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Enhancing Conceptual Change in Preschool Children's Representations of Light: A Sociocognitive Approach

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Abstract The aim of this study is to investigate the effect of a sociocognitive teaching strategy on young children's understanding of light. It explores their understanding of the concept of light as an entity that is transmitted independently of the light source and the final receiver. The study was conducted in three phases: pretest, teaching intervention, and post-tests. The sample consisted of 170 preschool children who were assigned to two groups. The children in the first group participated in activities which adopted a sociocognitive approach. In the context of this approach, a familiar metaphor was introduced in order to facilitate children to construct a "precursor model" about light. The children in the second group participated in activities with the same teaching objectives, but adopting an empiricist perspective. Statistical analysis using the Mann–Whitney *U* test indicated that the cognitive progress of the sociocognitive group was more significant than the progress of the empiricist group. This provides evidence for the effect of the sociocognitive strategy on enhancing children in constructing a "precursor model" for the concept of light.

Keywords Light · Metaphor · Precursor model · Preschool education · Pupils' representations · Science education

Theoretical Framework

Science Teaching: Trends in Preschool Education

Preschool education programs, regardless of their orientation, regularly involve activities related to science. In studying a wide spectrum of curricula and programs of science activities for preschool education, a classification scheme has been proposed consisting of

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three pedagogical frameworks. These frameworks may underlie and guide both the teaching practices adopted in preschool classes, as well as related research (Ravanis et al. 2004).

The first framework consists more of activities and less of research efforts which develop within an empiricist perspective (Conezio and French 2002; Saint-Georges 2011). In the context of this framework, learning is understood as the perception of stimuli offered by new data, and teaching as the presentation of knowledge and information drawn directly from science, after having been simplified. Of particular interest is the fact that the proposed activities derive from teachers' own experiences, rather than research aiming to explore children's reasoning.

The second framework consists of activities and research developed on the basis of the Piagetian perspective on the construction of knowledge. In this context, and according to research findings, the proposed activities help children interact with the selected pedagogical material in appropriately designed instructive environments. Thus, children are supported in constructing "*physical knowledge*" (Inagaki 1992; Kamii 1982; Kamii and Kato 2007; Metz 1997). Given, however, that the teacher mainly adopts a supportive and encouraging role, and that the educational material should be such that children themselves can act upon it, the Piagetian perspective on developing activities has certain limitations, related with young children's possibilities of direct manipulation of the material, and with the type/nature of teachers' intervention.

Within the third socio-cognitive framework fall research and activities which are based on a broad context of theoretical approaches. The sociocognitive framework for teaching and learning draws its theoretical foundation on the work of Vygotski (1962, 1978); it considers cognitive development as a primarily social activity and examines it within its cultural and historical context. According to this perspective, children develop their knowledge by means of participating in activities and practices of their community (Gauvain 1998) and by means of mediating cultural tools (Stetsenko 1999) such as language, algebraic symbolic systems, and any kind of visual representations (e.g., maps or diagrams). Especially in the field of science, learning presupposes that children interact with more knowledgeable and experienced individuals (e.g., teachers), or with diverse sources of information (e.g., books, educational software). Through these interactions children obtain access to the language of the scientific community as a way of seeing and thinking about natural phenomena, i.e., as a cognitive device (Shepardson 1999).

Therefore, while research in the field of science teaching and learning initially (that is within the constructivist framework, see Driver et al. 1994; Osborne 1985) focused on determining how the child constructs knowledge individually, during the last decade it has been turning attention to the dialectic interdependence between the child and the broader sociocultural influences s/he is subjected to within the classroom framework (Fleer and Robbins 2003; Robbins 2005; Shepardson 1999; Tytler and Peterson 2001). In this perspective, the study of knowledge construction concentrates on social practices (Lemke 2001; Roth 1998; Tsatsaroni et al. 2003), which go beyond the classroom social environment (teacher, children), and consider the broader educational context (i.e., school knowledge, pedagogic discourse, curriculum, etc.).

Adopting a sociocognitive perspective bares methodological implications on the study of young children's conceptions and thinking related to science. Apart from the individual level — traditionally investigated through clinical interviews— analysis is expected to also take into account the broader research context (e.g., the teaching material used, or the wording employed) since it is considered as determinant in the development, organization, and expression of children's thinking about the natural world (Robbins 2005).

Based on the sociocognitive perspective about learning in science, a multitude of experimental teaching sequences addressed to preschoolers has recently been developed internationally. These approaches aim at enhancing the development and use of thinking strategies and practices such as explaining, identifying and managing disagreements, adopting new, more satisfactory ideas, posing questions, constructing analogies, or thinking and working collaboratively (Venville et al. 2003).

A typical activity in this framework begins with children formulating predictions about the evolution of a phenomenon and providing explanations and reasoning for their predictions. Subsequently their predictions are experimentally tested, which usually triggers sociocognitive conflict by means of juxtaposition of different conceptions and explanatory schemata about the observed phenomenon. Particularly crucial in this process is the role of the teacher, who is expected to establish an environment of collaboration and communication that encourages comparison and conflict between, as well as synthesis of different conceptions to guide children —by means of appropriate concentrations— from subjective thinking to considering critical aspects of the phenomenon under study. This shift is regarded as particularly fruitful for conceptual change and for constructing preliminary but scientifically compatible models about entities and phenomena of the natural world (Christidou et al. 2009; Havu-Nuutinen 2005; Ravanis and Bagakis 1998; Shepardson 1999; Tytler and Peterson 2001).

