the child and also occur in the nature and organization of the knowledge entering into those judgements (Carey 1985: 135). Thus, in many cases the process of conceptual change is a slow and multidimensional process in which the changes involve different aspects of learning. However, Carey (1985) does not value conceptual change when changes in conceptual structures involve addition of knowledge but not restructuring. The view of conceptual change in the present study acknowledges, however, that knowledge addition is a relevant and important for conceptual change. Development of conceptual structures may sometimes be impossible if there is a lack of knowledge in some essential part of the model of knowledge. In the case of young children, the stage of knowledge addition is the starting point for the process of conceptual change.

Conceptual change has generally been investigated only through cognitive functions as a general process without consideration of the context. However, the process of conceptual learning in an instructional context supported by a teacher, as in this study, is not governed only by cognitive factors, and thus conceptual change should be discussed within the context in which the process is taking place. Tyson et al. (1997) and Duit and Treagust (2003) have provided a relevant model for analysing conceptual change from three different viewpoints: ontological, epistemological and social/affective. The analyses are useful in splitting up the components

Table 1. Theorists and their views about learning processes and conceptual change.

Theorist	*Main characteristics of learning process*	*Conceptual change is called*	*Main characteristics of the process of conceptual change*
Piaget (1966)	Individual process Cognitive conflict	Stage theory	Cognitive structures lead to development of the concepts
Vygotsky (1962, 1978)	Social process Language has an essential role	Zig-zag process	Concepts are formed by intellectual operations in which language is the guide
Posner et al. (1982)	Based on existing knowledge Rational approach to learning	Assimilation Accommodation	Intelligibility, plausibility Fruitfulness, dissatisfaction
Carey (1985)	Conceptual and rational approach to learning	Weak restructuring Strong restructuring	Novice-expert shift Theory changes Domain-specific
Hewson and Thorley (1989)	Rational approach to learning Based on the existing knowledge	Conceptual capture Conceptual exchange	Dissatisfaction is 'key stage' Metacognition
Thagard (1992)	Rational approach to learning. Conceptual replacement occur through problem-solving applications	Nine-stage theory	'Branch jumping' 'Tree switching'
Vosniadou (1994)	Active knowledge acquisition process, in which mental models have an significant role	Enrichment Revision	Slow process Process through the gradual suspension and revision of the presuppositions
Beeth and Hewson (1997)	Learning is both individual and social process. Metacognition has an important role	Conceptual change occur when there are changes in the status of a conception	Changes in declarative and procedural knowledge are important
Tyson et al. (1997)	Learning is cognitive and social process	Active multidimensional process from pre-scientific knowledge towards a scientific view of the concepts.	Epistemology Ontology Social/affective factors
Halldén (1999)	Learning is an oscillating process in which detailed facts and theories are simultaneously constructed	Three different changes: (1) replacement of old concepts (2) acquiring new concepts (3) new way conceptualizing word	Context has an essential role Conceptual change is contextualized and thus linked to the situational, cognitive and cultural contexts

of the process, but for developmental work in the schools more discussion is needed in order to include the situational and cultural contexts in the cognitive context, as discussed by Halldén (1999), who observed the role of everyday contexts in the use of scientific knowledge and of the explanations in the speech genre. Accordingly, this brings up the question of the holistic interpretation of conceptual change, which is relevant to this study. Halldén's way of thinking can be applied to analysing young children's conceptual change processes in the instructional context, and especially allows emphasis to be placed on their ways of discussing.

The social context of cognitive development, and especially the role of language in the learning process, was initially rooted in L.S. Vygotsky's work. Vygotsky (1962, 1978) saw knowledge construction as an ongoing, zig-zag process in which the child, in collaboration with a teacher or other children, integrates everyday concepts into a system of related concepts and transforms the raw material of experience into a coherent system. In interaction and communication the children start to reflect on their limitations, contradictions, presuppositions and the implications of their conceptions. This kind of awareness constitutes a critical condition for experiencing conceptual change in one's own knowledge structures (Vosniadou 1994) and, consequently, provides a key for encouraging conceptual change in young children.

Discursive communication in the classroom provides an opportunity for knowledge construction and reconstruction, which is embedded in the *instructional process* (see Havu 2000). Through the analysis of the instructional process, a deeper understanding is obtained about how conceptual change is reached and what are the elements that are involved in the change process. On the other hand, different problem-solving skills, the social discourse in the context of learning (Boulter 2000), and also an interpretation of scientific world and nature of scientific knowledge (see Osborne 1996) seem to have significant roles in the learning process.

In this paper I consider the understanding of young children's teaching and learning as a process of conceptual change, underpinned by the view that the social interaction, especially collaborative interaction (Boulter 2000), during the learning process has an impact on conceptual change at an individual level. The model presented next is constructed based on knowledge of previous studies and theories, and shapes the analysis of conceptual change process in this paper.

Young children's processes of conceptual change, which occur in an instructional context and in the environment in which a cognitive conflict can be established, happen mostly in social interaction with other peers and the teacher. The children's personal conceptual structures based on their everyday experiences interact with the views of other children and the teacher. The conditions that facilitate or hinder the cognitive conflict, or in some other ways affect the conceptual reorganization, can be either internal or collaborative factors, which are continuously involved in the process of reorganization of everyday experiences. Because the meaning of the collaborative talk has a varying role in knowledge construction or reconstruction, the contexts and their social aspects need to be described and interpreted.

