Precursor models construction at preschool education: an approach to improve scientific education in the classroom

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ABSTRACT

This study aimed to explore young children scientific precursor models construction and how the designed teaching strategy was successful for improving science learning at preschool in a social context. We describe how 6 years old children built a precursor model of flotation based on density. The exploratory study used a qualitative data collection and analysis following a pre-interview, instructional process and post-interview design. On analyzing children's answers after the instructional period, we realized that several children were led to both the construction of a precursor model and a general qualitative upgrade in reasoning. We conclude that learning activities were effective and that the approach used in this study may help expand and improve teaching and learning of scientific concepts in preschool education.

KEYWORDS

Science education, precursor models construction, flotation, teaching and learning strategy, preschool education.

RÉSUMÉ

L'objectif de cette étude a été d'explorer la construction des modèles scientifiques précurseurs et comment cette stratégie pédagogique est en mesure d'améliorer l'enseignement des sciences dans un contexte du dialogue en préscolaire. Nous décrivons comment les jeunes enfants, âgés de 6 ans, ont construit un modèle précurseur de flottation basé sur la densité. L'étude exploratoire est basée sur une collecte de données et sur une analyse qualitative en utilisant un dessin pré-entrevue, procédé d'instruction, et post-entrevue. Analysant les réponses des enfants après la période d'instruction nous avons observé que plusieurs enfants ont pu construire le modèle précurseur et ont montré en général un haut niveau qualitatif de raisonnement. Nous assumons que les activités éducatives ont été efficaces et que, dans le contexte de l'éducation préscolaire, l'approche utilisée dans notre étude a pu conduire l'enseignement et l'apprentissage scientifique à une meilleure compréhension des thèmes scientifiques dans la salle de classe.

MOTS-CLÉS

L'enseignement des sciences, construction des modèles précurseurs, flottation, stratégies d'apprentissage et d'enseignement, éducation préscolaire.

INTRODUCTION

Science Education at preschool

Teaching and learning science at preschool classrooms can be viewed through different theoretical approaches. Most studies conducted in early science education have focused on cognitive development with much of the research taking place in laboratory settings away from the process in the classrooms (Venville, 2004). On the other hand, as Ravanis, Koliopoulos & Hadzigeorgiou (2004) have pointed out, in preschool education science curricula differ in both form and structure from the curricula in primary and secondary education. In preschool, most of the science activities are approached in the context of the whole curriculum and children's overall development consequently, with only a small portion of these activities devoted to the discovery of the natural phenomena. In addition, although sometimes preschool curricula are founded on explicit theoretical principles of teaching and learning, science activities appear to be fragmentary and included science concepts are confused with logic-mathematical concepts and problems of everyday living. The structure of a concept or phenomenon is not clearly addressed, the aim of an activity and its function in concrete situations is not fully explored or articulated (Ravanis & Bagakis, 1998), and activities fail to really promote the development of scientific thinking skills (Canedo-Ibarra, 2009). Most of these activities are characterized by their empirical perspective in presenting experimental processes and teaching materials, and others are developed only on the basis of the Piagetian perspective on the construction of knowledge which has been criticized (Ravanis, Koliopoulos & Hadzigeorgiou, 2004) because it focuses on children's autonomous activity and cognitive development, independent of others and their contexts. Focusing on individual children and their construction of knowledge offers an enormously inflexible way of viewing both children and knowledge, and accordingly represents a very limited means of conducting educational research in the sciences (Robbins, 2005). Curricula based on logical sequencing concepts are not useful in promoting the change in conceptions that are not compatible with scientific ones. Children also need opportunities to build new explanations, develop models, think about analogies and conduct experiments (Carey, 2000).

In the last fifteen years, investigations have been conducted in the context of theoretical approaches in which learning is viewed as a product of social interactions taking place during exploration of target concepts (Ravanis, Koliopoulos & Hadzigeorgiou, 2004). Social interactions in the designed learning environment can help children to construct new representations that do not have or transform their incompatible to science models conceptual representations. In this view, vygotskian and neovygotskian perspectives of social constructivism (Wertsch, 1990; Wertsch & Toma, 1995) claim that social interaction is the main shaper of scientific knowledge in children (Chinn, 1998). Social interactions in contexts where children's own views and arguments become explicit, mediated by the teacher, are considered more efficient than those teacher directed or child-centred discovery learning approaches (Havu-Nuutinen, 2000). In this context, science education is viewed as promoting a way of thinking socially. Science thinking is not a disembodied set of procedures but a complex process of intellectual development and the major challenge children face, is not that of acquiring correct experimentation strategies but of developing the ability to coordinate their existing theories with new evidences they generate, in an explicit, conscious, and controlled way. That means to think about their own thought (Kuhn, 1993). In the development of this way of thinking besides scientific procedural skills and attitudes (Harlen, 1998), language, discourse and argumentation also play a main role (Driver, Newton & Osborne, 2000; Duschl & Osborne, 2002; Mercer et al, 2004). New concepts, learned in instructional contexts, are the result of building up existing ideas through social experiences where children share and discuss with others. As a result of this process the concepts are verified, or become more complete or they are completely reconstructed. In this paper we discuss how 6 years old children changed their ideas about flotation in a social context following a teaching strategy based on a precursor model of flotation based on density.

THEORETICAL FRAMEWORK

The goals of early Science Education

The central goal of science education should be to develop children's understanding and appreciation of the forms of knowledge-making that characterize scientific practice (Leach & Scott, 2000). In this process, the learner is engaged in making sense of the scientific view, and this learning is carried out against a backdrop of existing everyday ways of thinking about the phenomena under scrutiny. In this sense, learning science involves seeing phenomena in new ways (Sutton, 1992). Thus, in order to learn science, children should learn to see the phenomena in the same way as scientists and teachers.

Science education is thought to contribute to the development of scientific reasoning by engaging children in inquiry situations. In formulating questions, accessing and interpreting evidence, and coordinating it with theories, children are believed to develop the intellectual skills that will enable them to construct new knowledge (Chan, Burtis & Bereiter, 1997). However, it seems that there is a gap between the belief that science education based on inquiry will promote scientific reasoning and that the cognitive skills necessary to engage in inquiry may not be adequately possessed by children (Kuhn, Amsel & O'Loughhlin, 1988; Kuhn, Schauble & García-Millan 1992; Kuhn et al., 1995; Schauble, 1990, 1996), although according to several other research reports even younger children show the ability to think scientifically (Brown, 1990; Gelman & Markman, 1986; Koliopoulos et al., 2004; Krogh & Slentz, 2001; Ravanis, 1999, 2000; Ravanis & Bagakis, 1998; Robbins, 2005; Ruffman et al., 1993; Venville, 2004; Zogza & Papamichael, 2000). Thus, the main goals of learning science should be those of children's understanding and appreciation of the forms of knowledge-making that characterize scientific practice. Children should be engaged in scientific thinking to improve their interpretations and understandings about the world where they live.

Most of the studies concerning science education have been carried out in primary and secondary levels of education and have focused on children's conceptions about scientific phenomena. These studies have led to the widespread recognition that young children have naïve or spontaneous ideas about natural phenomena (Carmichael et al., 1990; Driver, Guesne & Tiberghien, 1985; Pfundt & Duit, 1994), and that these ideas do not always match with scientific ones. In addition, the evolution of student's ways of thinking about phenomena tends to be a slow and piecemeal process (Scott & Driver, 1998). These aspects have led researchers to look at how to develop effective and meaningful teaching and learning processes. In this sense, researchers have emphasized that children's cognitive abilities need to be enhanced, opportunities and contexts in which children are able to test their current views of the phenomenon must be provided, and that children's prior knowledge plays a critical role in the learning process.

Scientific precursor models

Based on the actual science education research agenda, some approaches to teaching science to young children have been reported (The National Research Council - U.S.A, 2004):

Methods of empirical inquiry and theory building. In this approach, children learn how to pose questions, to think carefully about how these questions could be answered empirically, and to master a repertoire of methods to carry out empirical investigations (Metz, 2000). On the other hand when building theories, children build their own science understanding based on explicit reflections (Hennessey, 2003).

Modeling. The process of learning via model construction appears to be central to theory formation in science and is central for science instruction (Clement, 1989; Coll, 2005). The inclusion of models in science teaching provides a link between science practice and science teaching (Coll, 2005), and the understanding of the role of models contributes to an 'authentic' science education in which the education reflects the nature of the different disciplines (chemistry, physics, etc.) as much as possible (Gilbert, Boulter & Elmer, 2000).