In the sociocognitive context for science teaching, an interesting possible perspective is the one that uses the concept of target concepts as organizing principles for designing teaching activities. According to research, target concepts constitute obstacles to children's thought (Martinand 1986; Skoumios and Hatzinikita 2006). Therefore, the proposed activities are developed on the basis of a series of organized teaching interventions, which facilitate the interaction between teachers and children with an aim to overcome predetermined cognitive obstacles (Christidou and Hatzinikita 2006; Ergazaki et al. 2010; Fleer and Robbins 2003; Kampeza 2006; Ravanis 2012; Skoumios and Hatzinikita 2005/2006; Zogza and Papamichael 2000). This can lead, under certain teaching conditions which facilitate the destabilization of preschoolers' inappropriate representations, to the construction —on the part of the children— of "precursor models". These are cognitive schemata compatible with scientifically appropriate knowledge, since they are constructed on the basis of certain elements pertinent to scientific models, which have a limited range of application and which prepare children's thinking for the construction of scientifically appropriate models (Lemeignan and Weil-Barais 1993). "*These precursors are cognitive constructions* (*concepts*, *models*, *procedures*, *etc*.) *generated by the educational context. They constitute the moulds for subsequent cognitive constructions*, *which*, *without their help*, *would be difficult*, *or impossible*" (Weil-Barais 2001, p. 188).

Scientific entities and phenomena —such as light and its propagation— are frequently complex and detached from children's perceptual experience. Thus, thinking tools are required that can support the transformation of an unfamiliar entity —target domain— into a familiar one —source domain (Black 1979; Cornell Way 1991; Lakoff and Johnson 1980; MacCormac 1985). Metaphors could play this role by attributing similar functions and relationships to entirely different things (Christidou et al. 1997).

When the attempts to mentally represent a target domain in order to understand and explain a new situation fail, metaphorical thinking is activated (MacCormac 1985). This involves selecting a source domain, which is structurally similar to the target domain and is associated with an explanation of how it functions and on what grounds it is similar to the target domain (Vosniadou 1989). Consequently, the structure of the source domain is mapped on the target domain, thus enhancing the construction of a new conceptual model to explain the latter (Black 1979; MacCormac 1985; Vosniadou 1989). If the new model —however simple, or preliminary— is estimated to provide a satisfying explanation, it is adopted; the target domain is understood and is no longer considered as problematic. At this stage, knowledge is transferred from the source to the target domain through the establishment of new rules and the connection of the target domain to the existing conceptual structures (Halford 1993; Petrie 1979). Therefore, metaphorical thinking provides a mechanism for conceptual change, by facilitating the construction of new models (Vosniadou 1989). Moreover, by supporting understanding of new concepts and phenomena, it constitutes a valuable teaching tool in science education (Nersessian 1984).

The present paper constitutes a comparative study between two different teaching interventions with preschool children, i.e., an empiricist approach and a sociocognitive one. Both approaches aim at enhancing children's understanding of light as an autonomous entity, that is distinct from light sources and from the phenomena they produce. The empiricist approach is based on the conviction that the provision of organized stimuli (activities) to children can ensure learning while the sociocognitive approach attempts to support children in constructing a precursor model based on the use of a familiar metaphor. Such a comparative study is considered as particularly interesting for teaching and learning, since it can reveal valuable processes that assist children in constructing mental entities compatible with scientific ones. It can also provide essential input for supporting kindergarten teachers in developing relevant and effective teaching activities.

Children's representations of light

Children's thinking from the point of view of concept formation and representations of phenomena of the natural world has already been extensively studied in the fields of science education, educational and cognitive psychology (e.g., Driver et al. 1985, 1994). It has been suggested that explanations pertaining to pupils' thinking about light are not compatible with the scientific model (Guesne 1985; Ravanis 1999; Galili and Hazan 2000; Ravanis and Boilevin 2009).

This underlines the necessity of organizing suitable teaching strategies for facilitating conceptual change (Di Sessa and Sherlin 1998; Duschl and Hamilton 1998). Indeed, a limited number of studies have focused on this issue, which attempted to facilitate the construction of the concept of light in children's thinking by means of specially designed teaching interventions (Galili and Hazan 2000; Osborne et al. 1993; Ravanis et al. 2011). These studies addressed pupils over 10 years old and their outcomes indicate that children are capable of constructing a thinking schema about light, which is compatible with that of school science, as Piaget (1971) had previously suggested. Other studies (Gallegos Cázares et al. 2009; Ravanis 2012) indicate that even at the age of 4, some children can use the same schema. It would therefore be of interest to investigate the conditions under which this schema can be introduced in kindergarten teaching activities related to light.

