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CHANGING PRESCHOOL CHILDREN'S REPRESENTATIONS OF LIGHT: A SCRATCH BASED TEACHING APPROACH

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Abstract. *The research presented here studied preschool children's representations of light. A teaching intervention was also carried out, with an aim to construct in children's thinking a precursor model according to which light is recognized as an autonomous entity, which is independent of the light sources and the results it causes. The teaching intervention was conducted through the use of special software created in a scratch environment. The study, consisting of three phases (pre-test, teaching intervention and post-test), included 30 children aged 4-6 years. The results of the research showed that in the children's initial mental representations light is identified mainly with light sources. After the teaching intervention, a large percentage of the children had constructed a precursor model which was compatible with the scientific one, based upon which children recognize light as an autonomous entity.*

Key words: *light, preschool pupils' representations, scratch software, precursor model, science education.*

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Introduction

In modern Science Education and the branch of Psychology that deals with learning, an important research topic is the way in which children's thinking approaches the natural world (Seker, 2008; Unal, 2008; Dedes & Ravanis, 2009). In this context, researchers often seek out in children spontaneous mental representations of the concepts and phenomena of the Natural Sciences. During the past few years, research regarding early childhood education has frequently tackled subjects relating to the construction of learning concepts drawn from the world of the Natural Sciences (Fleer & Robbins, 2003; Christidou & Hatzinikita, 2006; Fleer & March, 2009; Ergazaki, Saltapida & Zogza, 2010; Koliopoulos & Argyropoulou, 2011; Boilevin, 2013; Ravanis, 2013). Thus, on the one hand there is the study of the difficulties and obstacles faced by children's thought processes, while on the other, an effort is being made, through the appropriate teaching interventions, to create the conditions for conceptual change. These teaching interventions, which are based on the difficulties encountered by young children, are conducted either with or without the use of New Technologies.

Theoretical Framework

The development of early childhood education activities related to the natural sciences is closely connected to children's daily experiences. Indeed, from the preschool age, children form representations of the natural world that are not compatible with scientific knowledge and are resilient to both biological maturing and traditional teaching. Thus, in order to organize successful teaching activities for the initiation of small children to the world of Physics, the difficulties that stem from children's representations are used and an attempt is made to construct precursor models in their thinking. Precursor models are cognitive entities of limited range as far as use and practice are concerned, which include a restricted number of elements and relationships between the actual scientific models (Lemeignan & Weil-Barais,

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1993; Weil-Barais, 2001; Canedo-Ibarra, Castelló-Escandell, García-Wehrle & Morales-Blake, 2010; Ravanis, Papandreou, Kampeza & Vellopoulou, 2013). "Thus, if precursor models are successfully constructed, since these become established as intermediate entities between the children's first representations and the scientific models, they may offer certain crucial possibilities; namely, the systematization and explicit expression of personal representations, the understanding of simple causal relations and the identification of variables. It is exactly for this reason that precursor models fittingly prepare young children's thought for the construction of actual scientific models" (Ravanis, Koliopoulos & Boilevin, 2008).

The construction of a precursor model in preschool age children's thinking requires the planning of a suitable teaching environment based on the mental representations of the phenomena of that field; in this case, light. In research using personal interviews before and after a teaching intervention, it was found that children 5-6 years old equate light with light sources or with the bold light spots that it creates and do not recognize it as an autonomous entity that transmits through space (Ravanis & Boilevin, 2009). In these studies, the elements of a precursor model of the concept of light in children's thinking which are found and sorted are: (a) the recognition of light's autonomy from the light sources that produce it and (b) the comprehension of light's transmission in space and its interaction with the objects it encounters.

Fleer (1996) established that after a suitably planned teaching intervention, preschool children are in a position to discuss the concept of light and to refer to light sources and objects that were used in teaching. Upon studying their drawings, depictions of large rays of light are seen radiating from light sources. In general, a certain progress in children's thinking is established, although it is also noted that they have not fully understood the nature of light.

