Pre-energy reasoning in preschool children

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ABSTRACT

The research presented in this paper explores the degree to which preschool children have the ability to use mental representations which constitute precursor energy models. Twenty-five children (10 boys and 15 girls) participated in the study. They were presented with two different phenomenological situations considered as important for the establishment of pre-energy reasoning: the movement of a toy car with the use of batteries and the movement of an identical car with the use of a spring. The children were involved in personal, semi-structured interviews, which aimed at eliciting their explanations about the movement of the two cars. The analysis of children's explanations reveals that they tend to explain the movement of cars in both phenomenological situations in naturalistic terms. These naturalistic explanations were mainly agentive, that is they regard the batteries and the spring correspondingly as external agents causing the cars' movement. The major percentage of agentive naturalistic explanations was given in terms of the function of the objects under discussion, while a number of them were formulated in terms of distribution. These findings designate a developing understanding of physical causality and a pre-energy character in children's reasoning, since they are capable of accounting for the two phenomenological situations in terms of object chains. Therefore, an attempt to introduce the aspect of energy transfer in preschool education could be considered.

Keywords

Causal reasoning, energy, naturalistic explanations, precursor models, preschool children

Résumé

La présente recherche étudie la possibilité que des enfants d'âge préscolaire aient d'exprimer des raisonnements pré-énergétiques en utilisant des modèles précurseurs concernant le concept de l'énergie. 25 enfants (10 garçons et 15 filles) ont pris part à cette recherche. La technique de l'entretien a été utilisée. Les enfants devaient répondre à des questions qui concernaient deux situations naturelles lesquelles avaient différents caractéristiques phénoménologiques: le mouvement d'une voiture-jeu à l'aide d'une pile et le mouvement d'une voiture-jeu à l'aide d'un ressort. L'objectif des questions était de constater si les enfants peuvent donner des explications naturelles relatives au mouvement des deux voitures. L'analyse des explications des enfants révèle que tous les enfants ont essayé d'expliquer les deux situations phénoménologiques en termes 'naturalistiques'. Ces explications étaient principalement des explications causales, donc les enfants ont considéré que la pile et le ressort étaient les causes extérieures qui ont provoqué le mouvement des voitures. La plupart des explications causales qu'ont données les enfants ont été formulées en termes de fonctionnement des divers objets tandis qu'une partie très petite des explications ont été formulés en termes de distribution. Ces résultats montrent qu'il est possible que les enfants de l'âge préscolaire formulent des raisonnements causales en termes d'une chaîne d'objets, chose qui signifie qu'ils soient capables de construire des modèles précurseurs énergétiques. Par conséquent, il est possible que soit entrepris un enseignement sur le transfert d'énergie à l'éducation préscolaire.

Mots Clés

Raisonnement causal, énergie, explications 'naturalistiques', modèles précurseurs, enfant de l'école maternelle

Introduction

Over the last decades educational research in the field of preschool education has accumulated a series of outcomes suggesting that young children construct conceptions and representations on the basis of their interaction with the natural, social and cultural environment in which they develop. This early knowledge often diverges from the knowledge taught at school as well as from scientific models. The conceptions held by children about natural entities and phenomena influence the way they understand science activities in the classroom and consequently what they learn in the context of formal schooling (Fleer & Robbins, 2003). On the other hand researchers have claimed that children's knowledge can be modified through appropriate school teaching (Ravanis, 1999, 2000; Howe, 1993; Tsatsaroni, Ravanis & Falaga, 2003; Tytler & Peterson, 2003; Koliopoulos, 2004; Eshach & Fried, 2005; Havu-Nuutinen, 2005). It has also been pointed that preschoolers have the ability to construct so called 'precursor models', i.e. mental representations that have common characteristics with scientific models and prepare them for the acquisition of scientific knowledge (Lemeignan & Weil-Barais, 1993, 1994; Ravanis, 2005). The design of teaching activities which can facilitate the construction of precursor models requires systematic research in order to identify the nature and characteristics of children's representations. Only then is it possible to define appropriate teaching activities.