The topic of preschoolers' representations of light as an entity in space, independent of light sources and of the results of its interactions with objects interjected in its path has already been studied (Fleer 1996; Gallegos Cázares et al. 2008; Ravanis and Boilevin 2009; Resta-Schweitzer and Weil-Barais 2007). In these studies, interviews with children aged 4–7 in a series of different experimental situations have indicated that they do not recognize light as an autonomous entity, they cannot locate it in space and can only identify it in lamps or brightly illuminated spots. It is an obstacle often encountered in children's thinking when they have to deal with the movement of nonmaterial natural entities such as energy, heat, or light (Piaget 1971; Piaget and Lannoy 1967). Indeed, for a preschool child, understanding light as a concept centers on light sources (LS) and visible lighted areas (VLA), or a combination of the two, by means of a view of direct transition of the following form:

LS→VLA. As a result, children at this stage ignore the space in which light bundles propagate, that is to say, the space of light propagation (SLP). In contrast, an adequate understanding of the concept of light as an entity entails a particular two-step process of light propagation involving the transition: if LS→SLP and SLP→VLA then LS→VLA. This transition indicates an advanced type of reasoning which constitutes a precursor model, since it is compatible with the scientific model.

> "Therefore ….in the case of natural transition, the correlation among the elements of the problem of the propagation of light operates as a general schema of representation of light. The representation of light based on transition is important because, as a two-step procedure, it imposes the identification of the presence of light in space. The acceptance of light as an entity that is transmitted independently of the light source and the final receiver constitutes the necessary convention and beginning of the construction of other related light phenomena" (Ravanis and Boilevin 2009, p. 183).

For example, without the identification of light as an entity, it would be impossible to understand the notion of rectilinear propagation of light, or the formation of shadows.

Hypothesis

Recent research in the field of early childhood science education indicates the effectiveness of sociocognitive strategies (Ravanis 2010). This allows us to formulate the hypothesis that adopting a sociocognitive perspective in preschool science activities about light would result in better learning outcomes compared to those achieved by means of an empiricist teaching strategy.

Therefore, the present study was based on the premise that the children of an sociocognitive group participating in an instructional activity aiming at a systematic interaction with their teachers would more easily understand light as an entity in space that is independent of light sources and its respective results, compared to the children of a empiricist group participating in classroom activities concerning: (a) the discovery of light as an independent entity, (b) the classification of light sources as "strong" or "weak" and (c) the distinction between transparent and nontransparent materials and their relation with light. The systematic interaction instigated in the activities addressed to the sociocognitive group was based on the use of a metaphor, which is familiar to young children from their everyday experience. This metaphor was selected since it is expected to effectively challenge the difficulties identified in children's thinking.

Methodology

Participants

The sample of the study consisted of 170 subjects, 85 male and 85 female (age, 5.5–6.5; average age, 5.91 years). The children were attending public kindergarten classes with similar socio-economic characteristics and were randomly divided into two groups of 85 children each, thus forming the sociocognitive group (hereafter SCG) and empiricist group (hereafter EG), respectively.

The particular age group (i.e., approximately 6 years old) was selected for two reasons related with children's readiness to construct a precursor model about light on the one hand, and with the necessity to didactically support such a construction on the other. The first reason is essentially developmental; Piagetian research indicates that at this period, children acquire the capacity to conceptualize operational transitivity for entities related to energy, such as light (Piaget and Vergopoulo 1972). The second reason is related with teaching; any teaching activity related to optics would require at least a preliminary model of light as an autonomous entity. Therefore, the earlier such a model about light and its presence in space is constructed, the better outcomes one can expect from teaching topics related to optics. Otherwise, the longer children's pre-existing and inadequate representations remain intact and unaffected by teaching, the more resistant to change they are expected to become (e.g., Peterfalvi 2001; Thompson and Logue 2006).

Design of the Study

The study was implemented in four phases (pretest, teaching interventions, and two post-tests). The data of the study consisted of children's responses to and explanations of three tasks used during both the pretest and post-tests. These were collected through individual, structured interviews which lasted 10 min. Interviews were conducted by the researchers. The pretest took place 2 months before the teaching intervention and the two post-tests were held 2 and 4 months after the intervention. The second post-test aimed at assessing the stability of the newly constructed precursor model in children's thinking. Data analysis was based upon the recorded discussions (between the children and the researcher) and individual observation protocols.

Teaching interventions in both SCG and EG were implemented with groups of three to five children and lasted for 15–20 min. Eleven volunteer kindergarten teachers participated in the teaching interventions. Each of them worked with four groups of children in her class in different sessions; two of the groups were assigned to the SCG and two to the EG. The teachers were specially trained by the researchers (theoretically and practically), so as to be appropriately prepared to implement the two different teaching protocols (one for the SCG and one for the EG). The researchers attended all groups and engaged in systematic observations to ensure good and consistent implementation of the protocols throughout the process.

The pre-test and post-tests as well as the teaching interventions took place in a specially set up area on the kindergarten premises.

Tasks Used in the Pre- and Post-Tests

The three tasks involved experimental situations that permitted concentration on light sources and lighted surfaces, as well as recognition of diffused light in space. The rationale underlying these situations is based on the assumption that when children can locate light in space independently of its sources and thus overcome their perceptual concentrations on light sources and lighted surfaces, they are capable of reasoning based on transitive thought and therefore able to construct a precursor model compatible with the scientific concept of light. In the course of task 1, the children were asked to locate light in the room, i.e., in a familiar, everyday environment. During task 2, an artificial condition was produced, which was also familiar to children, while in task 3 the children were asked to locate light in a situation involving an entirely artificial setup, specially constructed for the purposes of the study. The three tasks are explicitly described in the following paragraphs.

Task 1 In a directly sunlit room, a table lamp was switched on. The children were asked to indicate at least three points of light in the room. They were encouraged to give as many answers as possible. This would allow the researchers to safely assess whether they recognized the existence of light in the room or not.