This approach emphasizes developing models of phenomena in the world, testing and revising models based on observations and data to bring them into better, and over time developing a repertory of powerful models that can be brought to bear on novel problems. Models and modeling are key tools for scientists, science teachers and science learners. The use of models and analogies within the pedagogy of science education may provide a route for students to gain some understanding of the nature of science, and in order to successfully develop conceptual understandings in science, children must be able to reflect on and discuss their understandings of scientific concepts they are developing (Coll, 2005). Modeling approaches (Clement, 1989, 2000; Boulter & Gilbert, 1996, 2000; Gilbert & Boulter, 1998; Gilbert, Boulter & Elmer, 2000; Gilbert, Boulter & Rutherford, 2000) have the advantage of avoiding the content-process debates that have been carried out in science education. When children are engaged in modeling, reasoning processes and scientific concepts are always deployed together. This approach has shown that it results in strong children's gains in their reasoning (Leher & Schauble, 2000).

Model construction as symbolic representations, is based on progressive articulations between the empirical, formal, and cognitive registers (Weil-Barais, 1997). However, the creation and use of models in science teaching are the result of specially oriented, long-term educational processes, whereas, their construction depends on a high cognitive level. Thus, the construction of a model by younger children could not be the acquisition of the model itself. In this respect, the concept of precursor model (Lemeignan & Weil-Barais, 1993) is a fruitful approach in aiming and observing young children cognitive progress (Ravanis, 2000). These scientific precursor models are compatible with scientific models, since they are constructed on the basis of certain elements included in the scientific model and have a limited range of application (Ravanis, Koliopoulos & Hadzigeorgiou, 2004). These precursors are cognitive constructions (concepts, models, procedures, etc.) generated in the learning environment. They constitute the moulds for subsequent cognitive constructions, which would be difficult or impossible (Weil-Barais, 2001) without the help of already acquired precursor models. Young children posses a natural desire for interpreting the world around them using the cognitive sources they have in doing so, however, children do not necessarily use the ones in order to make connections from a scientific point of view. From observing available data children are able to develop a repertory of more powerful models that let them to resolve new problems improving their reasoning (Leher & Schauble, 2000), changing gradually the naivety of their initial models to the complexity of scientific models (Arcá & Guidoni, 1989). A precursor model can be considered as a teaching model according to Gilbert and Boulter (1998), and Erduran and Duschl (2004), or a scholar model according to Izquierdo et al. (1999) and Sanmartí (2005), that is, a model specially built to promote the understanding of the consensual model (Gilbert & Boulter, 1998; Erduran & Duschl, 2004). These precursor models may become the tool that guides the teacher's instruction activity. They are models that grows in complexity from a set of basic central notions, and they also every time become complicated by new relations.

In this study the view of science is that of a process of articulation, test, evaluation and redefinition or revision of models representing the world (Giere, 1988, 2002, 2004), thus, the knowledge of multiple domains or sub-domains of science is constructed, firstly, in terms of families of theoretical models that represent important aspects of the external world (Giere, 2004). In the same way, the learning of science is viewed as a process of building domain-specific knowledge, assuming learning conceptual domains such as science and mathematic, are characterized by the development of structures and processes and domain-specific concepts. Therefore, the investigation has focused on helping children to acquire the nuclear ideas and ways of thinking that are central to a particular domain of knowledge, that is the flotation and immersion phenomenon. Furthermore, the teaching-learning process is contextualized on the socio constructivist perspective (Driver & Scott, 1996), which takes into account both social and individual learning. Learning is considered as a product of social interactions that take place around key scientific concepts. In this sense the social context is considered as a determining factor in the individual ownership of knowledge.

Based on scientific precursor model approach, some authors have designed teaching strategies for promoting different models construction. Koliopoulos et al. (2004) found that children aged 5-6 were able to construct a precursor model of flotation based on an intuitive concept of density considering the type of the material the objects were made. Ravanis, Koliopoulos and Hadzigeorgiou (2004) working with a precursor model of friction found the consideration by children aged 5-7 of both the 'weight' and the 'nature of the surfaces in contact' as variables in predicting the motion of an object on a track. In another study with children of the same age, there was an attempt to induce the construction of a precursor of living things based on biological properties related with environment dependence (Zogza & Papamichael, 2000). Not situated on precursor model approach but in general modelling, Acher, Arcá and Sanmartí (2007) reported that children aged 7-8 built a model that led to explain the behavior of different materials by using a "model of parts" created ad hoc. This model, built up from some kind of a discrete vision of the material, proved to be coherent for children of this age and evolved by relating the visible continuum with an imagined discontinuum.

Research contributions on children's ideas about flotation

There are several studies that have addressed the phenomenon of buoyancy (see Canedo-Ibarra, 2009). These studies show that young children explanations (4-7 years old) do not correspond to their observations. Children explain the phenomenon in terms of either an animistic or moral necessity or use a single object's property, such as weight, which they associate with an object purpose (Piaget, 1930; Piaget & Inhelder, 1974). From 5 to 7 years, children explanations depend on their observations, but they tend to believe that an object should float because it is strong or heavy (Biddulph & Osborne, 1984; Laevers, 1993; Piaget 1930; Piaget & Inhelder, 1974; Smith, Carey & Wiser, 1985) or considering size, presence of holes, or more than one variable as one. Others combine more than one variable but not listed in the appropriate form (Howe, Tolmie & Rogers, 1990; Dentici et al. 1987; Laevers, 1993; Rodríguez, 1980; Tenenbaum, Rappolt-Schlichtmann & Vogel Zanger, 2004). Some other children consider objects and water properties such as volume (Biddulph & Osborne 1984; Rodríguez 1980). Other studies have shown that many children give explanations about the phenomenon of floating considering the presence of holes, air, and weight (Biddulph & Osborne, 1984), and that they have an intuitive idea about density that led them to correct predictions about floating and sinking (Khon, 1993; Koliopoulos et al. 2004), although they are not able to relate the factors to formulate the concept of density (Havu-Nuutinen, 2000, 2005).

In summary, it seems that preschool children are able to develop a scientific thinking of the phenomenon but the concepts of volume and density does not necessarily have to be used. Studies in recent decades show that the physical properties used by children in explaining the phenomenon are only marginally relevant to the density. Moreover, the works of Biddulph and Osborne (1984), Khon (1993), Koliopoulos et al. (2004) and Havu-Nuutinen (2005) show that experimental activities encourage children to establish their own relationships and trials and, if these activities are interesting and understood, they are able to successfully solve scientific problems. What helps to establish a basis for formal reasoning depends on the concepts that children have acquired (Havu-Nuutinen, 2005), hence the importance of children's access to scientific concepts from an early age.

Since in a model-based teaching and learning strategy, conceptual development and evolution seems to be appropriate (Clement, 1989), precursor models construction in a social context appears to be a useful approach in guiding teaching and learning science at preschool education. They may help children to acquire some nuclear ideas and ways of thinking that are central to a particular domain of scientific knowledge when they articulate, test, evaluate and redefine their own models about the world. These precursors also may constitute the basis for subsequent models construction.

Assuming that preschool children are able to develop a scientific thinking about phenomena, this study was guided by the following research questions:

- Which are children’s ideas changes about flotation after an instructional period?
- Which are flotation precursor model’s characteristics that children construct after an instructional period?

METHOD

The exploratory study used a qualitative data collection and analysis and was approached as a case study (Merrian, 1998). Although the case study itself is not transferable, interpretations based on educational case studies can be valuable outside the contexts in which they were carried out (Havu-Nuutinen, 2000) to discover what is common and specific and to know the conditions certain assumptions are met in some contexts and not in others (Latorre et al., 1996). For the purpose of the study we have selected the phenomenon of floating and sinking of bodies in the water because it is a very familiar phenomenon to children.

The subjects of the study

Research was conducted in a public school in the city of Barcelona, Spain. We worked with a class of 24 children 6 years old (14 girls and 9 boys). The class, in turn, was divided into groups of 4-5 children to facilitate the exchange of ideas between them and the teacher (Rafal, 1996). This grouping was done by selecting boys and girls so the subgroups were mixed. In precursor model construction analysis, only children who participated in the whole instructional process (pre-test-training-post-test) were considered.