During the last years, a large number of research studies on young children's mental representations and explanations about natural phenomena have been implemented in Greece. The topics of these projects are relevant to the national curriculum for science teaching in preschool education and involve thermal phenomena, light, floating\sinking, magnetic properties, friction, the human body and the concept of "alive" (Ravanis, 1999; Katsiavou, Liopeta & Zogza, 2000; Raftopoulos, Constantinou, Koliopoulos & Spanoudis, 2001; Zogza & Ergazaki, 2001; Koliopoulos, Tantaros, Papandreou & Ravanis, 2004; Ravanis, Koliopoulos & Hadzigeorgiou, 2004; Christidou, 2006; Christidou & Hatzinikita, 2006; Ravanis, Koliopoulos & Boilevin, 2008). A field that has not been researched yet is that of energy transfer. Energy is a fundamental scientific concept, which -because of its social importance- is introduced in teaching from the early stages of education (as, for example in the English Curriculum – Nuffield Primary Science, 1995). Moreover, it has already been included as a topic on an experimental basis in Greek kindergarten schools (Xenelli, Katsouda, Mantikou, Pimenidou & Papadatou, 2001). Whether this kind of teaching is possible depends on its social, cognitive and pedagogic feasibility.

This study aims at investigating whether a cognitive basis related to energy transfer exists in preschoolers that would allow the introduction of relevant teaching activities in the kindergarten. Specifically, the research presented in this paper explores the degree to which children have the ability to use mental representations which constitute precursor energy models that would enhance their ability to participate in energy-related teaching activities and to construct more adequate representations. More particularly, this paper aims at investigating a) the types of explanations preschool children use in order to account for the movement of toy cars in different phenomenological situations (battery-operated and spring-operated cars) and the extent to which these explanations can be regarded as indications of pre-energy thinking; b) if the types of explanations adopted by children vary from one phenomenological situation to another.

Causal Reasoning in Preschool Children

Children's explanations about natural phenomena is of crucial importance for learning in science, since they play a central role in understanding the natural world (Carey, 1985) by promoting or developing their reasoning beyond simple observation of events, to the causal relationships that connect them and the rational construction of deductions. Causal explanations generated by children about a variety of natural phenomena have been extensively studied in the context of the development of children's reasoning by Piaget (1997), according to whom children's thinking is restricted by inherent constraints limiting the formulation of naturalistic causal explanations before the age of 7-8. Younger children's reasoning ability is therefore considered to be limited to explanations of other types, such as animistic, artificialistic, teleological, or magical (Gelman & Kremer, 1991; Hickling & Wellman, 2001).

However, other researchers have suggested that young children are capable of providing naturalistic explanations to account for events that occur naturally (Gelman & Kremer, 1991), rather than restricting their accounts to animistic, artificialistic or teleological statements (Stepans & Kuehn, 1985; Springer & Keil, 1991; Backscheider, Shatz & Gelman, 1993).

The analysis of children's explanations about natural phenomena that do not comprise obvious mechanisms (Gelman & Kremer, 1991) has lead to the assumption that their reasoning is not exclusively animistic, nor does it use all types of explanation in an undifferentiated or generalistic manner. Instead it depends on the context and the conceptual domain in which the phenomenon under consideration falls within (Carey, 1985; O' Loughlin, 1992; Carey & Spelke, 1994; Hickling & Wellman, 2001) as well as on their level of familiarity with the phenomenon (Berzonsky, 1971). Therefore, legitimate questions arise regarding preschool children's ability to formulate naturalistic causal explanations about phenomena that are considered as important in the construction of pre-energy reasoning, the characteristics of these explanations (provided they exist), and if these explanations are influenced by the phenomenology of the situations under discussion.

Method

Sample

The sample of the research consisted of 25 children (10 boys and 15 girls) who were attending two classes in a public nursery school in the city of Patras. The nursery school was randomly selected. The children participating in the study had already completed their fifth year of age. According to the information given by their teachers the topic of energy transfer had not been discussed in any of the classes prior to the study.