Task 2 A straight beam of light produced by a flashlight (3 V, 1.5 W) was directed towards a vertical surface at a 3-m distance in order to form a visible light spot on the surface. While the flashlight was on, the children were asked: “Where is there light produced by the flashlight?” If a subject only indicated the flashlight’s lamp and the lit spot, the interviewer once again pointed to the space between the flashlight and the wall, in which the flashlight beam is nonvisible in daylight and asked: “In the air, between the flashlight and the wall, is there any light?” At this point, the children were presented with an experimental situation that was more than familiar to them from their everyday life: the light bundle is visible when the light diffused in the same space is of low intensity. However, at the time of the interview, the light bundle was not visible in space. If that had been the case, simply looking would have been enough to lead to a response resulting from the simple concentration on the light beam and not from a transitive thought.

Task 3 Two vertical pieces of cardboard (17×25 cm) were set on a stable horizontal base at a distance of 12 cm from each other. A hole was cut out at a height of 17 cm from the base of one of the pieces of cardboard. At the same height as the hole, a portable lamp was placed (4.8 V, 2.4 W) at a 10-cm distance from the hole (Fig. 1).

When the experimental setting was presented to the children, the light was turned on and the interviewer asked: “Is there any light from the lamp between the two pieces of cardboard?” If the answer was positive, the children were asked to provide explanations. If it was negative or the explanations were not satisfactory, the interviewer asked and showed simultaneously: “Here, in the air, is there any light from the lamp?”

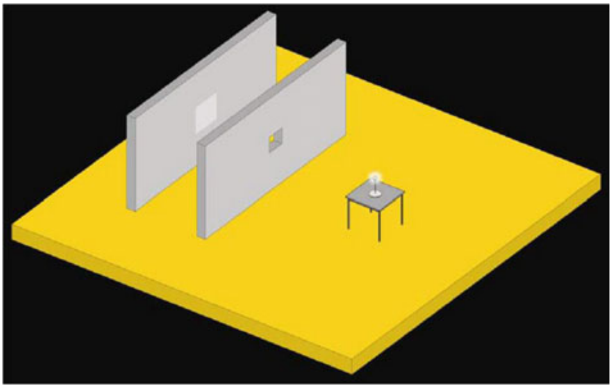
The particular experiment used in task 3 was chosen because, in contrast to the two previous tasks, it does not refer to an everyday situation. Again, the beam of light was not visible due to the abundant light emanating from the surrounding space.

Teaching Interventions

The Critical Differences Between the Two Teaching Interventions

The critical differences between the activities carried out by the two groups derive from the fundamental premises of the two approaches adopted. In the case of the SCG, within the context of the sociocognitive approach described above, the focus laid on the destabilization of inadequate light representations adopted by children, while in the case of the EG, within the empiricist approach, teaching was guided by an effort to “convey” scientific content without taking into account children’s existing cognitive schemas.

Fig. 1 The experimental setup used in Task 3



More specifically, in the approach adopted with the SCG, the destabilization of initial light representations is attempted by means of the use of a metaphor that will consequently promote operational transitivity in children's reasoning, which constitutes an essential basis for constructing a precursor model representing light as an autonomous entity.

In the case of the EG, the teaching activities also concentrated on establishing teaching conditions within which light would be identified as an autonomous entity. However, within empiricist approaches the emphasis lies not on the formation of models, but on the establishment of teaching conditions in which the breadth of topics and the variety of perceptional stimuli is considered to enhance the formation of concepts in children's thinking. Thus, the organization of teaching activities within this approach mainly concentrates on carefully organizing a diversity of opportunities for children to observe and describe a phenomenon.

The activities in both SCG and EG were implemented by the class teachers, who had been involved in different training sessions, in order to assure that the teachers within each group would coherently follow the same procedure and with the same pacing in their respective activities.

The Sociocognitive Group

The teaching intervention implemented with the children belonging to the SCG was planned based on children's representations as identified in the pretest and in the literature. Its aim was:

(a) to destabilize children's representations that do not involve light as an autonomous entity in space
(b) to facilitate children in constructing a precursor model, by means of the use of the concept of "travel" in its metaphorical sense

The general framework within which these activities unfolded comprises the following stages (Table 1):

(a) In order to destabilize children's representations, a powerful flashlight was used in an otherwise very dimly lit room. The flashlight was directed towards one of the walls and, without switching it on, the teacher asked the children "where is there going to be light from the flashlight when we switch it on?" Overall, the children easily replied that light would appear on the wall and/or the lamp. The teacher then switched the flashlight on and a bright beam of light appeared between the flashlight and the wall (Fig. 2).

The children were asked "where is there light from the flashlight?" and, as they located the presence of light in the room, the teacher asked them to compare their responses to their earlier ones.

After completing the discussion regarding the existence of light in the beam, and while still keeping the flashlight switched on, the teacher introduced light into the room, so that the flashlight's beam was no longer visible. A discussion was initiated with the children concerning whether the light produced by the flashlight was still in the room. The discussion completed with some of the children expressing the view that "it is still there but we cannot see it."