Conceptual change itself is an individual cognitive process, in which the new conceptions may change in several ways, ontologically or epistemologically (Chi et al. 1994, Duit and Treagust 2003, Thagard 1992) and through several phases, being continuously in interaction with the child's internal or collaborative learning. The children's epistemological or ontological conceptions may be deeply

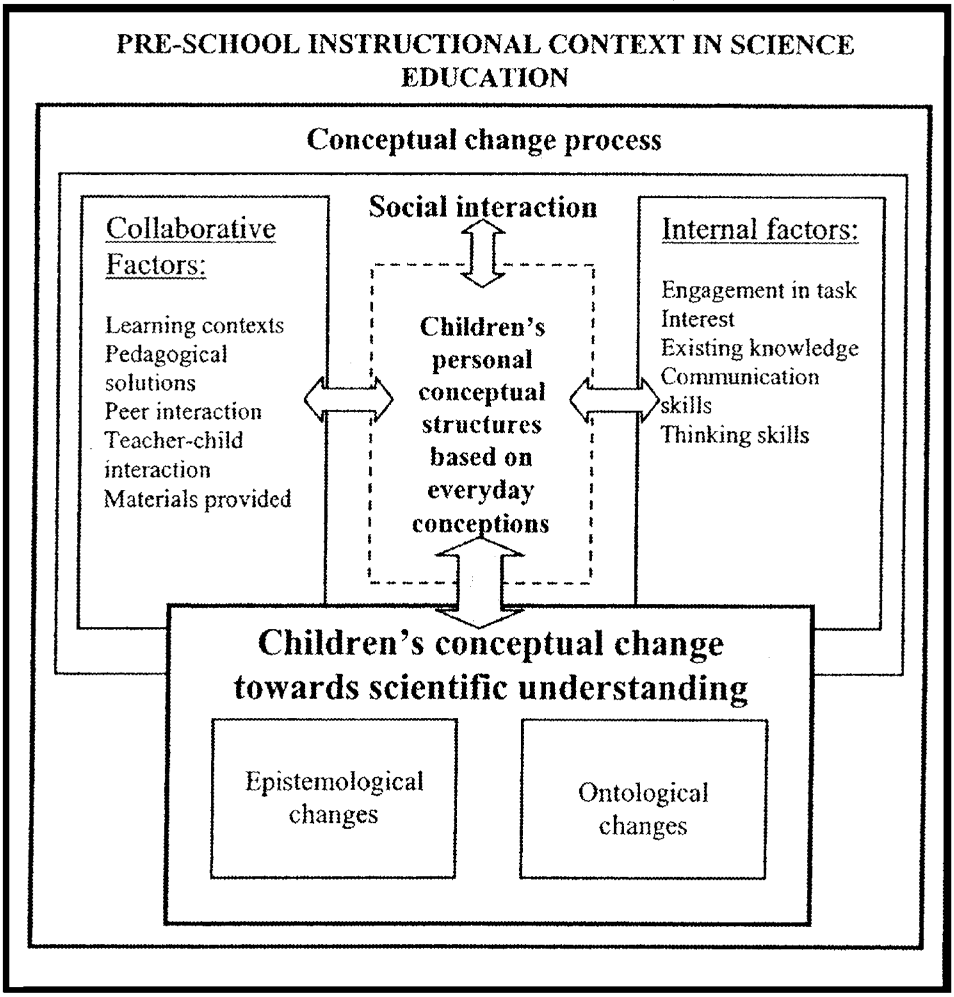

Figure 1. A framework for analysing the children's conceptual change.

rooted in everyday life experiences and thus also be supported or impeded by such activities.

This study is an attempt to find the answer to how six year olds change their conceptual understanding when instruction has been provided. Hence, it is also essential to pay attention to now verbal interaction and construction of shared knowledge facilitate the process of conceptual change.

Method

Subjects

The subjects of the study were pre-schoolers (n=10) aged six from the city of Joensuu, Finland. The children were from the kindergarten involved with a research project, ESKO project (for more detail, see Aho et al. 1999). The children came from a normal Finnish kindergarten, in which science teaching using a collaborative and problem-based approach has not previously been used. Thus the instructional process played an important role in the study. This group wanted to take part in the study voluntarily, although the teachers of the kindergarten did not agree to teach the topic so this was done by the researcher. Children came from two different groups in the pre-school, and these groups were of mixed genders.

Procedure

This study interprets the conceptual change process through children's verbal expressions, which are seen to express their current thoughts and understanding within the limitations of their skills to express themselves. The verification for the interpretations of verbal expressions is derived from analysis of the children's experimental work during the study. Conceptual understanding and change and progression of the construction process are approached through a qualitative case study design. The research was constructed in three parts: (a) pre-interview, (b) instructional process, and (c) post-interview.

The purpose of the pre-interview was to determine the children's existing knowledge and experiences of floating and sinking. To help children reflect on their own thinking and on alternative explanations, the semi-structured interview situation was constructed using an interactive approach. The pre-interview consisted of two parts. First, the children were asked to explain what the terms 'sink' and 'float' mean and what kind of objects float and sink and why. In addition, the children talked about their experiences of sinking and floating. The children's vocabulary was not highly developed so the children drew the sinking and floating objects as a way of expressing their thoughts. Finally, they were asked to make predictions about a collection of sinking and floating objects, and these were filled in on the worksheet (figure 2). Each child was interviewed separately in a peaceful setting, and all the interviews were audiotaped.