Data collection

Two different phenomenological situations considered as important for the establishment of pre-energy reasoning were studied: the movement of a toy car with the use of batteries and the movement of an identical car with the use of a spring (Lemeignan & Weil-Barais, 1993, 1994).

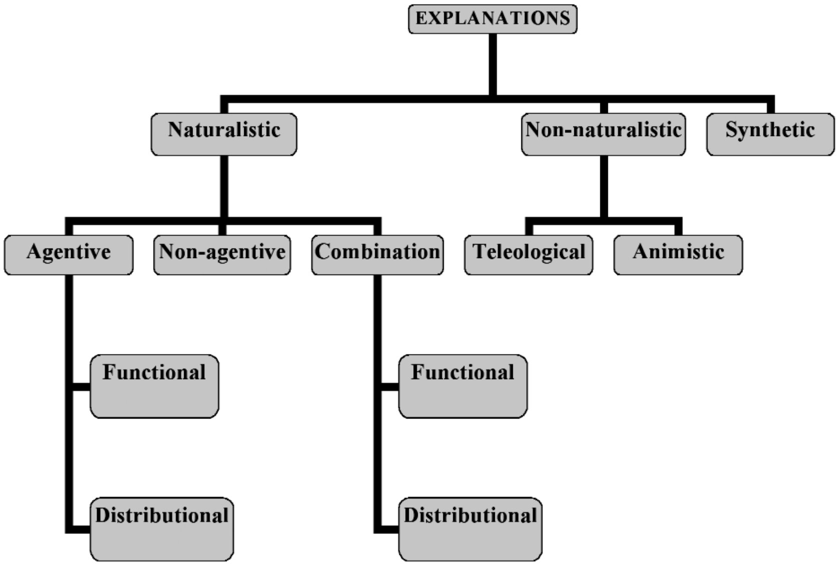
The technique of semi-structured interviews was used to elicit children's explanations. The children were asked to a) identify the objects used in the two situations, b) answer to a number of questions to predict and explain each car's movement, and c) find out what is common in the battery-operated and the spring-operated car movement. The validity and reliability of the interview scheme had been previously tested (Koutsiouba, 2003). The interview scheme and the rationale underpinning the questions involved are presented in the *Appendix*. The intention was to find out if the children are able to describe the movement of the cars either as a causal chain involving objects from the aspect of their function -i.e. the car movement is due to the battery-, or a chain involving objects from the aspect of distribution, which is the transfer of an action -i.e. the battery gives electricity to the car and so the car moves (Lemeignan & Weil-Barais, 1993, 1994).

Data Analysis

The groups of questions comprised in the interview scheme (see Appendix) formed the basis for the analysis of children's responses. Therefore, as far as the first phenomenological situation is concerned (battery-operated car) the responses to four groups of questions (IA, IB, IC, and ID) were analyzed, while the analysis of children's responses concerning the second situation (spring-operated car) involved another four groups of questions (IIA, IIB, IIC, and IID). Finally, a third group of questions (III) was analyzed concerning the comparison between the two situations. Through this procedure 225 fields of responses were created (9 groups of questions X 25 children).

The data in the fields corresponding to question groups IA and IIA (50 fields of responses) were related to the children's ability to identify the objects used in each phenomenological situation. From the rest of the response fields 160 contained explanations, which were analyzed according to a classification framework for children's explanations about natural phenomena previously developed and used in other conceptual domains, such as floating and sinking, dissolution, rain formation, or plant growth (Christidou, Hatzinikitas & Dimoudi, 2005; Christidou, 2006; Christidou & Hatzinikita, 2006). This methodological tool was modified and adapted to the needs of the present study and is presented in *Figure 1*. The types of explanations are described below illustrated by examples based on authentic interview excerpts.

Figure 1



The framework of analysis of children's explanations

Naturalistic explanations are rational and objective; their character is exclusively material. Children's ability to formulate naturalistic explanations is thought to mark the onset of physical causality, using concepts such as spatial contiguity, mechanical contact, temporal ordering, and logical deduction (Berzonsky, 1971; Gelman & Kremer, 1991; Springer & Keil, 1991).