In another study that aimed to change 5- to 6-year-old children's mental representations, the centrations, predictions and explanations of the phenomena caused by light were studied through personal interviews (Voutsina & Ravanis, 1998). The subjects were separated into two groups: a control group and an experimental one. The control group consisted of children who attended an empiricist didactical intervention concerning the conception of light, while the experimental group participated in activities which adopted a socio-cognitive approach aimed at creating cognitive conflict that could help children eliminate their centrations. Finally, the comparison of the results between the control and the experimental group showed that the progress of the experimental group was more significant than the progress of the control group.

In the Gallegos-Cázares, Flores-Camacho & Calderón-Canales (2009) research, use is made of preschool age activities that aim at the recognition of light as an important element in seeing an object. It is proven that after an organized teaching intervention based on the children's difficulties, substantial progress is made, since the majority of the children recognizes and discerns the light and its behavior towards the objects that produce or receive light.

The aim of another study was to investigate the effect of a socio-cognitive teaching strategy on 5- to 6-year-old children's understanding of light (Ravanis, Christidou & Hatzinikita, 2013). It explored 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: pre-test, teaching intervention, and post-tests. The sample was assigned to two groups. The children in the first group participated in activities which adopted a socio-cognitive approach. In the context of this approach, the familiar metaphor of "travel" was introduced in order to facilitate children's construction of a precursor model of light. The children in the second group participated in activities with the same teaching objectives, but adopting an empiricist perspective. The statistical analysis indicated that the cognitive progress of the socio-cognitive group was more significant than the progress of the empiricist group.

Through the study of relevant bibliography that was limited to research on the understanding of light in the preschool age, it has been established that the research being carried out for several years in this particular field emphasizes the effectiveness of socio-cognitive learning strategies. In the research presented here, an attempt is made to study the possibility of creating effective teaching occasions for the construction of a precursor model in 4- to 6-year-old children's thinking, using software. The teaching intervention was realized with the use of specialized software in a scratch environment that was used by children in cooperation with their instructors (Monroy-Hernández & Resnick, 2008; Maloney, Resnick, Rusk, Silverman, & Eastmond, 2010). The activities that were planned and carried out aimed at the destabilization of the children's mental representations and the investigation of light as an autonomous entity in space, namely the construction of a precursor model supported for the first time by a digital environment.

In this framework, two research questions were posed: (a) What are 4- to 6-year-old children's mental representations of light as an autonomous entity? and (b) Is it possible to change these mental representations and construct in children's thinking a precursor model of light using specially designed software?

Research Methodology

The Design of the Study

The study was implemented in three phases (pre-test, teaching intervention and post-test). The data of the study consisted of children's responses and explanations of three tasks set during both the pre-test and post-test. These were collected through individual, semi-structured interviews which lasted 5 to 10 minutes. The pre-test took place two weeks before and the post-test was held two weeks after the intervention. Data analysis was based upon the recorded discussions and individual observation protocols. The teaching interventions were carried out by a specially trained preschool teacher, involved groups of 2 children and lasted about 15 minutes for each group. The pre-test and post-test as well as the teaching intervention took place in a specially set up area on the kindergarten premises.

Sample

The research sample included 30 children (12 aged 4-5 years and 18 aged 5-6 years) from two classes of a public kindergarten. The children were randomly sampled among those willing to cooperate. The children that took part in the research had not previously attended any organized teaching activity on the entity of light. All socio-economic levels (low, middle, and high) and all levels of pupils' performance (low, middle, and high) were represented equally in the sample. The sample was small since the conditions under which the procedure was carried out were quite demanding: the children had to want to participate and to be able to use computers, the teacher had to want to undergo special training, the parents had to give special permission, and the school had to have a specially designed area for the research to be carried out.