The instructional process, conducted one week after the pre-interview, was an attempt to support and develop the children's conceptual understanding of floating and sinking. The teaching approach was collaborative, using guided discovery learning. Collaborative work places emphasis on social interaction during the sessions, on one's own judgements, and on discussions with peers that help to create situations where cognitive conflict can occur through discussions and sharing meanings. In collaborative interaction situations, the teacher's role is to maintain the rules of the discussion with many pauses (Boulter 2000). The guided discovery method of learning (Ausubel and Robinson 1969) is a traditional pedagogical approach in which an attempt is made to support the learner's active role in the learning process and to give an opportunity to observe, predict, explore, describe and make assumptions. In this study the guided discovery approach to learning was applied using a problem-based approach, in which the children actively participated in solving the problems of sinking and floating. The children had opportunities to express their current ideas, to make their predictions about flotation, explore the phenomenon with the concrete materials and, afterwards, to give their explanations. The amount of support from the teacher changed during the process, but was continuous. In particular, the teacher's role was especially to ask questions, raise new problems and to mediate the transitions between the conceptions to support the children's conceptual

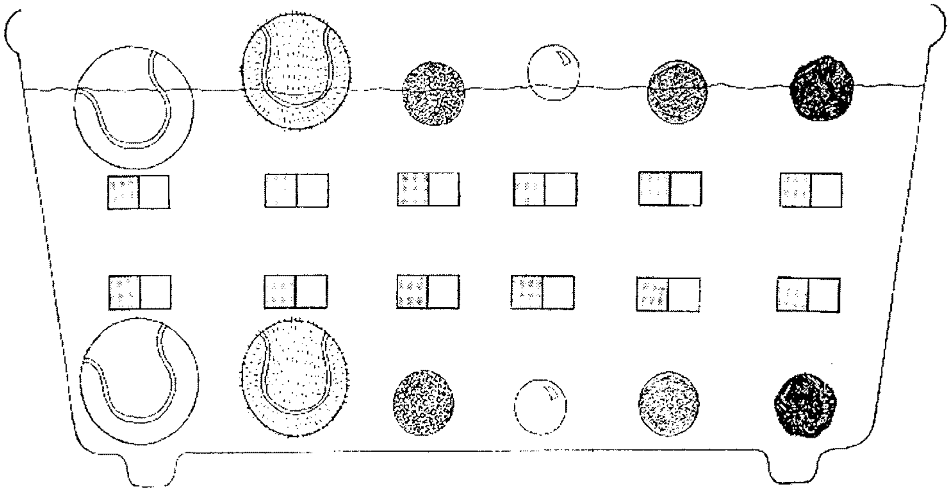

Figure 2. The children's worksheet during the teaching stage (first page).

1. **Merkitse rastilla tummaan ruutuun, mitä luulet pallolle tapahtuvan, kun se pannaan veteen. What happens to the balls when they are put into water? Mark your answer in the dark box.**
2. **Kokeile pallolla, mitä sille tapahtuu, kun se pannaan veteen. Experiment with a ball to see what happens when it is put into water.**
3. **Merkitse rastilla havaintosi vaaleaan ruutuun. What happened during the experiment? Mark your answer in the white**

restructuring (see Ausubel and Robinson 1969, Boulter and Gilbert 1995, Tomasini et al. 1990). The teaching session in the present study progressed as shown in figure 3.

The *Orientation* (Driver and Oldham 1986: 119), based on general discussion in the classroom, attempted to initiate a discussion of the phenomena. The children were asked to describe, in general, sinking and floating, and to talk about their previous concrete experiences with sinking and floating objects. For conceptual change, orientation is the stage at which the teacher gains an idea about the children's existing knowledge and provides an environment for enriching, reorganizing or changing the children's conceptions.

Conceptual change should start and continue in the *experimental session*, where learning activities were planned to support the children's conceptual restructuring and make their ideas explicit (Driver and Oldham 1986). The approach for that was collaborative working, in which the children worked in three mixed groups, each having three to four participants. The results of group work were discussed generally with all children under the teacher's guidance. The alternative perspectives, like heaviness/lightness, size, materials, and hollowness/vacuum, were discussed and the general reasons for flotation were built-up. If necessary, the children's language and new concepts were 'sharpened up' (Driver and Oldham 1986) by the teacher.

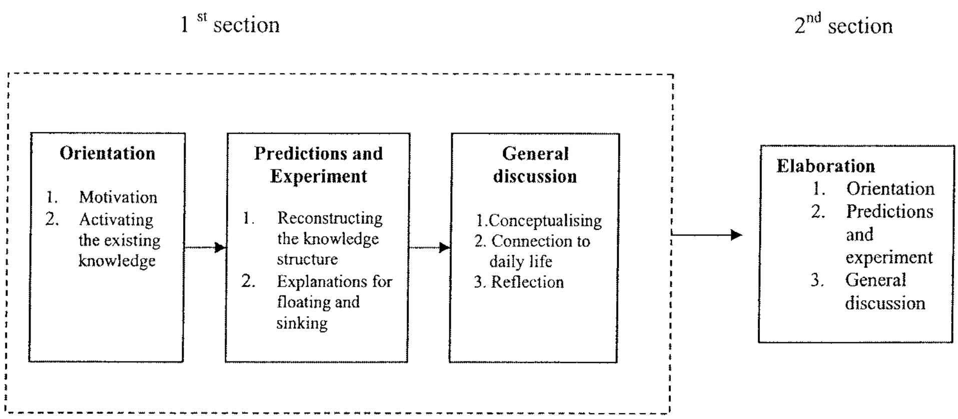

Figure 3. The progression of the instructional process.

The second part of the interactive phase, the *elaboration* (Brown and Palincsar 1989) session, was carried out two days after the actual experimental session. The aim of this elaboration was to support the children's adaptation of their knowledge to the new situation and, more generally, to foster their conceptual understanding. In the elaboration session the pupils worked in groups, and experimental activities were carried out using the children's own object that they brought in to school from home. Different groups tested different ideas and reported their findings and judgements to the whole class. The findings were generalized and conceptualized with the teacher through class discussions.