Naturalistic explanations can be *agentive* (Hatzinikita, 1995), if they involve an agent which is external to the substance or object that is undergoing change (see Example 1), or *non-agentive*, attributing change to internal properties or action(s) of the changing substance or object itself, without any external actor participating to the process. Moreover, a naturalistic explanation can involve both agentive and non-agentive parts. In this case, explanations are recorded as combinations of agentive and non-agentive elements (see Example 2).

<u>Example 1</u>
I: What should I do to make the car run faster?
Child1: Put more powerful batteries.

<u>Example 2</u>
I: If we want the car to move what should we do?
Child2: Press the button.
I: I press the button but it's not moving. What else should I do? Think. Do we need to do something else?
C2: Yes,…we should step on the gas.

Agentive naturalistic explanations (as well as the agentive parts of combination naturalistic explanations) can either refer to the function of objects (*functional*), or to the distribution of an action (*distributional*), which in the context of this study corresponds to energy transfer.

In the following example a child gives a functional explanation to account for the battery-operated car movement:

<u>Example 3</u>
I: Let's see now, what has happened?
Child3: The car moved.
I: Nice. Now tell me do you know why the car can't move without the batteries?
C3: Because it can't work without batteries. Just because... You have to put batteries in.

In the following excerpt the car's movement is explained in terms of distribution of power from the batteries to the wheels through cables.

<u>Example 4</u>
I: Right, now the car moved. Without the batteries it wouldn't move. Do you know why?
Child4: Well, it has some cables..... Power goes though and this makes the wheels move.
I: So, there is power.... do you know where this power is?
C4: Er...it is in the batteries we buy.

<u>Non-naturalistic</u> explanations recorded in the course of the present study were either *teleological or animistic. Teleological* explanations, which assume that entities or evens occur in order to serve specific purposes, functions or goals, are a critical aspect of human reasoning (Kelemen, 1999). *Animistic* explanations attribute a usually conscious, intentional and intelligent character to non-living things.

The child in Example 5 interprets the movement of the car in teleological terms, while the excerpt in Example 6 illustrates the use of animistic thinking.

Example 5
I: Why did you put the spring first and then the car?
Child5: Why did I put it this way?
I: Yes, please tell me.
C5: Because it's a car and a car should run.

Example 6
I: If I put the spring against the wall and press it, the car will move forward. Why will it move forward? Why will it move?
Child6: Well, it wants to go to work.

Last, synthetic explanations include both naturalistic and non naturalistic elements. In the following example the participant combines naturalistic (agentive), animistic and teleological elements in his explanation:

Example 7
I: What should we do to make the car move?
Child7: We should press the spring against the wall and then let go. And then brrr…it will move.
I: Very good, the car will move. Why will it move?
C7: It wants to pass the toll gate.
I: Oh, to pass the toll gate. Yes, but what made it move?
C7: Err…that's what all cars are supposed to do.

Results

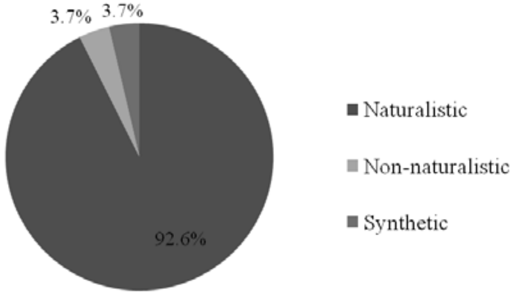
Identification of objects

The analysis of children's responses to question groups IA and IIA showed that without exception all children who took part in the study were familiar with and could identify the objects involved in both phenomena. Only some of them, even though they recognized the spring, could not name it, in which case the term was given by the researcher.

Children's explanations about the two phenomenological situations

Children's explanations about the movement of the cars in the two different situations (battery-operated and spring-operated) were recorded as responses to question groups IB, IC, ID, IIB, IIC, and IID (see Appendix). The responses to these questions yielded a total of 136 explanations, which are discussed in regards to the dimensions of the analysis framework (*Figure 1*) in the following paragraphs. Only a limited number of responses (14 cases) could not be classified in any of the categories of the framework.