Tasks

In all three tasks, situations were created that permitted the concentration on light sources and lighted surfaces, as well as the recognition of diffused light in space. In the room, there was artificial light from lamps, as well as natural light from the sun. Furthermore, there were turned off light sources and objects on the floor. Thus, it was deemed that if children were able to locate light in space independently of its sources and thus overcome their perceptive centralities, they would then be able to construct models compatible with the scientific concepts of light. In all these tasks an initial question was posed and then, based on each subject's answer, a dialogue ensued which was completed when a clear picture emerged of each child's representation. These tasks have also been used in other related research (Ravanis & Boilevin, 2009).

Task 1

In the first task the children were engaged in a conversation that began with the question "What do you think light does?" Through this question, an attempt was made to determine how children associate light with its results. Results that can be traced through direct sensory perception, such as heating or lighting, display persistence in intuitive reasoning. By contrast, reasoning that goes beyond perceptive centrations recognizes light as an independent entity associated to phenomena such as life and the growth of organisms.

Task 2

In a directly sunlit room, a table lamp was switched on. The children were asked to show points of light in the room. Afterwards, they were asked to give as many answers as possible. In this way, it could be safely confirmed whether they recognized the existence of light in the room or not.

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Task 3

Two vertical pieces of cardboard were set on a stable horizontal base at a small distance from each other. A hole was cut out at a height of 17cm from the base of one of the pieces of cardboard. At the same height as the hole, a portable lamp was placed at a short distance from the hole (Figure 1).

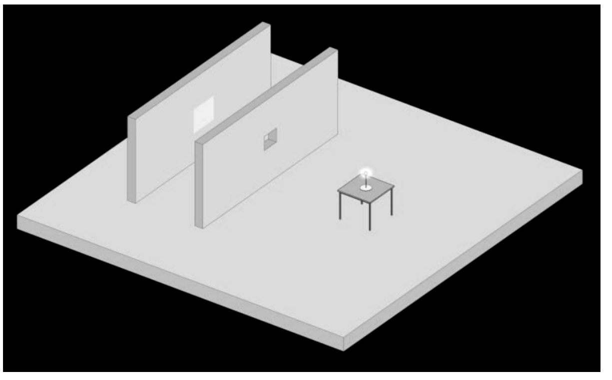

Figure 1: The experimental setup used in Task 3.

When the experiment was presented to the pupils, while the lamp was turned off, the children were asked: "If we turn on the lamp, will there be any light from it between the two pieces?" If the answer was positive, the child was asked to explain. If it was negative or the explanations were not satisfactory, the child was asked and simultaneously shown: "Here, in the air, is there any light from the lamp?" This experiment was chosen for task three because, in contrast to the other two tasks, it is not taken from an everyday situation.

The Teaching Intervention

During the teaching intervention, the children cooperated in twos and interacted with the computer using an application that was created with scratch software, especially for children from 4 to 6 years old. The application was based upon an older teaching intervention that was conducted using drawings (Voutsina & Ravanis, 1998). It was deemed suitable for the 4- to 6-year-old children's knowledge standards since it is based on their cognitive difficulties and aims at the destabilization of their mental representations, as well as the support of the recognition of light's presence as an independent entity from the sources that produce it. It was namely created aiming to help children discover in contrast to their centralities that light is transmitted, exists in space and interacts with the objects that it encounters. The teaching intervention was carried out in four phases.

Phase one

The teaching intervention is carried out in a virtual room with light sources, both natural and artificial. Furthermore, in the room there are depictions of various objects. The children, moving the mouse very simply, can turn on and off each lamp and open or close the windows. Each team first describes the room and familiarizes itself with the use of the software.

Phase two

The students are then asked to tell the researcher whether there is light in the room while it is nighttime and all the light sources are turned off (Figure 2). If their answer is negative, then they are asked to use a light source and, when its ray becomes visible, they are asked where the light is located in the room (Figure 3). After that, the children are asked to use the remaining light sources and tell the researcher what they observe (Figure 4).