Data collection

The strategy of data collection was participant observation based on audio and video recordings of class activity and diary recordings as well. The researcher took an active part in the process for deepening and enhancing children's understanding. To evaluate the construction of the precursor model by children a pre-test-interactive phase-post-test design was followed, and data collection was carried out in several steps. The main instruments for data collection were semi-structured individual interviews "about events" (Carr, 1996), both in pre-test and post-test, recordings of the class and a class diary. Interviews followed a pattern, but the structure varied with the interviewed child. They were conducted in an informal atmosphere to encourage children to feel comfortable. Initially, materials were shown to children and the interviewer made sure that children understood what they were going to do. In the same way, the interviewer allowed children to express their trials and gave them sufficient time for thinking. Each interview was conducted in a quiet place (the school staff room). During the interactive phase recordings were made as well, while the children carried out the activities. Thus, interviews and interactive recordings have been the primary data for analysis. Next we describe the different phases.

Procedure

A. Pre-instruction phase

Children's prior knowledge about floating and sinking of bodies was identified from the interviews conducted during pre-instruction phase. In the first part of the interview children were asked to explain what they understand about "this object floats" and "this object sinks", and what kind of objects they knew or had seen floating or sinking, and why. Most children asserted that an object floats when "it remains on the water" and sinks when "it goes down in the water". When children were not clear, the researcher asked them to clarify these concepts. In addition, they were asked to talk about their experience with the phenomenon and to draw the objects that floated or sank for clarifying their thoughts. In a second part of the interview children were asked to make predictions about some objects that float or sink.

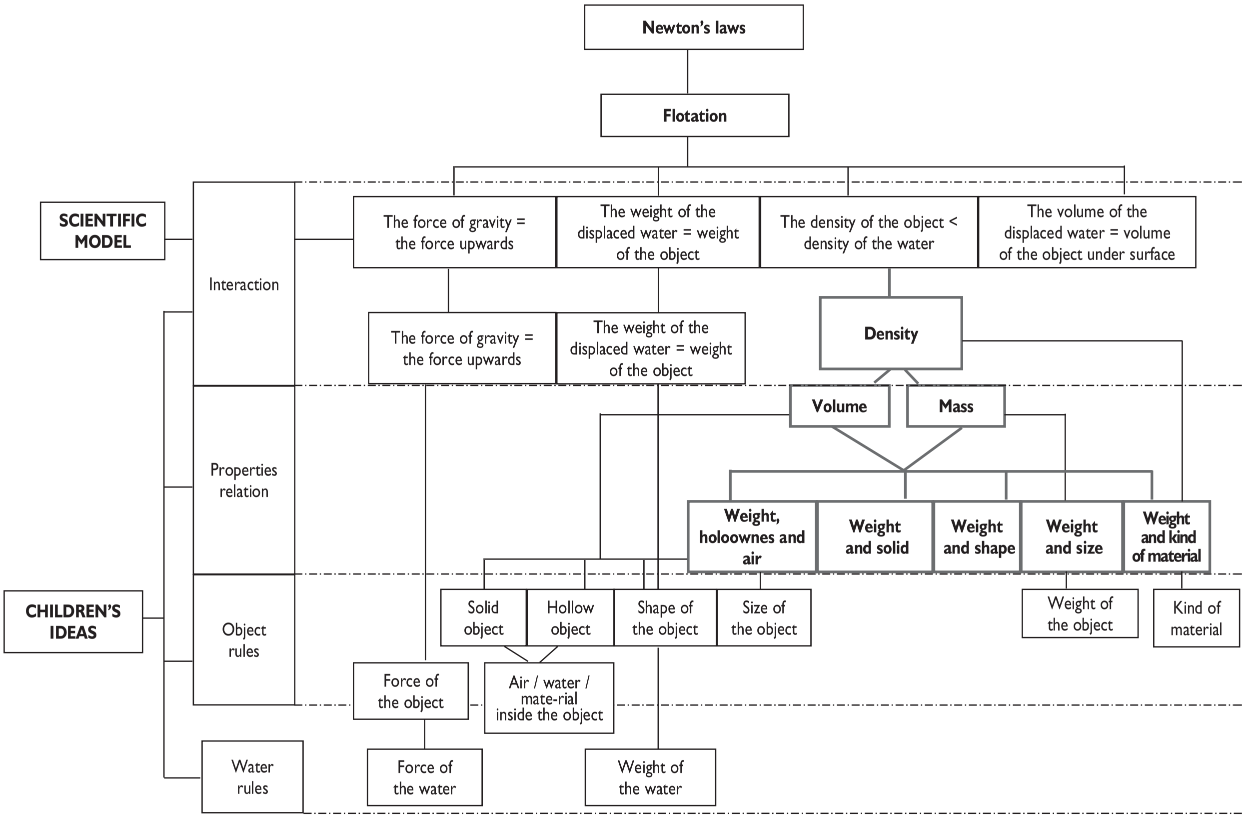
B. Design of the instruction at the interactive phase

a) Scientific precursor model characterization used in this study

Scientific precursor model of flotation (see Figure 1) was determined on the basis of the scientific model that considers Newton's laws, research contributions on children's ideas about the phenomenon, and our children initial ideas that were identified during the pre-test. These issues are discussed in the next sections.

FIGURE 1

Precursor model of flotation used in this study



- *Flotation scientific model*

A simple interpretation of a body flotation and sinking phenomenon may come in two different ways from the balance of forces mechanical model: A) considering the balance of forces or the comparison of forces, and B) considering the balance of densities or comparison of densities. The first conclusion is related to the comparison between the values of the forces acting on the solid body and is based on the classical definition of the principle of Archimedes. The second specification requires the definition of "density" (or the relevant term "specific weight") and is related to the comparison between the densities of the solid and the liquid where the body floats or sinks. Based on these concretions the phenomenon of floating and sinking can be explained in four ways taking into account force, weight and volume:

1. When a stationary object is floating in the water, the weight of the material is acting down and the water should provide an upward force called "upthrust". These forces must be balanced so that the object floats.
2. If an object floats in water, it displaces an amount of water whose weight is equal to the force of upthrust. Archimedes' law describes precisely this equality between upthrust (= weight of water displaced) and the weight of the floating body. If a body floats, the weight of the volume of water displaced equals the weight of the object.
3. When a body floats in water, volume displaced water is the same as the object on the water surface.

The buoyancy or not buoyancy of an object is determined directly by its density (more precisely, the density of the substance that the object is made of). Objects made of a substance with a density lower than water’s will float, while those that are made of a substance with a density greater than water’s will sink (Jardin & Kennedy, 1997; Khon, 1993).

- *Our children’s ideas about floating and sinking*

Children’s justifications categorization in pre-test is shown in Table 1

At first some children gave no answer or used irrelevant properties to explain the phenomenon. Most of them justified the phenomenon based on a single object property, mainly *weight*. They used other properties, some of them frequently, such as *type of material* and *size*. In the same way, some children used some properties putting together *kind of material*, *size, air,* and *hollowness*. Other children combined *weight* with the *presence of air* and *kind of material* in order to explain the phenomenon. Only a few children justified the phenomenon based on an *interaction model* relating objects and water properties (see Table 1). Based on these results we assumed that most children had an initial flotation model based on the *weight* of the objects, which is consistent with previous studies (see Biddulph & Osborne, 1984; Havu-Nuutinen, 2000, 2005; Laevers, 1993; Piaget 1939; Piaget & Inhelder, 1974; Smith, Carey & Wiser, 1985).