Materials

The worksheet (figure 2) prepared for data collection consisted of the selected objects listed on the sheet: a baseball, tennis ball, ping-pong ball, golf ball, squash ball, plasticine ball, an empty glass bottle, a glass bottle filled with water and a small plastic boat. These objects were available and could be handled for making judgements during the interviews and the instructional process. In this study the university research group chose a density approach to understand flotation from many possible different viewpoints, to allow the analysis of the phenomena in small and concrete elements. Using a density approach, the phenomena can be described in terms of volume and mass. At the children's level this means the consideration of the floating and sinking objects from several viewpoints such as hollowness, the shape of the objects, the size of the objects and weight of the objects in relationship to each other (see Havu 2000). An alternative approach that uses the concept of upthrust is strongly related to the ideas of forces. Considering the previous studies of forces (Viiri 1995), however, this is more difficult to illustrate. In addition, the concept of force in the Finnish language is often related to contexts that have a totally different meaning to the physical concepts. Even though concepts such as volume and density are abstract for pre-school-aged children, this approach provides a multidimensional way of considering floating on the descriptive level, which is seen as possible in recent studies with young children contrary to Piaget and

Inhelder's (1974) arguments that the young children are incapable of differentiating concepts of global quantity (see Smith et al. 1985). The objects for the investigation allow the determination of which of the object's properties influence the subjects' judgements and provide several examples of each different dimension used in explaining floating and sinking. In addition, most of these materials were familiar to the children and had a meaningful relation to their everyday life. A similar worksheet was used in all parts of the study, except for the elaboration part, where a special worksheet was prepared. The worksheet for elaboration did not include any particular objects, but rather the children were expected to fill it in with their own objects from home. Children marked their predictions and the empirical results of the experiment on the worksheet. The general discussions with the teacher were based on the observations and on the completed worksheets.

Data analysis

The analysis of the interview data was influenced by ideas on the content analysis of verbal data (Chi 1997, Fraenkel and Wallen 1996). The most appropriate method of analysis was to establish a pattern in the contents of the interview conversations. The study focused on the content of the responses, not on its form or function. After data segmentation, the answers of each child were classified in accordance with the preliminary categories according to their own justification. The final categorization was produced from the codes of the data but the general guidelines for the classification were influenced by Howe et al.'s (1990: 463) and Denticini et al.'s (1984: 239–241) studies. In the final phase, to reach more holistic and valid view of each category, and consequently to build clearly indicated interpretations, the codes were mapped to the categories in detail.

The analysis of the knowledge construction process is based on video material and audio-tapes recorded during the instructional process. Four videos and

Table 2. Categorization scheme for the description of children's understanding of the phenomena of floating and sinking.

(1) *Non-relevant and non-scientific explanations*. The child did not mention any physical properties or the responses were non-relevant to the phenomenon of sinking and floating.

(2) *Non-relational justifications*
- (a) The justifications are based only on the weight of the object. The child stated arguments only for weight, even though some of them seemed to understand that it is not the only reason.
- (b) The phenomenon is explained in arguments for the effect of material or shape or the air. It seems that the child has an intuitive conception about the relationship between mass and volume (density); however, it is not clear.
- (c) The responses consist of many characteristics, and non-relevant explanations are also used. The child explains the phenomenon with different relevant characteristics based on volume. The answers may also include non-relevant properties.
- (d) The justifications are based on many relevant characteristics. The child explains the phenomenon with at least two relevant properties and it understands that the weight is not the only reason for sinking and floating.

(3) *Water-related justifications.* The child produces evidence for sinking and floating by comparing the weight of the object and the weight of water.

audio-tapes were recorded simultaneously; one from each group and one from the whole room. Video-tapes and audio-tapes were transcribed strictly following the verbal conversations held in the instructional settings. Non-verbal episodes were added to the transcriptions by interpreting the video-tapes. The analysis is based on children's and teacher's conversations during the interactive phase. The units of data analysis consist of the content units of the verbal interaction. Thus, each code is a *unit of meaning*, which occurred in the interaction context.

Through the two phases of data coding, intial data coding and forming coding families, the construction of typologies of the discussions according to their content and nature was formulated. This process yielded four different types of discussion. Within these four types of discussion, the content of discussion varies and those subtypologies indicate in detail the progression of discussion and it's several characteristics during the interaction process (shown in table 3).

In this paper the conversations that deal explicitly with the children's cognitive changes are discussed. Those discussions are mostly categorized into conceptually orientated conversations, because in those conversations the aim was to construct the understanding of floating and sinking. The significance of other types of discussion are discussed when the context is seen to be meaningful for conceptual change (for more detail, see Havu 2000).

Results

All children were able to combine several relevant properties of the objects in the post-interview, whilste in the pre-interview most of them used only one property (see table 4). Although the children changed their way of justifying flotation towards a scientific way of looking at flotation, the responses varied in all qualitative levels (see table 4) depending on the context. The children's ways of justifying the reasons for the phenomena varied qualitatively between objects. Thus the material used in the study has a marked influence on the children's ways of thinking about floating and sinking.

In the next four subsections, the changes in the children's conceptions are discussed in more detail and are connected to the context of the instructional process. The conversations during the instructional process are split into two categories; the peer group discussions and teacher–child discussions are interpreted separately in regard to changes in the children's conceptions.

Table 3. Categorization scheme of verbal interaction.