However, if the children's answer to the question "Is there light in the room?" based on Figure 2 is positive, then they are asked to indicate parts of the room where they believe light exists. If they point to the lamps, the researcher insists on the word "light" and asks them whether the lamp is turned on. After they've confirmed that the lamp is turned off, the researcher suggests they turn it on and then ask them where the light is. If the students point at the visible ray that originates from the light sources, then the researcher aims at destabilizing their reasoning, since they were previously claiming that the light is in the lamp. However, if they insist that the light is in the lamp, it then becomes clear that the cognitive obstacle of light's identification with the light sources is still strong.

Figure 2: When the light sources in the room are turned off

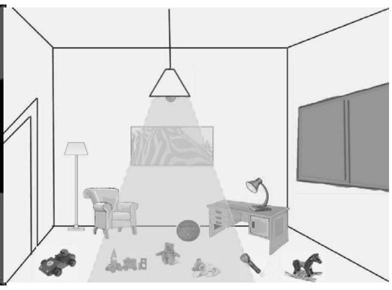

Figure 3: When a light source in the room is turned on

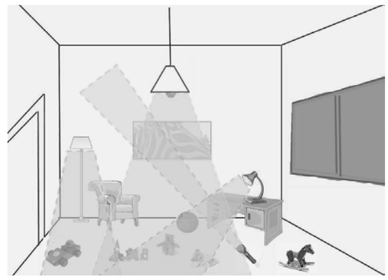

Figure 4: When the light sources in the room are turned on

Phase three

The children are asked whether and where there is light in the room during the day, with all of the artificial light sources turned off and the window closed. If while answering they suggest the use of the light sources and do not try to open the window to let the light into the room, they are urged to leave the lamps turned off and to open the window (Figure 5). After they have opened it, they are asked to tell us where there is light and where it comes from, and then we discuss their answers.

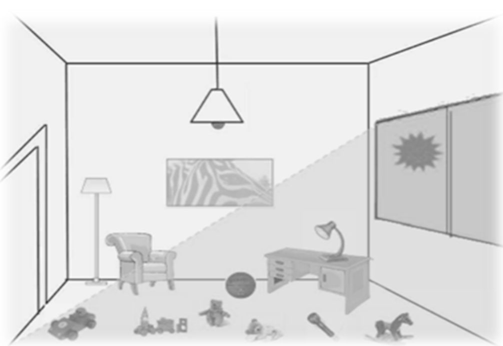

Figure 5: When the room is lighted by the sun.

Phase four

After they have opened the window and the rays of the sun appear, they are asked whether there is any way to further light the room. If they answer negatively, they are urged to use the remaining light sources and to tell the researcher what they observe. A discussion then ensues based on their answers (Figure 6).

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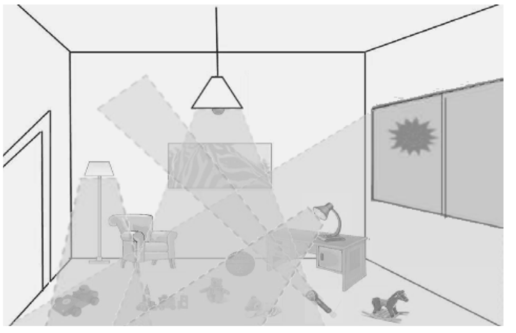

Figure 6: **When the room is lighted by the sun and the light sources.**

Research Results

The analysis of the data was carried out by two independent researchers based on the transcribed texts and the analysis of the special protocols that were observed. Categories were created for each task based on the children's answers. The degree of consensus between the two researchers was 95%. The categories of answers in each task are shown below, including examples of the clarifications offered by the children or of the dialogue that took place between the children and the researcher.

Task 1: "What do you think light does?"