TABLE 1

Children's criteria at the pre-test

Criteria	
Irrelevant /non scientific answers	
Justifications based on properties of the objects or of the water (non interaction)	*Weight*
	Size
	Effect of the air/water
	Kind of material
	Solid (something inside)
	Hollowness
	Properties put together different from weight
	Relevant properties put together with weight
	Force
Justifications based on interactions among the object and the water	*Weight of the object/Weight of the water*
	Force of the object/Force of the water

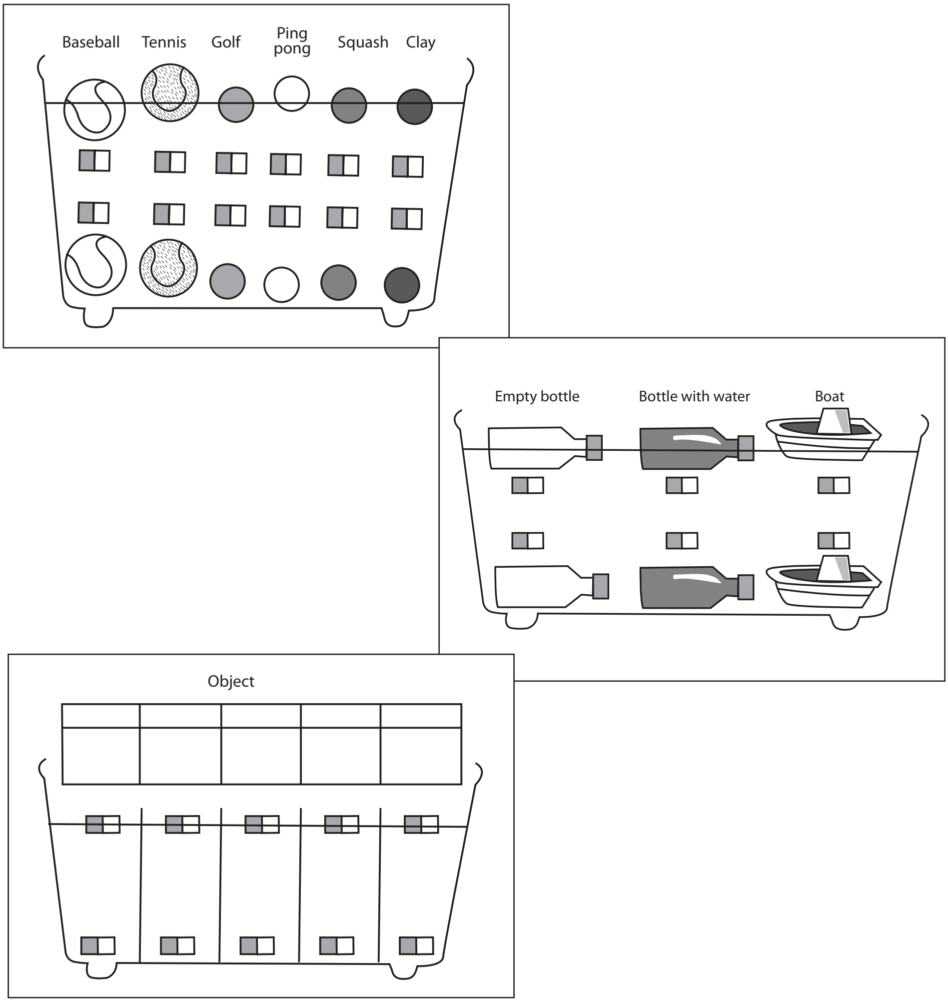
- *Construction of precursor model of flotation based on density*

The precursor model was constructed considering the scientific model based on density, that is, objects with a density lower than water or equal to water will float, and objects with density greater than water will sink (see Figure 1). One reason for selecting this model approach concerns the realization that the interaction of forces is more difficult for children's understanding due to its high degree of complexity and abstraction. Thus prior to a forces model construction, children should develop a model of interaction to fully understand the mechanism of action of forces (Lemeignan & Weil-Barais, 1993; Goffard & Weil-Barais, 2005). Moreover, most children in our study initially based their judgments on the objects' *weight*, and a very few times they linked *weight* with *form* and *size*. In this sense, it was feasible that children would develop an understanding of the phenomenon by relating the *weight* of objects with properties related to *volume*, and consequently build the concept of *density*. This approach is considered to be more relevant to illustrate the phenomenon and seems appropriate for children to develop a scientific idea of flotation in early childhood education, although the concepts of volume and density are not used (Havu-Nuutinen, 2000, 2005; Koliopoulos et al., 2004).

b) The interactive phase

The interactive phase was conducted one week after the pre-instruction phase and took place in the laboratory of the school. This phase was conducted with each group of children (4-5 children each) to support the development and construction of the precursor model of flotation. The viewpoint of the research on children's learning was based on the socio perspective, thus each child was considered as an independent and active participant in the process. Furthermore, the teaching design followed a teaching strategy based on modeling (Boulter, 2000; Boulter & Gilbert, 1996, 2000; Boulter & Buckley, 2000; Clement, 1989, 2000; Coll 2005; Gilbert & Boulter, 1998; Gilbert, Boulter & Elmer, 2000; Gilbert, Boulter & Rutherford, 2000), and scientific precursor models particularly (Lemeignan & Weil-Barais, 1993; Weil-Barais, 1997, 2001). In this perspective, the teacher provides children with information, learning activities and uses instructional strategies to facilitate the construction of mental models individually and collectively, i.e. by each of the children and between the children, members of the

FIGURE 2



Work sheets used during the instructional phase (from Havu-Nuutinen, 2000).

group (Gobert & Buckley, 2000), during the process of instruction. In addition, this stage involved a collaborative teaching approach (Boulter, 2000), using a guided discovery learning strategy (Ausubel & Robinson, 1969; Havu-Nuutinen, 2000, 2005). In collaborative lessons, social interactions promote the individual trials and discussions with peers and the teacher, and the teacher helps creating situations which may lead to cognitive conflict. Learning by guided discovery supports the active role of learners during the learning process and provides opportunities to observe, predict, explore, describe and develop hypotheses (Havu-Nuutinen, 2000).

At the interactive phase children developed predictions and assumptions about the behavior of different objects in the water, recording their predictions on working sheets (Figure 2). Later, children tested floating behaviour of objects in the water, discussing and evaluating their predictions and hypotheses. Working sheets supported children when comparing their predictions with the results obtained during experimentation (See Havu-Nuutinen, 2000, 2005).

Finally, in a development phase, we asked children to bring objects from home for testing them in the water at the laboratory. In this activity children again made predictions, hypotheses, experimented and discussed their results by recording their data and giving the reasons for the behavior of the different objects in the water.

C. Post-instruction phase

Children explanations after the instruction phase were explored by interviews that were the same as in the pre-instruction phase. The purpose of this post-training test was to evaluate children's learning, and to characterize the precursor model constructed.

Materials

The materials used in this study were working sheets, objects that appear in the tabs (tennis balls, baseball, pin pong, golf, squash, clay ball), a plastic bottle full of water, an empty plastic bottle, a small boat made of plastic, aluminum foil, and several objects children brought to the laboratory.

Data analysis

Interviews and instructional phase video recordings were transcribed for analysis. Data analysis was conducted on the basis of a content analysis of verbal data (Chi, 1997). Content analysis usually is related to the “what and how” the phenomena under study develop, and is extremely valuable in analyzing data from observations and interviews (Fraenkel & Wallen, 2003). Although the frequencies of some identified categories were not as significant to the study, in some cases they were taken into account. The objective was to determine whether certain categories of units were present or not in communication.

Data analysis was focused on children's conceptions about the phenomenon of buoyancy at particular time and contexts. Based on these conceptions, categories were set and we explained how children understood the phenomenon. Moreover, the study sought to explain the manner in which these concepts were extended and reconstructed mainly on the basis to what was discussed during the training process. The content analysis aimed to investigate the nature of children's representations about the physical phenomenon in an instructional context.

Children explanations categorization was based on Havu-Nuutinen's (2005) schema, although some others categories emerged inductively. Once the codes successfully described all data, we established the whole categorization pattern and all transcripts were recoded using the final scheme.

RESULTS

Flotation has been selected for this study because it is a phenomenon very familiar to children, and yet, for children and even adults it is difficult to understand and explain in scientific terms because of its complex and multidimensional characteristics (Havu-Nuutinen, 2000). Children recognize this phenomenon at an early age through their explorations and experimental activities performed in their natural environment. However, difficulties in understanding may lead to the development of alternative ideas that subsequently affect the development of a scientific view. Scientific understanding of the phenomenon of flotation may be achieved from the change of ideas based on concepts of everyday life that children use to develop rules that explain it in a scientific manner (Havu-Nuutinen, 2000). To understand the phenomenon of floating children should concentrate on the interactions that occur between objects and the fluid in which these are immersed, and this requires a change from mental and matter ontological categories to processes ontological category (see Canedo-Ibarra, 2009). In this sense, this physical phenomenon explained by its observable properties, must be explained from the interaction processes that take place in the physical system (see Pozo & Gómez Crespo, 1998; Pozo, 1999). Considering the density approach selected for this study, we think that a way children could understand and explain flotation may be that of establishing the relationship between the mass and volume of objects as a factor that can affect the phenomenon. In a first step, children should explain the phenomenon in terms of the relationship between weight and properties of the objects related to volume, and not only in terms of weight, or isolated properties of the objects.