FIGURE 2



Types of explanations used by children

The analysis of children's explanations reveals that they tend to explain the movement of cars in both phenomenological situations (battery-operated and spring-operated) in naturalistic terms. *Figure 2* presents the percentages of the different types of explanations recorded in regards to the aforementioned groups of questions. The vast majority of explanations introduced by the participants were naturalistic ones (92.6% of the total number of explanations). Only 3.7% of the explanations were purely non-naturalistic, while another 3.7% of explanations involved both naturalistic and non-naturalistic parts (synthetic explanations).

A detailed examination of the results including the more subtle distinctions of the analysis framework is presented in *Figure 3*, where the frequencies and percentages for each category are presented.

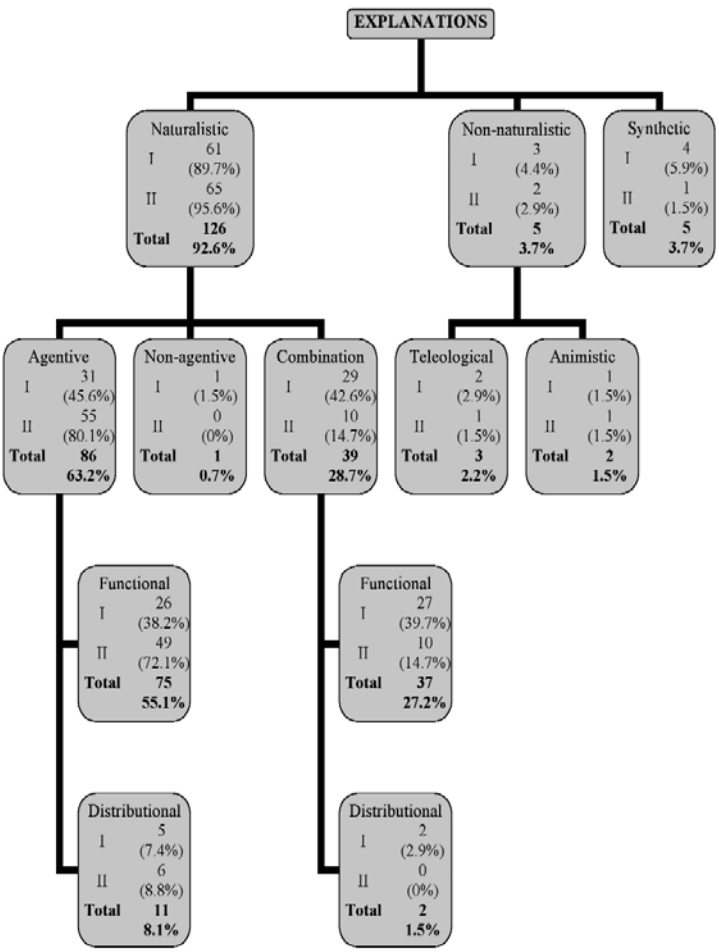
This analysis reveals that 63.2% (86 out of 136) of the explanations recorded were agentive naturalistic ones. A considerable percentage (28.7%) of the explanations given concerned combinations of agentive and non-agentive parts. In these explanations most of the participants attributed the cause of the cars movement to the batteries and the spring correspondingly, which were considered as external causal agents. Only one explanation (0.7%) was purely non-agentive.

The major percentage of agentive naturalistic explanations were given in terms of the function of the objects under discussion (75 instances, or 55.1% of the total of explanations recorded), while 8.1% of the explanations were formulated in terms of distribution. A similar image is reflected in the agentive part of combination naturalistic explanations (i.e. 37 instances, or 27.2% of the total of explanations were combination functional explanations and 2 instances, or 1.5% of the total of explanations were combination distributional explanations).

As far as non-naturalistic explanations are concerned, these were either teleological (3 instances, or 2.2% of the total of explanations), or animistic (2 instances, or 1.5% of the explanations).