(1)	*Conceptual.* Dialogues concerning the phenomenon (sinking and floating) and its properties and reason or causes for it. The conceptual discussion of test materials (properties)
(2)	*Procedural.* Dialogues in which any kind of practical, procedural supervising and management features of activities are discussed
(3)	*Direction of the interest.* Expressions in which the children's interest in the activities is involved
(4)	*Everyday themes.* Conversations that are dealing with some other subjects or content areas than those in the task. Also the interaction units of meanings, which mostly or explicitly are in irregular relationship for the task but are implicitly or partly involved

Table 4. Children's judgements on flotation in pre-interviews (♦) and in post-interviews (♥).

	1	*2a*	*2b*	*2c*	*2d*	*3*
Anna (241)	♦♦♦♦ ♥♥	♦♦♦♦♦♦ ♦ ♥♥♥♥	♦♦♦♦ ♥♥ ♦♦	♦ ♥	♦♦♦	
Sara (229)	♦♦ ♥	♦♦♦♦♦♦ ♦♦♦♦♦ ♥♥♥♥	♦♦♦ ♥♥♥♥	♦♦ ♥♥	♦♦ ♥♥♥♥	♦
Julia (243)	♥	♦♦♦♦ ♥♥♥♥♥	♦♦ ♥♥♥	♦ ♥	♦ ♥	♥
Taina (223)	♦♦♦	♦♦♦♦♦ ♥♥♥♥♥♥	♦ ♥♥♥	♦♦♦♦♦ ♥	♦♦♦♦♦ ♥♥♥♥♥	
Teemu (228)	♦♦♦♦♦♦ ♦♦♦ ♥♥♥	♥♥♥♥♥		♦ ♥♥♥♥♥♥ ♥		
Tuuli (237)	♦♦♦♦♦ ♦♦♦	♦♦♦♦♦♦ ♦♦♦ ♥♥♥♥	♦♦♦♦♦♦ ♥♥♥♥	♦♦♦♦ ♥♥♥♥	♦♦♦♦ ♥♥♥♥♥♥ ♥♥	♦♦♦
Jussi (225)	♦♦♦♦	♦♦♦♦♦♦ ♦♦♦♦♦♦ ♥♥♥♥♥♥ ♥	♦♦ ♥♥♥♥		♦♦♦♦ ♥♥	♥♥
Paula (245)	♦♦	♦♦♦♦♦♦ ♦♦♦♦ ♥♥♥♥	♦♦ ♥♥♥	♥♥♥	♦♦ ♥♥	♥
Harri (226)	♦♦♦	♦♦♦♦ ♥	♦♦♦♦ ♥♥♥♥♥♥ ♥♥♥♥		♦ ♥♥♥♥♥♥	♥♥
Kaisa (240)	♦♦♦♦	♦♦♦♦♦ ♥♥♥♥♥	♦♦	♥♥♥♥♥♥ ♥♥♥♥♥♥	♥	
Pre-interview	22%	37%	16%	6%	9%	2%
Post-interview	4%	29%	20%	22%	20%	5%

Note: Total percentages of each level pre-interview and post-interview are presented.

Changing non-relevant and weight-based justifications

Notable differences occurred among the children who expressed non-relevant or non-scientific explanations (lowest category) or considered flotation to be based on many relevant characteristics (the two highest categories). The justifications that belonged to the lowest group in the pre-interview seemed to develop towards more relevant explanations in the post-interview. In the pre-interview many of the children explained flotation with non-scientific or irrelevant reasons. The children based their arguments on everyday experience ('I have sunk a baseball once'), the explanations had been heard from the adult ('My mum told me') or the flotation occurs because the object is made to float or to sink ('It will sink, because it must sink'). By the post-interview, most of these justifications had almost disappeared. These changes show that in the post-interview children began to consider flotation more accurately in terms of the event itself. Consequently, the reasons why the object sinks or floats were not judged based on their previous life experiences, but the object in this particular context was seen as more significant.

In both of the interviews, the pre-schoolers mostly explained the flotation using the weight of the object. In the pre-interview the weight of the object was the only and sufficient reason for flotation. In the post-interview, however, many responses were provided including the idea that the '*weight of the object is too much*'. Some children linked their answer to the water, using the supportive question of the teacher.

Interviewer:	I have some steel balls here in the bag. What do you think will happen to those when we put them in to the water?
Julia:	They will sink.
Interviewer:	Why will they sink.
Julia:	I don't know.
Interviewer:	They just sink?
Julia:	Yes.
Interviewer:	What might be the reason?
Julia:	They are too (excessively) heavy, I suppose.
Interviewer:	Oh, yes, they are too heavy, but for which/whom?
Julia:	I don't know, but for water at least. (Post-interview, P14: Julia2. txt, 254:267)

In the post-interviews water was an element that was seen as an essential reason for sinking. First, the objects were seen to be too heavy for water to hold up. Second, the children saw that water inside the objects is a critical feature for sinking. In these cases the weight of the object became excessive.

Considering the discussions during the instructional process, there were no discussions in which the children together or with the teacher deliberate upon the non-scientific reasons or only the weight of the objects. The understanding developed implicitly through several other content areas.

Towards multidimensional views of floating and sinking

During the study the children's explanations were reconstructed, becoming more multidimensional. In the post-interview, children considered flotation to have some relevant and irrelevant properties (see tables 2 and 4, level 2c) or they established their judgements in terms of many relevant properties (see tables 2 and 4, level 2d). The effects of heaviness or lightness were mostly justified in terms of air, material, size or shape.