The answers given in this task were classified into three categories:

1. Answers in which light is treated as an entity separate from the light sources. In this category there are answers like, "Light helps us see at night (Subject 16)", "Light warms and dries the clothes (S. 1)", "Light warms people (S. 2)", "Light causes plants to dry up (S.1)".
2. Answers in which light sources prevail, like, "Light turns on and off (S. 4)", "Light burns (S.1)", "Light shines (S. 2)", "Light is like the sun (S.1)".
3. Answers in which no representation is formed.

Table 1. **Frequency of the children's answers in Task 1.**

What do you think light does?	4-5-year-olds		5-6-year-olds	
	Pre-test	Post-test	Pre-test	Post-test
Light as an entity	2	7	5	16
Light sources	10	5	11	2
No representation	0	0	2	0

As can be seen in Table 1, progress has been made in the children's answers between the pre-test and the post-test. Particularly in the pre-test, the majority of children from both age groups (11/18 in the 5-6-year-old children's group and 10/12 in the 4-5-year-old children's group) identifies the light as an entity mainly with the light sources and the effects it causes. However, in the post-test, it seems that the majority of children from both age groups (16/18 of the older children and 7/12 of the younger ones) can recognize light as an entity separate from the light sources.

Task 2: "Show us points of light in the room."

In the second task, the children's answers were classified into four categories:

1. Answers in which light is recognized as a separate entity in space, such as "There is light on the book, toys, carton, but not only there (book) and there (carton)… it is everywhere in the classroom (S.1)".
2. Answers in which the presence of light is recognized in surfaces and objects lighted strongly or less strongly by diffused light, such as "There is light on the windows and on the toys (S.8)", "There is light on the wall (S. 5)", "There is light on the chair (S.4)". Here students frequently indicate the existence of light in the light sources as well.
3. Answers in which the existence of light in the light sources is recognized, even if they are not turned on, such as "There is light in the lamps (S. 23)".
4. Answers in which no representation is formed.

Table 2. Frequency of the children's answers in Task 2.

Show us points of light in the room	4-5-year-olds		5-6-year-olds	
	Pre-test	Post-test	Pre-test	Post-test
Light as an entity	0	0	0	8
Light on subjects	2	12	3	10
Light sources	10	0	13	0
No representation	0	0	2	0

As can be seen in Table 2, progress has been made in the children's answers between the pre-test and the post-test. Major changes are observed in their mental representations. Particularly in the pre-test, the majority of children from both age groups (13/18 of the older children and 10/12 of the younger ones) detect light only in the light sources, in contrast to the post-test, where the students (10/18 of the older children and 12/12 of the younger ones) detect light in various places of a space strongly or less strongly lighted by diffused light. There are also 8/18 of the 5-6-year-olds that can recognize the light as a separate entity in space.

Task 3: "Light between the two pieces of cardboard"

The third task used the experimental arrangement described above and, without turning on the lamp, the children were asked to say whether there will be light between the two pieces of cardboard when the lamp is turned on. The children's answers were classified into two categories.

Answers in which the existence of light between the two pieces of cardboard is recognized, such as "There will be light… Since it goes across, there will be… as long as it keeps going… (S. 2)", "The light will go through the hole and… will fall on the second piece of cardboard… as long as the lamp stays on there will be light, since it keeps going through (S. 11)".

Answers in which the existence of light between the two pieces of cardboard is not recognized, such as "No, the light will be in the lamp… and where we see it on the piece of cardboard... (S. 30)".

Table 3. Frequency of the children's answers in Task 3.

Light between the two cardboards	4-5-year-olds		5-6-year-olds	
	Pre-test	Post-test	Pre-test	Post-test
Presence of light	5	6	12	15
No presence of light	7	6	6	3

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As can be seen here, about half of the younger children and 4/6 of the older ones recognize the presence of light in the air between the two pieces of cardboard in the pre-test. A small improvement is observed among the older children, as in the post-test 5/6 recognize the existence of light in space. The children's performance results are quite high for the age of 4-6 compared to the results of other related studies which, however, were carried out using real objects rather than software (Ravanis & Boilevin, 2009; Ravanis, Christidou & Hatzinikita, 2013).