Categorization of children's ideas

To interpret data, coded units were compared considering the flotation precursor

TABLE 2

Categorization used in children's understanding about flotation

1) Irrelevant /non scientific answers		Children do not use physical properties of the objects or they give irrelevant answers.
2) Non interaction justifications	**a) Based on the weight of the object or the weight of the water**	Children give arguments based only on the weight of the object or the weight of the water. It includes contradictory answers.
	b) Based on kind of material or volume (form, size), or effect of the air or water.	Children explain the phenomenon using these properties but not put together
	c) Based on two or mores properties of the objects put together	Children explained the phenomenon using different relevant properties based on volume, such as shape, size, solid or hollow.
	d) Based on relevant properties of the objects put together with weight.	Children show an initial idea about density but not in a clear way. They put together the weight of the objects with other relevant properties.
	c) Based on the force of the object.	Children arguments are based only on the force of the object.
3) Justifications based on interactions among the object and the water	**a) Children use arguments based on the weight of the objects and the weight of the water.**	
	b) Children use arguments based on the force of the objects and the force of the water.	

scientific model (see Figure 1), and previous studies on child's conceptions about floating. In this section, the analysis focused on each child's cognitive representation as it was conceived from their replies, thus the evaluation of the instruction phase was based on changes in their justifications. Changes in thinking were revealed by comparing children's justifications during pre-test and post-test, and the purpose of this analysis was to find qualitative differences in children's explanations before and after the instructional phase. Categorization is shown in Table 2.

This categorization considers floating and sinking from the viewpoints of *weight*, *volume*, *density*, and *interaction of forces*. First, we have taken into account the evidence in which children did not establish relations of interaction between the properties of the objects and the water, and second, reasons based on interaction between the properties of the objects and the properties of the water. In Justifications *not based on interaction*, floating and sinking were explained considering issues related to *weight*, *volume*, *density* and *force* of the object or of water either. These properties appeared in children's judgments to explain the phenomenon in the pre-test, in the post-test, or both. At the same time this categorization considered three main levels of reasoning in which level 1 (irrelevant responses / non-scientific) was the lowest level, and level 3, the highest (interaction forces) (see Table 2).

In the first category, *non-scientific and irrelevant replies* (level 1), children justified the phenomenon based on personal experiences e.g. "*Floats because I tested it*", gave tautological answers e.g. "*Floats because it is a floater*", or based their judgments on irrelevant properties of the objects e.g. "*Floats because it is red*".

The second category, *justification of non interaction* (level 2) included several subcategories in which the reasons for the buoyancy were several properties of the objects, both irrelevant and relevant. In this category, subcategory *a* included judgments based only on *weight* e.g. "*Sinks because it weighs*", "*Floats because it weighs a lot*". Subcategory *b* included responses in which children based their judgments using properties of the objects different from weight but not put together, e.g. "*Sinks because it is clay*"; "*Floats because it has nothing inside*", "*Floats because it's small*". In subcategory *c* replies were based on two or more - not weight-related - properties of the objects e.g. "*Floats because it is small and it is plastic*", "*Floats because it is empty, there is air and can float, and has a material floating, plastic*", "*Sinks because even it is small it has as……..an iron that makes it sink*". Answers in subcategory *d* were considered as representing high level in children's reasoning and were related to the precursor model proposed. In these justifications children put together *weight, size, shape, type of material, hollowness and emptiness.* In this category children also mentioned the *force of the object*, e.g. "*It floats because it is lightweight, strong. It is hard but not too heavy and the other is different, a different size*", "*It sinks because it has not enough force to float.*"

Finally, the third category included justifications based on the *interaction* between the objects and the water, and represented the most developed children's reasoning in which they related relevant properties, both of the objects and water. At this level, children justified flotation connecting the *weight* or *force of the objects* with the *weight* or *force of the water* e.g. "*It sinks because it has more weight than the water*"; "*It floats because it endures, endures a bit of the boat force*". Table 3 shows how each unit of analysis has been placed following the categorization scheme. The first column corresponds to the participant children.

Children's explanations about flotation before and after the instructional period

Notable differences were observed to children who expressed non-relevant or non-scientific explanations. The justifications that belonged to the lowest group in the pre-test seemed to develop towards more relevant explanations in the post-test. In the pre-test many of the children explained flotation with non-scientific or irrelevant reasons basing their arguments on everyday experience e.g. 'I have seen a boat floating on TV',

TABLE 3

Children's judgements about flotation in pre-test (▲) and post-test (♣)

Children	**Irrelevant and non-scientific answers**	**Non-interaction justifications**				**Justifications based on interactions between the object and the water**		
Levels	**I**	**2a**	**2b**	**2c**	**2d**	**2e**	**3a**	**3b**
SER		▲▲▲▲▲▲▲	▲ ♣♣♣♣	♣♣♣♣♣	▲ ♣			
ES	▲▲▲	▲C▲C▲ ♣	▲▲ ♣♣	♣♣	♣♣♣		▲ ♣	
OR	▲▲▲	▲	▲	♣♣♣♣♣	♣♣♣			▲▲▲
PA	▲	▲▲▲▲▲▲	▲ ♣	♣	▲ ♣♣♣♣♣	♣		♣
JP	▲▲ ♣♣	▲▲▲▲▲▲▲C ♣	♣	♣	♣♣♣♣			
AI		▲▲▲ ♣	♣♣♣	♣	▲	▲C ♣♣♣	▲▲▲▲	
ARI	▲▲▲▲	▲C▲C	▲ ♣♣♣	♣	▲ ♣♣♣			
SAN	▲▲	▲▲▲		▲ ♣	▲▲▲ ♣♣♣♣♣♣♣♣			
JM	▲▲▲▲▲		▲ ♣♣	♣	▲▲ ♣♣♣♣♣♣		▲	
AN		▲ ♣	▲▲▲▲ ▲ ♣♣♣	♣	▲ ♣♣♣♣			
AN	▲ ♣♣♣	▲▲▲C▲C	▲▲ ♣♣♣	▲	▲C ♣♣♣			
ADR	▲▲	▲	▲▲▲ ♣♣♣	♣	♣♣♣♣♣	▲		▲C
MIRE	▲▲▲		▲▲▲ ♣♣♣♣	▲ ♣♣	▲▲ ♣♣♣♣♣			
CATA	▲▲	▲▲▲▲▲▲	▲ ♣	♣♣	♣♣♣♣			
ON	▲	▲▲▲ ♣	▲▲▲ ♣♣♣	▲	▲ ♣♣♣♣♣			
NIL		▲▲▲▲▲▲▲ ♣	♣		▲▲ ♣♣♣♣♣			
LID		▲▲▲▲▲▲ ♣	▲ ♣♣		▲▲ ♣♣♣♣♣♣			
MIRI		♣♣♣♣♣	▲▲▲▲ ♣♣♣	▲▲ ♣	▲▲▲			
AR	▲	▲▲▲▲▲	▲ ♣♣♣♣	♣♣	▲▲ ♣♣♣			
AL	▲▲▲ ♣♣	♣♣♣♣♣♣♣♣♣	▲▲▲▲▲	♣	▲			
VIC	▲▲	▲▲▲C	▲▲▲	♣♣	▲ ♣♣♣♣♣			
TAT		▲▲▲▲▲▲▲ ♣♣		♣	▲▲ ♣♣♣♣♣♣			
MERI	▲▲▲▲▲▲▲▲▲ ♣♣♣♣♣♣♣♣♣							
CAR		▲C▲C▲C ♣♣♣♣♣♣♣	▲▲▲▲▲▲ ♣		▲C▲C ♣			
Pre-test	21%	36%	21%	3%	13%	0.5%	3%	2%
Post-test	7%	11%	19%	16%	41%	0.5%	2%	0.5%

or on some characteristics of the objects e.g. 'This ball will float because it has hair'. By the post-test, most of these justifications had almost disappeared (see Table 3). In the post-test children began to consider flotation more accurately in terms of the event itself basing their arguments on many relevant characteristics (category related with the precursor model). By the post-test, children still judged flotation in terms of the properties of the objects but the way they considered these properties changed substantially. The nature of the phenomenon of flotation is multidimensional, so the perception of these dimensions is central to the changes in children's ideas (Havu-Nuutinen, 2005). After the instructional process, most children used *weight* and several relevant properties of the objects (see Table 3, Figure 1) to explain the phenomenon whereas in the pre-test, isolated properties were the most relevant criteria used by children. Although children changed their way of explaining flotation towards a more scientific way, the answers varied widely at all levels of quality depending on the context. Different materials used by the children had a remarkable effect on children's changes of ideas supporting their forms of reasoning. These changes are described below.