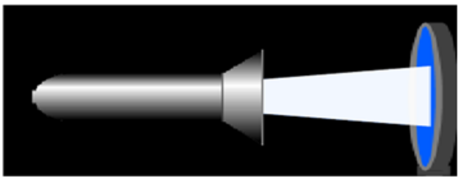


Fig. 2 A clearly visible beam of light appearing between the flashlight and the wall when the flashlight is turned on in a dimly-lit room

(b) Subsequently the activity focused on facilitating children in constructing a precursor model for light. Therefore, the discussion focused on how the earth is lit by the sun and the children were asked to provide their explanations. Most children referred to "rays that come from the sun", which gave the teacher the opportunity to introduce a familiar metaphor (Cornell Way 1991; Petrie 1979) from everyday life, i.e., "the travel of light through space". The metaphorical concept of "travel" was used in order to signify an object's movement in space. In other words, it connects the beginning and end of an object's trajectory with its interim movement through material means. Therefore, using the one-step scheme (i.e., source receiver) —spontaneously adopted by the children— as a starting point, the two-step scheme (i.e., source–area of diffusion and area of diffusion–receiver) was introduced to the SCG. The activities in the SCG therefore attempted to facilitate children in shifting their focus from a model concentrated on the light source or on the receiver to another, which regards light as an autonomous entity. To this end, the teacher posed two questions: (1) "where does light come from?" and (2) "how does light come to us?" In answering these questions, the teacher explained that light comes from light sources, for example, the sun or lamps, and travels through space towards other planets or us.

Furthermore, the teacher initiated a discussion to analyze the direction of sunlight towards the earth through space and the atmosphere using light and its rays as equivalent concepts; the teacher also made a geometrical shape of light in space. Next, the teacher presented two images —a photo and a sketch— which comprised "visible" bundles of light, in order to instigate a familiar experience from everyday life, i.e., that of a bright bundle of light in the air. The children were asked to explain these pictures, and the discussion focused on the fact that initially they had not referred to the presence of light in the air. This discussion further enhanced the destabilization of children's pre-existing representations, since their line of reasoning identifying light with its sources and/or its final receivers arrived at a dead end. To facilitate children in overcoming this dead end, the teacher proposed to use "the travel of light" metaphor to explain the apparent presence of light in the air and thus completed the sociocognitive teaching intervention.

The Empiricist Group

The teaching intervention implemented with the EG was designed based on an effective technique (Tsatsaroni et al. 2003). Five experienced kindergarten teachers were invited to develop several light-related activities of a specific duration and to produce detailed lesson plans. The proposed plans were analyzed and, based on those that were more elaborate, a series of activities was set up, which focused on:

(a) the presentation of light sources and the related discussion about the light they produce
(b) the location of light spots caused by the sun on different points where they are visible, and
(c) transparent and nontransparent objects and the creation of shadows by nontransparent ones

The general framework within which these activities developed comprised the following stages (Table 1):

(a) The children were presented with three artificial light sources: a flashlight, a table lamp, and a ceiling light. The room was dimly lit since the curtains are drawn. The children were asked where there was light and, based on their answers, the teacher initiated a discussion. The teacher suggested the children turned on the lights and showed her the light in the lamps. Then she asked them to direct light wherever they wished and based on children's actions the teacher guided the discussion towards distinguishing light

Table 1 The teaching interventions

Sociocognitive group		Empiricist group	
Expression of children's predictions about the location of light in the room		Presentation of light sources and discussion about the light they produce	
Experimental setting: In a dimly lit, room a flash light is directed towards the wall without turning it on		Experimental setting: In a dimly lit room three artificial light sources (i.e., a flashlight, a table lamp, and a ceiling light) are presented to the children	
Teacher: prompts children's predictions	Children: express their predictions	Teacher: prompts children's answers and initiates a discussion based on children's answers	Children: express their ideas
Destabilization of children's representations that do not involve light as an autonomous entity in space		Experimental setting: the teacher suggests they turn the lights on.	
Experimental setting: The teacher switches the flashlight on and a bright beam of light appears between the flashlight and the wall.			
Teacher: asks for children's observations	Children: locate the presence of light in the room	Teacher: asks children to show her the light in the lamps	Children: locate the presence of light in the room
Teacher: asks children to compare their predictions with their observations	Children: discuss the existence of light in the beam	Teacher: asks children to direct the light wherever they want and to name "things that produce light"	Children: name "things that produce light"
Experimental setting: while still keeping the flashlight switched on, the teacher introduces light into the room, so that the flashlight's beam is no longer visible		Experimental setting: pictures of four light sources (the sun, a powerful lamp, a small flashlight, a candle)	
Teacher: initiates discussion with children, asking whether the light produced by the flashlight is still in the room	Children: express their views	Teacher: asks children to create a sequence of pictures from the strongest to the weakest one	Children: propose a sequence of the four light sources' pictures from the strongest to the weakest one

Table 1 (continued)