The air inside the objects was mentioned in the pre-interview, but only a few children could explain why air affects flotation. In the post-interview the air justification appeared more widely, and in the justifications air and other properties were combined. Air, besides the weight of the object, seemed to be a fundamental reason for floating and sinking, although for many children the significance of the air seemed to remain unclear. The children seemed to have an intuitive understanding of the role of volume or density in the flotation, but they could not construct the proper definition or concepts to describe it.

The shape, size and the material of the object were mentioned in the pre-interview but not put together. In particular, size of the object was used to explain the lightness of an object. In the post-interview those properties were combined with some other relevant features.

Interviewer: How about the boats, big and heavy boats why do they not sink?
Kaisa: The shape of them is appropriate.
Interviewer: Oh, that's true, you are right, which kind of shape do the boats have?
Kaisa: They are like an oval.
Interviewer: So, what is about that shape which makes it so that the boats do not sink?
Kaisa: It moves water, in that way [showing with the hands the idea of displacement]. (Post-interview, P18: Kaisa2.txt, 18:8, 62:71)

During the instructional process, in the peer groups, the children were concerned with the reasons for the phenomenon. Even if most of the conceptually orientated peer interaction consisted of describing the test results, in some cases the children in the peer groups tried to determine the reason for the flotation. These conversations took place either with the test materials (balls, bottles and plastic boat) or in situations in which the children made the experiments with their own objects without the teacher's guidance.

[*Context*: Group I has finished their tests and they are waiting for a while. Anna and Sara continue testing with their own materials. Anna has put the pencil on the water.]
Anna: There is no air in the pencil.
Sara: The lead is made from iron.

In this example, Anna explained sinking as lack of air, and Sara continued explaining it (lack of air) with the material of the lead, which is inside the pencil. Sara had her own conception of the material of lead, but she based her justification of sinking on that property. Both girls bring their knowledge to the situation, trying to understand it. The consensus model (see Gilbert et al. 2000) between the girls was not built up explicitly, and thus this short discussion did not support the girls' complete conceptual change, but it is a clear indication of a developed way of considering the phenomenon. The girls did not accept only presenting the result of the experiment, but tried to find reasons for their observation. At same time in group II, after testing their test material, the children started to test their own objects:

Kaisa: Sari!
Teacher: Yes, what?
Kaisa: The pencil is floating.
Taina: The pencil is made from wood.
Harri: Yes it is.
Kaisa: or the pencil is … [thinking] … yes, the pencil is made from wood.

Through these peer discussions the children began to explain flotation by through an analysing the object being tested. According to Thagard (1992) the children started to find part-relations. The children discovered the new parts of volume or density and they explained the phenomenon by connecting the properties such as hollow or solid object, material of the object or the air inside the object to each other. The implications of this kind of construction process were clearly externalized during the post-interview. During the children's group work the teacher and children also reciprocally discussed the reasons for the phenomenon.

[*Context*: Assistant teacher is discussing with the children in group III]
Assistant teacher: Everybody should think about the reasons why this sinks?

Tommi:	I marked that it floats [laughter].
Child:	It is solid.
Assistant teacher:	And something else?
Child:	There is no air inside.
Assistant teacher:	There is no air inside.
Child:	And it is made by glass.
Assistant teacher:	Yes, it is made of glass, will that affect it?
Harri:	It's heavy.
Assistant teacher:	Do all objects made of glass sink, will you think about it? Which kind don't sink?
Harri:	*Not ones that have air inside*.
Assistant teacher:	That kind don't sink, you say? And this one does.
Harri:	*Yes, because it's solid*. (P 1: elab.txt – 1:15, 232:246)

The properties of the object were discussed widely in the teacher–child dialogues. The teacher asked the children to describe their results from the experiment and to explain why this happened. Through the teacher's questions the object was considered deeply and the children were guided to justify their explanations. Cognitively, the discussions demanded several thinking skills; for example, reasoning and consequently promoted the process of conceptual change.

Most of the children used only two different relevant attributes of the object in their justifications, but some of them were capable of combining even *three* relevant attributes.

Interviewer:	Let's take an empty bottle. What will happen?
Tuuli:	It will float.
Interviewer:	Why will the empty bottle float?
Tuuli:	I suppose, *there is air* and *it's so light* and there *is nothing inside*, and if there is pop corns it is light as well. But if there is water inside, it could sink. (Post-interview, P11:Tuuli2.txt, 11:18, 132:137)

In this case a child has an initial understanding of density. She compared different substances for sinking. The argument that *it is so light* gives an impression that the object is related to something else. In these cases the teacher's help and ambitious questions or prompts were needed, to promote the children conceptual change process towards seeing flotation as an event, in which the objects and water are in relation.

The understanding of the density of the objects was looked at through the discussion during the instructional process in which the different materials were compared. The children's justifications were questioned. With the teacher's support, the situations outside the current experiment were added and discussed. These conversations enhanced the children's way of justifying the observations but also encouraged the making of hypotheses and the formulation their justifications more precisely.

[*Context*:	A general discussion after experimental exploration:]
Teacher:	Well, yes. Why will the bottle filled in water sink?
Child:	I'm not sure. It's full.
Teacher:	Why the water, does it affect it? If it was something else, will it sink then as well? If there is juice.
Child:	Yes it will sink.
Teacher:	Oh yes, why does it sink if there is water or something else inside?
Teacher:	How about pop corn, if there was pop corn inside the bottle?
Child:	He, heh [laughter].
Teacher:	Would it sink then? What might happen then?

Teacher: Because it would be full then or Styrofoam would it sink?
Child: [Shaking head]
Teacher: Why not?
Child: Because they are so light.