The lowest changes in children's ideas were those in which they showed a poor understanding about flotation, that is, children judgments after the instructional phase were still irrelevant and their arguments were based on different properties of the objects without putting them together. However, these children began to use the *weight of the objects* more frequently.

During pre-test:

T: AL, here you have different objects: two bottles and a little boat. If you put them in water what would happen? Would they sink or would they float?

AL: I have probed with some stones and ducks, and ducks float because there is more and more water then they sink because there is no water.

T: OK. That is what you have observed but, now you must think about this bottle -empty- you have here Does it float or does it sink?

AL: It will float.

T: Why does it float?

AL: Because I did it.

T: And what would happen with the other bottle -filled with water-?

AL: It will sink because has a lot of water.

T: How is that? Can you explain that to me?

AL: It sinks. That is all.

T: And what would happen with the boat?

AL: It will float.

T: Why does it float?

AL: Because it does.

During post-test:
T: AL, here you have the bottles and the boat again, what happen if you put them in water? Will they float or sink?
AL: This one -empty- will float because it is small and it is made of plastic.
T: What will happen with this one -filled with water-?
AL: It will sink because it has water but if you take off a little water it will float.
T: Why does it sink when it is filled with water?
AL: Because it does.

During pre-test:
T: We have now these different balls. If you put them in water will they float or will they sink?
AL: This baseball will sink because is fat.
T: How is that?
AL: It will sink because is big.
T: What will happen with the tennis ball?
AL: It will sink because is a little fat, big.
T: And what about these other three?
AL: The golf ball will sink because is hard and has a lot of weight. This one -ping pong ball- will float because has little weight, and the clay ball will sink because it weights.

During post-test:
T: Al, what do you think will happen to the balls we used if you put them in water? Will they float or will they sink?
AL: The baseball will float because it weighs a little and it is soft.
T: And what will happen with the tennis ball?
AL: It will float because it has less weight and it is hard.
T: And the golf one?
AL: It will sink because it is hard and it has weight.
T: What do you think about clay and squash balls?
AL: This -squash- will sink because it has little weight and it is very soft and the clay ball will sink because it is hard and has weight.

On the other hand, the greatest changes were those in which children's arguments were based on several relevant properties of the objects combined some of these related to *density*.

During pre-test:
T: And here we have a tennis ball, will it float or will it sink?
JM: It will float.

T: Why does it float?
JM: Because it has hair and it has a kind of material that protects it.
T: What do you think will happen to the clay ball?
JM: I do not know.
T: And what about the boat?
JM: It will float because it is strong and it has nothing inside.

During post-test:
T: If we put the balls in the water again what will happen? Will they float or will they sink?
JM: This -baseball- will float, although it seems the material is hard. It is a kind of material that floats.
T: What do you think will happen to the golf ball?
JM: It will sink because it has weight, it is very heavy, and it is another kind of material, it has another form.
T: What can you tell me about the ping pong ball and the squash ball?
JM: The pin pong ball will sink because has air and the material weights a little, it is a material that weights. The squash ball will float because it is plastic, we now know that it does not sink because has a little air, it does not sink at all. A half ball sinks because the material is little light.

During pre-test:
T: Now, here we have this bottle -filled with water- will it float or will it sink?
JM: I think it will sink because it does not have air.
T: How is that?
JM: It has air but it sinks because it has the same weight as the water, although it is different.
T: What is different?
JM: The weight.

During post-test:
T: What will happen with the bottles and the boat if you put them in water? Will they float or will they sink?
JM: This bottle -empty- is like the squirt, it just has air and as the air does not weight, it could float. The one that has water will sink because is not the same as the other one. If the water weights, it is able to sink.
T: What about the boat?
JM: It floats because of the form and because it is plastic.

These interactions show that JM's reasoning about the phenomenon improved significantly. These sorts of changes were the most important in children. Before

TABLE 4

Criteria children used in explaining flotation in pre-test and post-test

Criteria			Pre-test	Post-test
			Frequency	Frequency
Level 1	*Irrelevant /non scientific answers*		**45**	**16**
Level 2 **Non-interaction justifications**	2a	*Weight*	78	24
	2b	*Effect of the air/water*	8	26
		Form	0	1
		Size	13	1
		Kind of material	17	7
		Solid (something inside)	1	3
		Hollow	6	2
	2c	*Properties different from weight put together*	7	34
	2d	*Relevant properties put together with weight*	24	66
	2e	*Force*	1	1
Level 3 **Justifications based on interactions between the object and the water**	3a	*Weight of the object/ weight of the water*	7	4
	3b	*Force of the object/ force of the water*	5	4

instruction JM gave irrelevant answers or he did not answer at all. However, JM showed an intuitive idea about an interaction mechanism among the objects and the water based on weight but this idea was not very clear and he used this argument only once. After instruction, JM used several relevant properties and put them together such as *weight, form* and *kind of material*. He also used the *effect of the air* or the *water* in flotation and sinking.

Children's explanations after the instructional period were based mainly on non-interaction judgments, that is, their justifications were based on the properties of the objects. The way in which this relationship was established depended on the context in which tasks were performed. Criteria used by children to explain the flotation in the pre-test and post-test are shown in Table 4.

At pre-test, some children gave irrelevant and non-scientific answers (level 1), and most of them based their reasoning on the *weight* of the object (level 2a) as the main factor to explain the phenomenon (see Biddulph & Osborne, 1984; Dentici et al., 1984; Havu-Nuutinen, 2005; Leavers, 1993; Piaget 1930; Piaget & Inhelder, 1974; Smith, Carey & Wiser, 1985). *Kind of material* and the *size* of the objects were also important properties for children as well as the presence of *air* and *hollowness* (level 2b) (see Biddulph & Osborne, 1984; Dentici et al., 1984).

In a few cases children put together two or more properties of the objects (level 2c) to explain the phenomenon, such as *kind of material* and *hollowness* and the effect of *air* (see Havu-Nuutinen, 2005).

At the same time, for most children *weight* was not the only reason for explaining flotation (level 2d) (see Leavers, 1993). Children related this property with the *type of material* and the effect of other factors such as the presence of *air* or *water* inside the objects. *Fullness*, *emptiness* and *hollowness* were important judgments for children but the frequency of such evidence was low. Before the instructional period children related *weight* with other properties.

It seems that only one child had an emergent intuitive idea about *density* (see Khon, 1993), relating *size* and *weight*, and *size* with the *type of material*, but he used these judgments just in one case. For this child, the main reason for floating was the presence or absence of something inside the object.

In other specific case, a child justified flotation in terms of the *force* of the object (level 2e) but in terms of purpose or volition as Piaget (1930) has mentioned, however, he also explained the phenomenon in terms of the *force* of the object and *force* of the *water*, but in contradictory ways. As in the latter case, there were few other cases in which children based their judgments on interactive relations linking correctly the *weight* or *force* of the object with the *weight* or *force* of the water (levels 3a and 3b). Apparently these children initially had an intuitive idea about a mechanism of interaction between objects and water, but their explanations were not clear.

Before the instructional period most children had an initial flotation model based on the *weight* of the objects, which is consistent with previous studies (see Biddulph & Osborne, 1984; Havu-Nuutinen, 2000, 2005; Laevers, 1993, Piaget 1939; Piaget & Inhelder, 1974; Smith, Carey & Wiser, 1985) (see Tables 3 and 4).

Towards flotation precursor model construction

In general, children reconstructed their ideas using a more multidimensional perspective in explaining the phenomenon (Havu-Nuutinen, 2000, 2005). After the instructional period, irrelevant and non-scientific answers appeared less frequently in children's arguments, and they began to think about new properties of the objects (see Tables 1 and 2, levels 2b and 2c), or to put together relevant properties with *weight* (see Tables 1 and 2, level 2d). The properties children related with *weight* were those of *kind of material*, *size* and *form. The effect of the air* and *of the water* was also an important reason in justifying the phenomenon.