Sociocognitive group		Empiricist group	
Construction of a precursor model by means of the “travel of light” metaphor		Location of light spots caused by the sun on different points where they are visible	
		Experimental setting: the teacher turns all artificial light sources on and lets a beam of sunlight enter the room	
Teacher: initiates discussion focused on how the earth is lit by the sun and asks for explanations	Children: provide their explanations	Teacher: proposes a game (each child has to silently find as many spots of light in the room as he/she can)	Children: point out spots with light in the room
Teacher: introduction and presentation of the “travel of light” metaphor	Children: express their ideas and discuss	Teacher: asks children to explain their reference to beams produced by the flashlight or the sun.	Children: explain their views/ideas
Teacher: initiates discussion to analyze the direction of sunlight towards the earth through space and the atmosphere using light and its rays as equivalent concepts; makes a geometrical shape of light in space	Children: discuss	Teacher: encourages children to discuss with the rest of the class.	Children: participate in class discussion
Further enhancement of the destabilization of children’s pre-existing representations		Transparent and nontransparent objects and the creation of shadows	
Experimental setting: two images —a photo and a sketch— comprising “visible” bundles of light in order to instigate a familiar experience from everyday life, i.e., that of a bright bundle of light in the air		Teacher: asks children to express their ideas/to describe transparent and nontransparent objects	Children: describe transparent and nontransparent objects
Teacher: asks children to explain these pictures	Children: provide explanations, discuss and arrive at a dead-end (i.e., identify light with its sources)	Experimental setting: transparent and nontransparent objects	
		Teacher: demonstrates transparent and nontransparent objects and asks children to experiment in order to produce shadows	

Table 1 (continued)

Sociocognitive group		Empiricist group	
Teacher: facilitates children in overcoming the dead-end through the use of "the travel of light" metaphor	Children: use "the travel of light" metaphor and explain the apparent presence of ight in the air	Experimental setting: experimentation with a flashlight and a nontransparent plastic board	
		Teacher: asks children to experiment with a flashlight and a nontransparent plastic board	
		Experimental setting: make a shadow with a small walking stick	Children: experiment with proposed materials
		Teacher: asks children to make a shadow using a small walking stick and a flashlight	Children: experiment to make a shadow
		Teacher: initiates a discussion about the creation of the shadow, emphasizing the autonomous presence of light	Children: discuss

sources from light itself and the phenomena it produces. In these discussions, children typically concentrated on light spots created on walls, on the possibility of seeing that light gives us, and —less frequently— on shadows. If the children did not concentrate on visible light beams, the teacher encouraged them to do so. When the discussion concluded the teacher asked the children to name "things that produce light". The children mentioned lamps, candles, red hot metal objects, and —typically— the sun and the moon. The teacher also asked them to help her create a sequence of pictures of four light sources (the sun, a powerful lamp, a small flashlight, a candle), from the strongest to the weakest one. Apart from the light sources, the pictures also included the light beams produced by each of them.

(b) The teacher turned on all artificial light sources and let a beam of sunlight enter the room. She proposed a game: each child had to silently find as many spots with light in the room as he/she could. They would then count them, and the child who would have found the most would be the winner. The children pointed out bright spots of light, some of them mentioned the lamps, and others mentioned the beam produced by the flashlight or the sun. When they mentioned the beams, the teacher asked them to explain what they meant and encouraged them to discuss it with the rest of the class. Within the specific activity context, several children referred to "*light in the air*". However, if this implies decentralization of their thinking from light sources —which would signify a deeper transformation in their reasoning— or is merely a result of the communicative context of the activity, would require further investigation to identify.

(c) The teacher asked the children what a transparent and what a nontransparent object is. Very few children were able to give a valid description, but even if they were, they simply listed examples of transparent (usually glass) and nontransparent (plastic, metallic, etc.) objects. The teacher then showed them "transparent objects that let the light through" and "non-transparent objects that do not let the light through and create a shadow". After they experimented with a flashlight and a nontransparent plastic board, the teacher gave them a small walking stick and asked them to make it cast a shadow (Fig. 3).

Each child tried to create a shadow of the walking stick and the teachers helped the children overcome possible difficulties in this task and succeed in creating the shadow. While the children experimented, a discussion was initiated about "the light of the flashlight falling on the walking stick" and "the fact that the walking stick won't let the light through", using terms that refer to the autonomous presence of light.

Criteria of Evaluation

A scale consisting of three levels (progress, no progress, and regression) was used to assess conceptual change between the pre- and post-test phases, in the children of both groups.

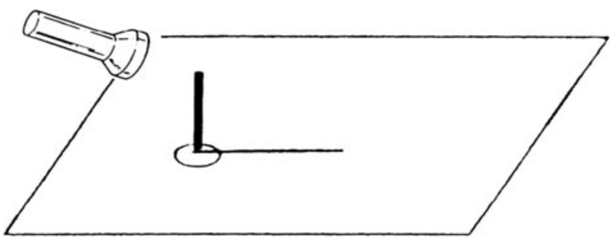


Fig. 3 Attempting to make a walking stick cast a shadow

"Progress" was defined as a shift from not taking into account light as an entity in space, to taking that factor into account. The level of "no progress" was defined as a representation that has the same qualitative characteristics in both the pre- and the post-tests. Finally, "regression" was defined as a conceptual shift from taking into account light as an entity in space during the pretest, to not taking it into account in the post-tests.

Analysis

The Mann–Whitney *U* test was utilized for calculating the statistical significance of the observed differences in cognitive change between the SCG and EG subjects. The selection of this kind of test is justified on the grounds that the measurements were performed on an ordinal scale and that two independent samples were used, drawn from the same population. The level of statistical significance was set at 0.05.