If the types of explanations introduced by children for each of the two phenomenological situations are examined separately, further interesting outcomes are revealed. Although at the higher level of naturalistic versus non-naturalistic and synthetic explanations no significant differentiations appear, this is not the case for the finer distinctions of the analysis framework. In particular, the participants tended to

FIGURE 3



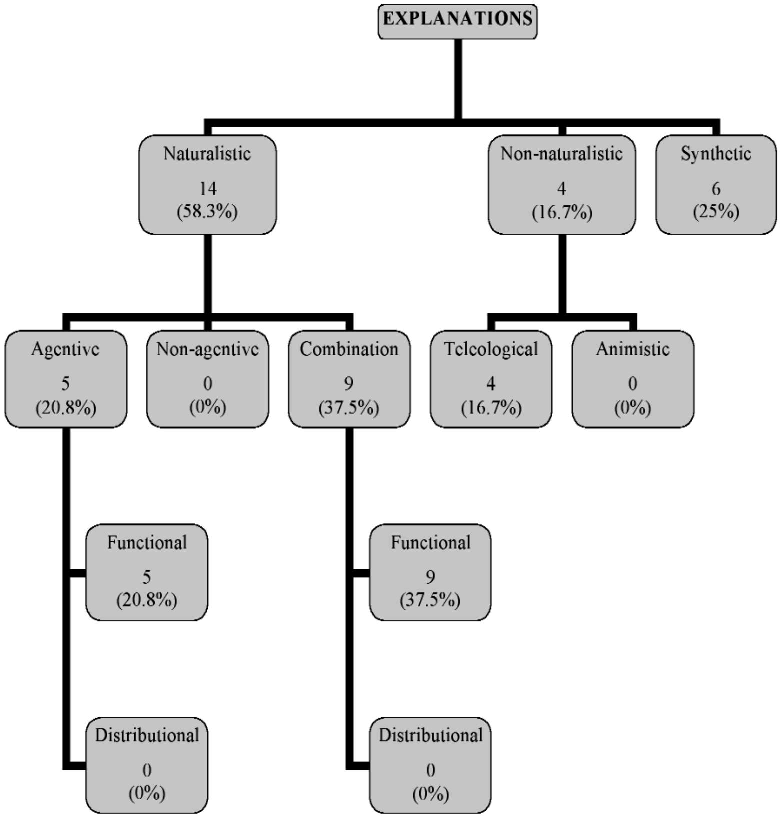
Frequencies and percentages of children's explanations regarding the two phenomenological situations (I: battery-operated car, II: spring-operated car)

prefer purely agentive explanations in the case of the spring-operated toy car, while they tended to resort to combinations of agentive and non-agentive elements more frequently than expected in the case of the battery-operated toy car. This difference is statistically significant (x^2=16.8, df=2, p<0.001) and could be attributed to the fact that the cause of action (compressed spring) of the spring-operated toy car, is obviously external and distinguishable from the observed result (car movement). On the other hand, the movement of the battery-operated car is not as evidently –or exclusively- attributed to the batteries inside it as an external agent.

Children's explanations about the comparison of the two phenomenological situations

Another type of analysis performed concentrated on the comparison of the two phenomenological situations, which was based on children's responses to question group

FIGURE 4



Frequencies and percentages of children's explanations regarding the comparison of the two phenomenological situations

III (see Appendix). These responses yielded a total of 24 explanations, which are distributed in the categories of the analysis framework as shown in *Figure 4*. Again naturalistic explanations prevail (14 instances, i.e. 58.3% of the explanations) over non-naturalistic (4 instances, or 16.7%) and synthetic (6 instances, or 25%) ones. However, this prevalence is not as marked as in the discussions of each phenomenon separately, presented in the previous section. More specifically, the children tended to give synthetic and non-naturalistic explanations more frequently than expected in when comparing the two phenomenological situations than when discussing each of them separately, and this difference is statistically significant (x^2=22.4, df=2, p<0.001).