The children's explanation for sinking was the *full bottle*. The teacher guided the child to find a relevant descriptor and helped the child to notice that 'full' is not enough of an explanation. These conversations, in which the reasons for the floating and sinking were thought through, improved the children's abilities to think causally about the phenomena and to reorganize their conceptual constructions. These conversations demanded reasoning about causes and consequences and about the properties of the matter.

The importance of the problem-solving task for the conceptual change

One of the increasing elements in the children's explanations in the post-interview was the meaning of the shape of the objects. The importance of the shape was derived from the shape of the boat generally, and from the reshaping of the plasticine ball into the plasticine boat during the instructional process. This problem-solving task, how to get a plastice ball to float, had an amazingly strong connection to the children's post-interview explanations. During the task the discussion dealt with the properties of the object and how to solve the problem of the plasticine ball. The children together observed their testing materials and adapted their knowledge to shape the plasticine ball to float.

[*Context*: Group II is trying to get their plasticine ball to float]
Tuuli: Here is a hole.
Paula: Yes, here is the hole.
Tuuli: We must to cover it.
Julia: Look at, this is floating.
Julia: We have two [plasticine balls], I will take this my very own.
Tuuli: Now it is very good boat.
Child: Let's put both in.
Julia: Our object is floating, our object is floating [yelling and laughing and shaking hands]! (P3: kelkokl.txt, 3:179, 855:861)

The importance of experimental work in collaborative groups became very apparent. This problem-solving task required children to share their understanding and try to find the best solution. They noticed that the hole affects flotation and thus, as a consequence, the hole was covered. The conceptual understanding of flotation was reinforced but the task was also very motivating. The children undoubtedly seemed to be very happy when the sinking plasticine ball was floating. Thus, the problem-solving task produced emotional satisfaction and reshaping had a meaning for the children's conceptual change. In post-interview almost every child explained how to get a plasticine ball to float and or used the justifications in which understanding of the area and the shape of the object became clear. However, the reason why this particular shape affects floating or sinking was not fully understood.

Towards density rules: learning new concepts

The children's justifications of flotation were categorized at the highest level of understanding when the child had a limited understanding of the mechanisms of displacement and density. These children based their reasons for flotation on an argument that connected the weight and some other properties of the object to the weight of the water. Nevertheless, they were not able to use the concepts of displacement and density properly.

Interviewer: What kind of object usually sinks?
Jussi: Heavy.
Interviewer: Heavy.
Jussi: When the object has the same weight as water.
Interviewer: If the object has the same weight as water it will sink?
Jussi: Yes, or then it is heavier.
Interviewer: Oh, or heavier. (Post-interview, P17: Jussi2. txt, 17:20, 194:201)

No child could provide a full understanding, which was based on the rule of density. In the post-interview, however, many children took account of the properties such as hollowness and solidity. During the teaching section the concepts of *hollow* and *solid* were presented and defined by the teacher, and later the children used the concepts in their definitions. The children learned or reconstructed many concepts during their discussion. The concepts were defined mainly through describing the test materials, but some discussions dealt with the verification of content of the concepts.

[*Context:* A conclusion at the end of elaboration session]
Teacher: Oh, yes what might be a reason why that Kaisa's steel ball sinks?
Kaisa: It is solid
Teacher: Do what does it mean?
Kaisa: There is no air inside. (P2: elab2.txt, 2:65, 388:392)

But verifying concepts did not occur only from teacher to children, but also children asked the teacher to determine concepts like 'water resistant'. Consequently careful use and defining of the concepts have consequences for how the children learn to use new concepts and how the alternative conceptions are constructed. In respect of the new concepts, Thagard (1992) sees that adding new concepts is an important part of the development of scientific knowledge (Thagard 1992: 36). Even if used, the concepts of solid and hollow are not scientific concepts, like density; they indicate important descriptive elements of this scientific concept.

Summary

The children's changes in their conceptions were mostly epistemological and, according to Thagard's (1992) terms, showed a 'piecemeal belief revision'. The children added or deleted beliefs without a strong reorganization of conceptual structure. However, new links and notes were added, which is seen as a significant in the process towards fundamental or strong restructuring (Carey 1985). The collaborative constructions during the instructional process were mostly conceptual and the children actively discussed in the peer groups and with the teacher the phenomenon and the properties of the test objects. With the teacher's supportive questions, new concepts and conditions were found and used in justifications. Thus the assistance of the teacher was substantial for improving the children's way of looking at sinking and floating, but also in using the concepts.

The change in the children's ways of looking at sinking and floating objects, and especially their level of understanding, emerged during the problem-solving task. The children enjoyed the task and the discussions of the activity were expressed during the post-interview. The task had an essential role for the children's conceptual change because of the cognitive conflict and emotionally positive feelings.

Discussion

The aim of this case study was to describe the changes in children's conceptions of floating and sinking and to understand how the social discourse during the instructional process is related to the changes in children's conceptions.

According to this study, analysis of the children's conceptual change process is important in terms of developing teaching and supporting the children's knowledge construction. However, the process of conceptual change seems to be varying and context dependent. If children become familiar with the aspects of the phenomena as early as possible, the cognitive conflicts in the instructional settings produce new ways of looking at the phenomenon. In this study the children started to consider flotation in a more multidimensional manner and achieved descriptive understanding. Furthermore, the metacognition become a part of learning. When the children noticed that their way of thinking is not complete or that other thinking models existed, a change may occur in their conceptual structure.