Results

The analysis of children's responses in all three tasks resulted in the construction of the two following models, common in both the pre- and post-tests and for both groups (see Table 2):

Model A The existence of light in space or in the air, which means in areas where there are "visible" light beams, is recognized in responses indicating operational thinking. Typical examples of children's responses falling in this category, involve:

Subject (*S*) *36*. "*Here*, *where we are sitting… almost in the whole area…*" (*Task 1*).
S. 66. "*In the light's path … and here*, *on the wall*" (*Task 2*).
S. 113. "*On the wall*, *it passes from here and there is light there…* (*he shows the direction of light*)" (*Task 2*).
S. 141. "*There is the light… from here to the air…it lights up the air… but we cannot see it*" (*Task 3*).

As indicated in Table 2, during pretest, only one child of the SCG and two children in the EG gave answers belonging in model A in task 1. During task 2, the relevant pretest responses amounted to 19 and 17 for the SCG and the EG, respectively, while 10 children in the SCG and 11 in the EG introduced responses compatible with model A in task 3. In other words, some of the children could provide adequate responses — i.e., compatible with model A— even before the teaching interventions in one or more tasks. This finding suggests that some children were capable of intuitively constructing a precursor model.

Model B The existence of light is only recognized by the children in the light sources or in areas where there are visible spots illuminated by light bundles; the children do not rely on the precursor model about light.

S. 37. "*There is light where light shines*" (*Task 1*).
S. 96. "*On the floor… there is light in the lamp*, *in the flashlight*" (*Task 2*).
S. 144. "*It isn't… because the light goes here* (*through the hole*) *and directly here* (*to the piece of cardboard*)*… it does not go there* (*into space*)" (*Task 3*).

Table 2 Frequency of responses in the sociocognitive and empiricist group in the three tasks

		Pre-test		First post-test		Second post-test	
		SCG (%)	EG (%)	SCG (%)	EG (%)	SCG (%)	EG (%)
Task 1	Model A	1 (1.2)	2 (2.4)	41 (48.2)	8 (9.4)	47 (55.3)	10 (11.8)
	Model B	84 (98.8)	83 (97.6)	44 (51.8)	77 (90.6)	38 (44.7)	75 (88.2)
Task 2	Model A	19 (22.4)	17 (20)	48 (56.5)	26 (30.6)	50 (58.8)	27 (31.8)
	Model B	66 (77.6)	68 (80)	37 (43.5)	59 (69.4)	35 (41.2)	58 (68.2)
Task 3	Model A	10 (11.8)	11 (12.9)	51 (60.0)	21 (24.7)	55 (64.7)	23 (27.1)
	Model B	75 (88.2)	74 (87.1)	34 (40.0)	64 (75.3)	30 (35.3)	62 (72.9)

During the pretest, the SCG's responses falling within model B were 84 for task 1, 66 for task 2, and 75 for task 3. The relevant answers of the EG were 83, 68, and 74, respectively.

According to the evaluation criteria described above (see section "Criteria of Evaluation" section), a shift from model B to model A would constitute "progress", while a reverse shift would constitute "regression"; adherence to either models A or B would be regarded as "no progress".

As is apparent in the results reported in Table 2, both groups exhibited an overall progress between pre- and post-tests, since the frequencies in model A are considerably higher in the post-tests for both groups. In Table 3, the evolution of children's reasoning in terms of shifts between categories A and B that have been observed from the pretest to post-tests in the responses of both SCG and EG subjects are presented.

The observed shifts in the models adopted by the subjects seem to verify our hypothesis. From the results presented above, it becomes palpable that the subjects of the SCG are able to recognize light as an entity in space more readily than those of the EG.

In task 1, for both the first and second post-test, the SCG subjects exhibit more progress than those of the EG. The differences between them are statistically significant (task 1, first post-test: U=2167.5, p<0.001; second post-test: U=1997.5, p<0.001). More particularly, in terms of task 1, an important improvement in the responses of the SCG in regards to the recognition of light in an everyday context was observed. In the first and second post-tests, it seems that the exclusive and restricted focus on light sources and strongly lit areas declines. Two and 4 months after attending the teaching intervention, a considerable number of the SCG subjects were able to indicate the existence of light in other areas located in the space between/outside these spots.

Table 3 Evaluation of children's responses indicating model shifts between the pre- and post-tests

		Pretest/first post-test		Pretest/second post-test	
		SCG (%)	EG (%)	SCG (%)	EG (%)
Task 1	Progress	40 (47.1)	6 (7.1)	46 (54.1)	8 (9.4)
	No progress	45 (52.9)	79 (92.9)	39 (45.9)	77 (90.6)
	Regression	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Task 2	Progress	31 (36.4)	10 (11.8)	32 (37.6)	10 (11.8)
	No progress	52 (61.2)	74 (87)	52 (61.2)	75 (88.2)
	Regression	2 (2.4)	1 (1.2)	1 (1.2)	0 (0.0)
Task 3	Progress	41 (48.2)	11 (12.9)	47 (55.3)	14 (16.5)
	No progress	44 (51.8)	73 (85.9)	36 (42.3)	69 (81.1)
	Regression	0 (0.0)	1 (1.2)	2 (2.4)	2 (2.4)

In task 2, the difference is statistically significant for both the first (U=2,768, p<0.02) and the second (U=2,715, p<0.014) post-test. In this task, the verification of our hypothesis becomes apparent in both the first and second post-test, by means of a common daily life experience, that is the visual verification of light's presence along a flashlight bundle. Here, the SCG subjects indicated considerable progress. At the same time, it seems that the EG subjects who had attended an empiricist teaching procedure gradually adopted the idea of light's autonomous presence in space. However, the progress of the SCG was significantly greater.