Kind of material was mentioned during pre-test as a characteristic of the objects but not as a property that affected the phenomenon. At the same time, *air* was mentioned during pre-test but children did not explain how it affects flotation. After instruction, air justifications were more frequent and children related this with other properties of the objects mainly with the *kind of material*. The presence of *air* inside the objects, *kind of material* and *weight* were the leading judgments children used to explain the phenomenon after the instructional period.

During pre-test:
T: ON, What will happen with these balls if you put them in water? Will they float or will they sink?
ON: The baseball floats.
T: Why does it float?
ON: Because it is made of plastic.
T: Do you think it is important that it is made of plastic?
ON: Yes, because things made of plastic float.

During post-test:
T: What will happen to the balls if you put them in water? Will they float or will they sink?
ON: This -baseball- floats because it weights a little, and it is made of a kind of plastic that floats because has little weight.
T: And what will happen to the golf ball?
ON: It sinks because it is made of a different kind of material that is very, very heavy.

During pre-test:
T: What do you think will happen to the ping pong ball?
ADR: It will float.
T: Why does the ball float?
ADR: Because it has not air -contradictory answer-.
T: What will happen with the clay ball?
ADR: It sinks because is the same, it has no air.
T: So, is the air important?
ADR: Yes.
T: Why do you think it is important?
ADR: Because things that have air float.

During post-test:
T: What will happen with the ping pong ball?
ADR: It floats because has air and with the air is lighter.
T: What will happen with the clay ball? Will it float or will it sink?
ADR: It sinks because is very heavy and has not air.

The presence or absence of *air* inside the objects was evident in the materials used by the children during experimentation. The reason children were able to put together the *effect of the air* and the *kind of material* was that they worked with a kind of material approach in a pilot test carried out previously (see Canedo-Ibarra, 2009). It seems that in this study, children had new elements in their reasoning for relating these aspects with the *weight* of the objects. At the same time, for the children the *effect of the water* inside the bottles was a significant reason affecting the *weight* of the objects. The bottles were *heavier* because of the water inside, so they sunk, whereas the *empty* bottles were *lighter* with *air* inside, so they floated.

Hollowness and *solid* were mentioned by the children during pre-test separately or with *kind of material* or *air* as well. At the same time, children used these properties with *weight* in their reasoning but they did not explain how this relation affected the phenomenon. After the instructional period this relation was clearer for them.

During pre-test:
T: What will happen to the clay ball?
MIRE: It will sink.
T: Why do you think so?
MIRE: Because it weights, because it is empty.
T: And how does this fact affect it?
MIRE: Mmmmmmmmm……. I do not know, it has weight.

During post-test:
T: MIRE, what will happen with the clay ball?
MIRE: It sinks because has a lot of clay inside, and the ball falls easier in the water because it has weight as well.

In general, the *size* and *form* of the objects were not very important properties in children's judgments both in pre-test and post-test, although at the post-test children used the *size* of the objects more frequently. At pre-test only few children mentioned these properties, and in post-test the *size* of the objects and the *kind of material* or the *weight* were important reasons in explaining floating and sinking but children were not able to understand at all how the *size* or the *form* were related with the *weight* of the objects.

During pre-test:
T: CAT, here we have the balls again. What will happen with the baseball if you put it in the water?
CAT: It sinks because is not very heavy and we said that if it is not very heavy then sinks and also because it is big.

T: How is that the size of the ball relates with the weight?
CAT: Because it is heavier.

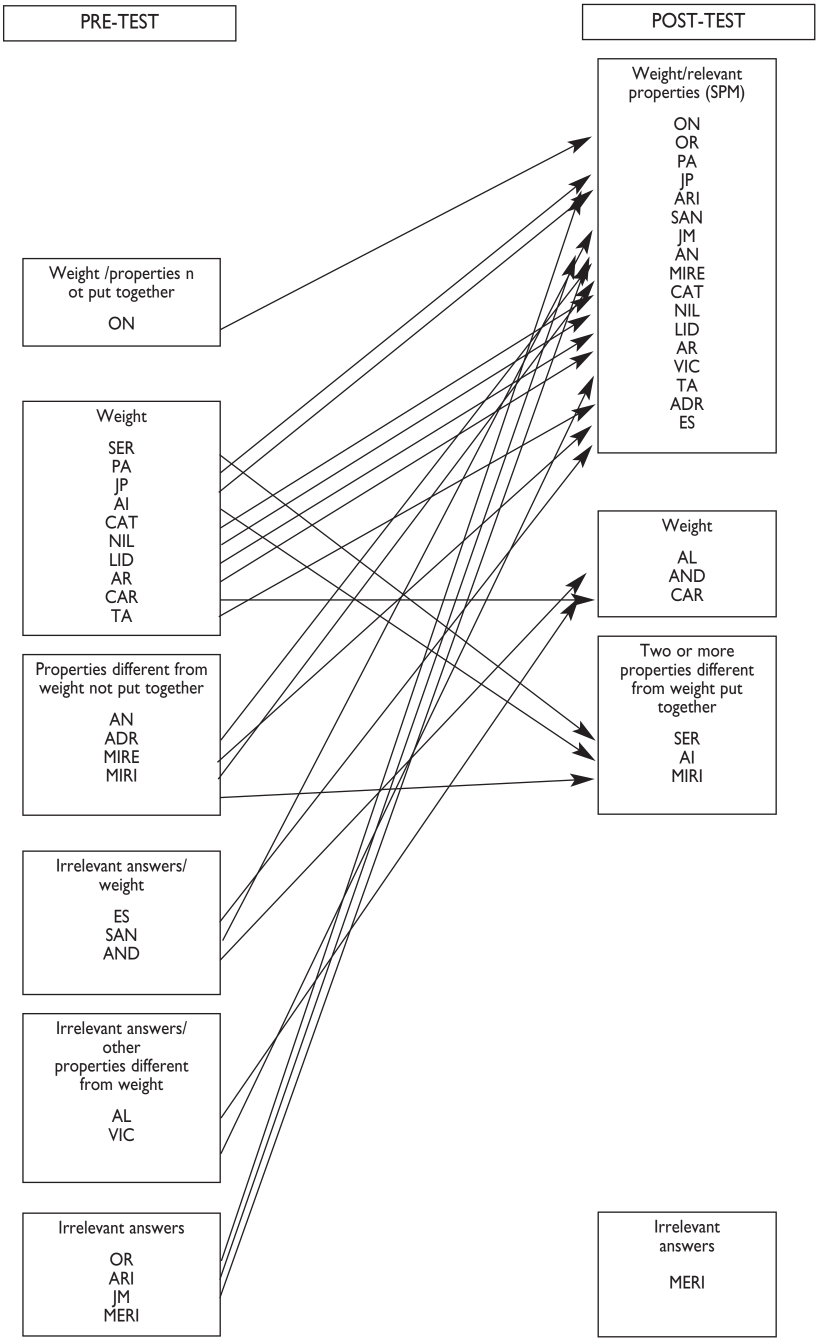
During post-test:
T: What will happen with the tennis ball?
CAT: Floats because it is light. It is strong, but it does not weight like the other one and it has a different form.
T: How is that the form of the ball relates with weight?
CAT: I mean…..it is small.
T: OK, is a different size but, how does size affect the weight?
CAT: I do not know how to explain it.
T: Don't you have a little idea?
CAT: No.

After the instructional period most of the children used properties of the objects of marginal relevance such as *kind of material, hollowness and solid* (levels 2b and 2c) in their arguments, and some others used physical properties of partial relevance related with *density* such as *weight* and *size* (see Howe, Tolmie & Rogers, 1990), even though the *density* concept was not used. The way in which children understood the phenomenon improved substantially. Almost all children (21) used at least one *relevant property* related with *weight* (level 2d), and the most elaborated explanations were those in which children used several *relevant properties* with the *weight* in their arguments, showing in this way an emergent idea about the *density* of the objects.

During pre-test:
T: What will happen to the boat, will it sink or will it float?
SAN: I think it floats.
T: Why does it float?
SAN: Mmmmmmmm………because……ships floats. A toy ship also floats, but it sinks if it has weight. It depends on the kind of material too.