Discussion

The aim of this study is to investigate 4-6-year-old children's mental representations of light and whether it is possible to guide preschool children's thinking towards the construction of a precursor model for the phenomenon of light, through the use of specialized software.

Firstly, in the pre-test, where the tracing of the children's mental representations takes place, in accordance with the relative bibliography, we discovered a large-scale recognition of light's existence only in light sources, and on a smaller scale in the lighted areas or the objects (Fleer, 1996; Ravanis & Boilevin, 2009; Gallegos-Cázares, Flores-Camacho & Calderón-Canales, 2009). Simultaneously, we found a difficulty in the recognition of light's existence in the space between the light source and the object upon which it ends up.

However, after the teaching intervention on children's thinking, as is recorded in the post-test, we observe a remarkable cognitive progress. Indeed, in the first task, 50% of the younger children and 85% of the older ones, from among those who did not recognize the effect of light as a separate entity away from the light sources, made progress. In the second task, the effect of the teaching process on both the children's groups is very interesting. Among the younger children in the pre-test, only 1/6 recognized that light can be traced outside of the light sources, while in the post-test, all of the children are capable of pointing out spots that are lighted. Here, the destabilization of younger children's thinking from the light sources is total. Also, from among the older children, while in the pre-test only 1/6 recognized the presence of light outside of the light sources, in the post-test all of the children trace the light outside of the light sources and more than 4/10 attribute to it a separate presence in space. In the third task, the differences between the pre- and post-test were positive, albeit small, since the children's performances were satisfactory in the pre-test. Thus, it is established that the artificial condition with the two pieces of cardboard that was proposed proved suitable in order to allow a large number of children to identify light as a separate entity (17 children total in the pre-test and 21 in the post-test).

In all three tasks of the whole experimental situation, many children formulate reasonings that are based on the recognition of the continuous presence of light in the space between the light source and the lighted surfaces. Those are reasonings that signal the construction of a precursor model of light. Certainly, the hesitations and inconsistencies of the young children do not allow us to speak of a complete model that steadily imposes the presence of light between the light source and the lighted surfaces in their thinking, locating the imaginary course of light in all proposed situations.

However, this study's results are considerably better than those yielded by teaching interventions of the same theoretical approach, but which were carried out with regular educational means, rather than with the use of a computer (Voutsina & Ravanis, 1998; Ravanis, Christidou & Hatzinikita, 2013). This finding takes on special significance since it appears that, through the use of a scratch environment and especially this particular software, it appears possible that younger children can be guided towards the construction of a model for light and its diffusion. According to the relevant bibliography using conventional teaching materials, such a model would normally be constructed at age 9-10 or even slightly later (Guesne, 1985; Osborne, Black, Meadows & Smith, 1993; Ravanis & Papamichaël, 1995; Galili & Hazan, 2000).

Conclusions

In this study, an effort was made to obtain evidence of the effectiveness of a specialized educational software in the destabilization and the reconstruction of preschool children's mental representations on light as a distinct entity. It appears that the results tend to confirm the dynamics of this process and to widely show the importance of the related research with the scratch software, that very adequately allows the creation of interactive learning environments even for children of a very young age. If these results are confirmed in studies using larger samples, they might permit an attempt to study the phenomena of Optics in early childhood education, since the understanding of light's autonomous presence in space is a prerequisite for understanding any interaction between light and matter, as for example in the formation of shadows.

Given this prospect, it would be of great interest to conduct comparative studies regarding the matter of understanding light through teaching interventions using conventional and digital educational material, in order to systematically ascertain the differences that seem to have been noted in this study of preschoolers. Moreover, it would be interesting to study the use of the same software or other, more complex softewares on older children, in order to observe how the understanding of light evolves in children of different ages.

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