The social interaction during the lesson was active and it was mostly conceptually orientated. Thus, plenty of essential aspects for changing the children's conceptions were discussed during the instruction, both in peer interaction and teacher–child interaction. This emphasizes the significance of social interaction and collaborative knowledge construction. When exploring together, children support each other in conceptually and procedurally orientated discussions, which at the same time improve their verbal skills. On the other hand, during the teacher–child interaction Vygotsky's (1978) view about the zone of proximal development can be easily identified in use. In the beginning of the instructional process, during the peer interaction, the children only briefly described their observations. During the process, the phenomenon was considered with teacher's support and through her questions. Already, in the elaboration part, the peer interaction occurred at a cognitively higher level. The children in peer groups explained and found the reasons for the floating and sinking. Through guidance and conceptualization by the teacher during the instructional process, new properties and concepts of floating and sinking entered discussions.

The children used new concepts and their definitions were more accurate in the post-interview. The children were more able to describe in detail their justifications. During the instructional process, both in peer conversations and in teacher–child conversations, unsuitable concepts were corrected and better ones were defined. Again, new concepts were learnt in social interaction with the other learners. Indeed, Vygotsky's (1978) assertion about the importance of language in the learning process is proved in this study. However, in some cases the concepts used were rote learned, and thus the meaning of the concepts were not internalized. The distribution of the discussions based on the analysis of the cognitive level is presented in table 5.

Analysing the cognitive level of the discussions, it can be seen that the discussions based on the teacher–child interaction also had quantitatively more variation. Most of peer interactions remained in the descriptive stage, and only a few conversational entities reached the stage of reasoning. The teacher–child interactions, by contrast, showed all stages, but mainly descriptions and reasoning, in which only

Table 5. The frequencies of cognitive nature of the discourses during the instructional process of floating and sinking.

	Descriptive				***Reasoning***	
	One case	*Comparative*	***Deliberation***	***Hypothezing***	*One case*	*Comparative*
Peer interaction	13		4		4	
Teacher–child interaction	61	6	27	17	98	7

one case was taken to consideration. In few cases the comparative elements appeared, which itself increased the quality of the discussion.

It seems that collaborative experimental exploration produces much discussion in which the children and also teacher with children discuss their observations and findings. The teacher's job is to focus attention concretely on perceiving the phenomenon, supporting the children reforming their understanding, but especially encouraging the children to freely express their ideas. For pre-school children, describing is a significant thinking skill (see Aho 1999).

To produce conceptual change, collaborative discussion that encourages the children to synthesize their views and draw relationships of causes and effects, compare and summarize is seen as important (see Costa 1990: 51–57). Thus for the children's conceptual change process the discussions held with teacher seemed to be the most significant. The causes for the flotation and different properties of the testing objects were reasoned about several times during instruction in collaborative discussion between the children and teacher, but only a few times in peer interaction. Thus the instructional process of sinking and floating achieved the collaborative discussion that supported the children's conceptual change process and provided the several types of discussion in terms of cognition.

The conceptual understanding concerning the density of the objects and that of water were not identified in the post-interview. The concept of density was not used in the instructional process, and only the weight of the object and the weight of water were related to each other by the teacher during the instruction. The children were not able to connect all the factors formulating density concepts, because of the cognitive skills and inexperience. To receive a more scientific view of floating and sinking, the density of the object in terms of the density of the water should have been discussed more clearly and, especially, more focusing on the 'event' – directed approach for flotation would have been needed to promote the changes in ontological level. This approach, which is based on the balanced forces, is used in the curriculum in the UK. In this study the explanatory framework was based on the density. It helped the children to get rid of their 'weight-based model' and the children started to consider flotation as a phenomenon that depends on the several physical properties. In later years these properties may help children to understand the concepts of volume and density. The explanatory framework, which is based on the balanced forces, does not reveal all the elements involved. Furthermore the problem with the concepts of force is its abstract nature. In Finnish language it is confusing because it may be mixed with the word 'strong' (*voimakas* in Finnish). However, for understanding flotation as an event, the balanced forces framework would be proper. Thus, in teaching floating and sinking, both approaches should be taken account at the same time.

The issues discussed are linked to the ideas of Halldén (1999) about the contextualization of the conceptual change. The context in which the new concepts are learned are related to the cognitive context, but also to the cultural speech context. The cognitive skills or higher order concepts, which are used in the learning process, are based on several language backgrounds among the children. Thus the concepts introduced for the children should be well-balanced with the children's speech culture but also with their cognitive level. Thus the children are supported to become conscious of the nature of the language that is going to be used during later schooling.

Implications for the educational practice

In this study, during the instructional process, the children worked enthusiastically in collaborative groups for more than two hours. Thus experimental exploration is an appropriate, motivating and activating approach to science learning. In addition, the experiment in which the children transformed the sinking plasticine ball to a floating object was a particularly motivating and exciting one: all children participated actively in group work. In the post-interview this experiment was mentioned by many children, who related it to their conceptual justifications and descriptions of the instructional process. Cognitively demanding challenges are interesting for the children, but also very valuable for the process of conceptual change and for collaborative constructions. In addition, the skills for doing science were introduced to the children.

From the perspective of teaching and learning this study supported the *inductive approach* (see Sahlberg 1991) to instruction, which recommends analysing the phenomenon as a target. The phenomena of floating and sinking are difficult areas in primary science because of the four-dimensional aspects of density and including several viewpoints to examine. The phenomena include many dimensions and properties, which can be divided into parts. In this study the children considered floating and sinking from the viewpoint of several relevant properties of the phenomena, and succeed. The next step in the learning process would be a combination of the elements for the construction of abstract concepts such as volume and density. In addition, other possible explanatory frameworks also need to be taken into account.

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