During post-test:
T: What do you think will happen to the boat, will it sink or will it float?
SAN: I think it floats because it has air inside and also is made of plastic, this kind of plastic floats. It depends on the weight, the air and the form of the ship.
T: Can you explain to me how these different properties make the boat float?
SAN: Mmmmmmmm……it's a little difficult but I think that the ship is not very heavy and this kind of plastic floats because is light. Like in the bottles, the air helps too.

FIGURE 3


PRE-TEST
POST-TEST
Weight /properties n ot put together
ON
Weight
SER
PA
JP
AI
CAT
NIL
LID
AR
CAR
TA
Properties different from weight not put together
AN
ADR
MIRE
MIRI
Irrelevant answers/ weight
ES
SAN
AND
Irrelevant answers/ other properties different from weight
AL
VIC
Irrelevant answers
OR
ARI
JM
MERI
Weight/relevant properties (SPM)
ON
OR
PA
JP
ARI
SAN
JM
AN
MIRE
CAT
NIL
LID
AR
VIC
TA
ADR
ES
Weight
AL
AND
CAR
Two or more properties different from weight put together
SER
AI
MIRI
Irrelevant answers
MERI

As we mentioned at the beginning of this section, some children (5) based their judgments on the *weight* or on the *force of the objects* with the *weight* or *the force of the water* (levels 3a and 3b). However, after the instructional period only two children used the *weight of the object* and *the weight of the water* in their justifications. Moreover, PA showed to be developing a model based on *force interaction.*

During post-test:
T: What will happen to this bottle -filled with water-?
AI: It sinks because it has water inside and it is heavy for the water.
T: What will happen to the boat?
AI: It floats because is not so heavy for the water. It is made of a kind of plastic which is not heavy.

During post-test:
T: PA, what do you think will happen to the boat? Will it float or will it sink?
PA: It floats because has air and is able to hold it.
T: What do you mean about?
PA: The boat is able to hold the water.

The reason children did not use interaction justifications any more was due probably to the concentration of their attention on perceptible characteristics of the objects and to the fact that the teacher did not give any attention to this approach. Figure 3 shows children's ideas changes before and after the instructional period.

DISCUSSION AND CONCLUSIONS

This study examined children ideas' changes about flotation from *non relevant* and *weight* based ideas to a more multidimensional way of understanding the phenomenon. The aim of the instructional process in this case study was to support children's active role in the learning process, intended for promoting the construction of a scientific precursor model of flotation based on density. It seems that activities children carried out at the school laboratory led to a better understanding about the flotation and immersion of the objects in the water. They looked at new variables and how these different variables were related to each other. These results show, as in other studies, that physical properties children initially used in explaining the phenomenon were marginally relevant (see Biddulph & Osborne, 1984; Dentici et al., 1984; Howe, Tolmie & Rogers, 1990; Leavers, 1993; Havu-Nuutinen, 2000, 2005), although some times they used properties of partial relevance such as the *weight* and *size* or *form* of the objects. As in Havu-Nuutinen's study (2000, 2005) children in our study began to consider flotation from a descriptive and multidimensional perspective even though most of them were not able to put together the properties related with *density* such as *weight/form*, *weight/size*. Nevertheless, our children did better than those of Havu-Nuutinen's study (2000, 2005), putting together *relevant properties* and *weight* such as *weight/kind of material*, *weight/hollowness, weight/emptiess* more frequently. We assume that these results come from a children's knowledge integration of several characteristics of the objects that they were exploring since a pilot test done two months earlier (see Canedo-Ibarra, 2009). This knowledge integration led them to construct and reconstruct their explanations in more advanced ways each time. Such results show the relevance in following a spiral curriculum aimed to children's progressive knowledge construction and reconstruction to develop and improve scientific explanations.

During the activities children worked in collaborative groups solving problems and testing different objects in the water using the scientific method, exploring, testing and evaluating their hypothesis. This instructional approach showed to be suitable for children of this age, as most of them were extremely engaged in the learning process in an active, enthusiastic and interesting way. In the interactive phase the teacher was always questioning children and encouraging them to talk about their predictions, hypotheses and results. Children reflected on and discussed with the teacher and their partners the scientific concepts' understandings they were developing (see Coll, 2005). In this way, they used new concepts and situations for constructing and reconstructing their explanations. Social interactions were the main shaper of scientific knowledge in children (see Chinn, 1998). Children were 'knowing that' and 'knowing how to' (see Eshach & Fried, 2005), and in this way children found relevant properties of the objects in order to explain the phenomenon under study sharing their ideas explicitly, thus knowledge was shared and constructed socially. This approach proved to be effective, although sometimes only the more active children participated and in other times, some children did not participate at all. Moreover, their ideas were not discussed spontaneously. In these cases the teacher's role was to involve these children in the process, therefore her assistance was very important in motivating all the children to think and talk, and express their needs. Collaborative work is effective when children thoughts are listened carefully and they are given sufficient time to think over the ideas of others (Gilbert & Boulter, 1998). The nature of this case study was enrolled in language use. Children discursive skills were encouraged, as well as the conceptual and procedural ones. General language and scientific skills development should be considered as important issues. Through the conversations during the learning activities, children used language to express knowledge, emotions and feelings. We think that these aspects have a significant impact on children's personality development, self-confidence and auto-regulation (Hidi, 1990; Pintrich, 1999). In our study science education was viewed as promoting a way of thinking socially, and in the development of this way of thinking, language and discourse also played a significant role besides scientific procedural skills and attitudes (see Driver, Newto & Osborne, 2000; Duschl & Osborne, 2002; Harlen, 1998; Mercer et al., 2004).

The teaching and learning approach based on precursor model construction helped children to look at basic scientific ideas on how to explain flotation and immersion changing their initial models to more complex ones. As we mentioned earlier, after instruction most of the children explained the phenomenon using arguments based on marginal and relevant properties of the objects put together with *weight*, and these changes showed to be context dependent. In general, most of the children moved from a model based on isolated properties of the objects or a model based on *weight* to a model based on *weight* and properties related with *density*. In a lower level, some of the children that at the pre-test gave irrelevant and non-scientific answers showed to be moving towards a model based on *weight* or remained in this model. From observing available data and discussions children made about these data when experimented with objects, they were able to develop a repertory of more powerful models that allowed them to improve their reasoning (see Leher & Schauble, 2000), and they showed to be gradually taking the naivety of their initial models to the complexity of scientific ones (see Arcá & Guidoni, 1989).

These results support findings of other studies that have asserted it takes a long time for a complete understanding of this phenomenon (Esterly & Barbu, 1999; Havu-Nuutinen, 2000, 2005; Wilkening & Huber, 2002) due to its multidimensional character. Thus, for volume and density concepts' construction more exploration is needed (Havu-Nuutinen, 2005). From the point of view of teaching and learning, this multidimensionality could be approached in steps or intermediate models (see Clement, 2000) as we have shown in our study. Children looked at the phenomenon using several marginal and relevant properties of the objects. A next step could be that children put together those properties specifically related with density, and/or the development of a precursor model based on interaction (see Goffard & Weil-Barais, 2005).

Implications for the educational practice

This study has showed that children are able to develop a scientific understanding in an instructional context. This fact has implications in scientific education at preschool, because when children's epistemologies are shaken up at early years, acquiring strong alternative ideas can be minimized (Havu-Nuutinen, 2000). Results have enabled us to identify relevant aspects in learning about a physical micro-domain such as flotation, and these aspects are useful to match and improve scientific curriculum at preschool education.

We assert that it would be fruitful if teachers change their ideas about scientific teaching and learning at preschool going further the activities where children only classify, arrange and observe, and promote those where children additionally predict, formulate hypotheses and evaluate them discussing about results with others. Our results have shown that children are able to think scientifically using both inductive and hypothetic-deductive reasoning. To the extent teachers realize children's skills and the ways in which they learn, teachers will become more effective in adapting the instructional processes to the different needs children have. Scientific precursor models construction approach has shown that it may be useful in guiding and supporting teaching and learning processes in the classroom. Developing scientific precursor models by teachers in different specific scientific domains, may be useful for them in understanding the scientific content and the scientific process by which this content is constructed.

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ACKNOWLEDGEMENTS

The research reported in this article was supported by the University of Barcelona.