Similarly, in task 3, the shifts in the responses between the post-test and pretest are also significant (task 3, first post-test: U=2315.5, p<0.002, second post-test: U=2,243, p<0.002). Moreover, the confirmation of our hypothesis in both post-tests for task 3 is of great interest. Here, an unusual situation in terms of a child's experience was presented. The SCG subjects consistently succeeded in identifying the presence of light between the two pieces of cardboard. This observation merits interpretation based on a precursor mental model completely deconcentrated from the visible characteristics of the experimental situation.

In order to test the possibility of systematic —positive or negative— effects of specific teachers on children's reasoning and achievement, the results of each post-test (that is first and second post-test) between all the subgroups of children participating in the SCG who were taught by the 11 different volunteer teachers were compared. The same procedure was carried out for all subgroups of children participating in the EG. No significant differences were detected between either SCG or EG children involved in subgroups of different teachers that would designate that different teachers had varying effects on children's achievement.

Furthermore, analysis proceeded to determine to what extent the children exhibited a consistent progress —i.e., if the same children exhibited progress throughout the three tasks. As comparison between pre- and post-tests for SCG indicates, in the first post-test 40 and 41 children exhibit progress in tasks 1 and 3 correspondingly. These subgroups of children coincide by 93 % (38 common subjects). Thirty-one of the subjects who exhibited progress in task 2 also belong to the aforementioned subgroups of 40 and 41 children. During the second post-test, 46 and 47 children exhibited progress in tasks 1 and 3, respectively, and these subgroups overlap by 95 % (45 common subjects). Thirty-two of the subjects who progressed in task 2 belong to these subgroups of 46 and 47 children (tasks 1 and 3). These outcomes suggest that a homogeneous and concrete part of the sample progressed during the study; this finding is not surprising, since the children who succeed in constructing a precursor model are expected to be capable of using it as a basis of reasoning in different situations.

Discussion

The study presented in this paper attempted to provide evidence to support a sociocognitive theoretical perspective, according to which the initiation of children to some aspects of the natural world is possible even from the preschool age, given that preschoolers are supported and facilitated in constructing precursor models compatible with the descriptive characteristics of scientific models. The results of the present study tend to support our hypotheses. According to our research findings, the subjects of the sociocognitive group were able to identify light as an autonomous entity more consistently than those of the empiricist group.

The present study also provides evidence for the importance of destabilizing children's spontaneous representations and of using metaphor in the construction of a precursor model for the concept of light. Indeed, it seems possible that this procedure, as a mechanism of social interaction, drives psychological prerequisites of reasoning to a higher level, that is it facilitates the transition of children's reasoning from an one-step process (LS→VLA) to a two-step process (if LS→SLP and SLP→VLA then LS→VLA). Thus, after the teaching interventions with both groups, 5 out of 10 children in the SCG made progress compared with 1 child out of 10 in the EG. These results indicate the significant contribution of the teaching activities involving interactions that were structured around the existing obstacles to children's cognitive development.

Furthermore, a crucial factor in the sociocognitive teaching strategy designed and implemented in the present study —apparent throughout children's activities— is the teachers' role. Not only do they organize the teaching environment, but they also systematically follow children's reasoning, intervening precisely at the points where it requires support in order to effectively address cognitive obstacles. In this way, the teachers perform activities with the children which the latter are not as yet able to perform without scaffolding and which they will later be capable of successfully undertaking alone. From this point of view, the proposed activities and the role undertaken by the teachers are indicative of the idea of Vygotski (1962) on learning at the zone of proximal development. These observations indicate that these issues should be systematically considered and dealt with in teachers' initial and in-service training.

It therefore seems that the teaching intervention implemented with the SCG leads to more satisfactory learning outcomes than that implemented with the EG. However, the entire organization of the activity with the children of the sociocognitive group is quite different from the actual conditions that exist in a kindergarten, no matter how interesting the results of this study may be. The critical difference between the sociocognitive teaching intervention and the usual kindergarten activities —typically empiricist in their perspective— is that the teachers in the SCG of this study were especially trained to facilitate the children in restructuring their mental representations. Yet this "distance" has been deliberately chosen since it offered certain possibilities. This choice can indeed allow to assess preschoolers' cognitive ability to construct a precursor model, though in a particularly favorable teaching environment. If children are able to fulfill the cognitive prerequisites of that precursor model, instructional processes can be subsequently designed, which gradually approach, from the same theoretical perspective, the actual conditions found in real kindergartens. In such a study, which is now being under implementation, the interactions between a preschool teacher and a small group of children appear to render remarkable learning outcomes.

In any case, the sociocognitive approach adopted in this study engendered a possible route that could lead to the development of instructional activities, which favor children's initiation into the properties of physical objects, natural phenomena, and scientific concepts. Research implemented over the last 20 years (Canedo-Ibarra et al. 2010; Koliopoulos and Argyropoulou 2011; Lemeignan and Weil-Barais 1993; Ravanis et al. 2004) has made possible the study of the construction of precursor models by children, which, although descriptive and not explanatory, are compatible with scientific ones. From this perspective, and from the perspective of children's entire development, it could be more meaningful to design activities appropriate for preparing children for adequately understanding science at a later stage, instead of proposing organized activities simply aimed at presenting simplified scientific content.

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