The naturalistic explanations recorded in regards to the comparison of the battery-operated and the spring-operated car movements were mainly combinations of agentive and non-agentive elements (9 instances, or 37.5% of the explanations recorded in response to question group III), followed by agentive explanations (5 instances, i.e. 20.8%). This as well is a –statistically significant– reversal of the tendency recorded in the explanations yielded from question groups I and II, where agentive explanations prevailed (x^2=6.2, df=2, d<0.05).

Discussion and Implications

The results presented in the previous section indicate that a) preschool children can identify the objects involved in the experimental settings used in this study; b) most of them give explanations that designate a developing understanding of physical causality and do not restrict their explanations to animism or teleology; c) such explanations have a pre-energy character since the children are capable of accounting for the two phenomenological situations used in the present study in terms of object chains, mainly from the aspect of their function; and d) some children are able to account for these situations in terms of object chains from the aspect of transfer of an action from one object to the other.

As the results of this study suggest, the vast majority of preschool children are capable of giving naturalistic explanations about the movement of toy cars. On the other hand, the predominance of naturalistic over non-naturalistic, or synthetic explanations in children's reasoning does not imply a general trend, since same age children have not proven as competent in other research contexts (Christidou, 2006; Christidou & Hatzinikita, 2006) concerning plant nutrition or the water cycle. Nonetheless, these outcomes are very encouraging and confirm previous research findings (Christidou, 2006; Christidou et al., 2005) claiming that, even prior to systematic teaching, preschool children have the capacity to handle observation input to generate explanations of the appropriate type, i.e. naturalistic explanations.

As far as the finer distinctions of naturalistic explanations are concerned, it has been observed that the children tended to explain the toy cars movement mainly in agentive terms, that is they attributed the cars' movement to the action of an external agent (battery or spring). This outcome differentiates the present study from previous relevant ones, which indicated that when discussing dissolution, floating, magnetic forces, or the water cycle the children tend to ignore the presence and role of external agents acting on objects and substances, and that they have a difficulty in representing the involved entities as systems of interacting parts (Christidou, 2006; Christidou & Hatzinikita, 2006). Looking at children's prevalent agentive reasoning in more detail, i.e. in terms of function and distribution of an action among different components of a system, yields further interesting conclusions. Overall, the participants in this study preferred to account for the cars movement using functional explanations. Distributional agentive explanations were only occasionally used, but their formulation by young children is considered as a very important finding, as it indicates that (at least some) preschool children are capable of constructing representations that can be considered as 'precursor models' of energy transfer.

Therefore, it is reasonable to consider the development of understanding and explaining -as elements of scientific thinking- as teaching objectives of specifically designed activities for the early years of education (Metz, 1991; Fleer, 1993; Venville, Adey, Larkin & Robertson, 2003). More particularly, the results presented here suggest that an attempt to introduce the aspect of energy transfer in the preschool education curriculum could be considered, on the condition that such an attempt is regarded as both socially important and pedagogically feasible. The explanatory performance of the participants in this study does not seem to contradict such an attempt. Apparently the children's explanations are closer to the model of energy chains, according to which the energy content of an object acts on, or is transferred to another object, which results in the emergence of an observed effect (Halbwachs, 1971; Lemeignan & Wei-Barais, 1993, 1994; Tiberghien & Megalakaki, 1995; Koliopoulos & Ravanis, 2000). Indeed, the outcomes of this study suggest that a teaching strategy of developing a 'germ-model' could be employed in the course of relevant activities in the nursery school. According to this strategy, it is assumed that presenting a conceptual model to children –simple in content and structure and compatible with causal mental representations– it is possible to support learning in a specific field. In the case of teaching energy transfer, such a model could involve simple energy chains, which would interact with pre-energy reasoning (instances of which were presented in this paper) during teaching and become progressively refined and developed according to the teaching objectives set (Tiberghien & Megalakaki, 1995; Devi, Tiberghien, Baker & Brna, 1996; Koliopoulos & Ravanis, 2000).

Further research should be carried out not only to broaden the existing knowledge about the pre-energy reasoning in preschool children (for example by broadening the phenomenological fields of application of this reasoning, by investigating the children's possible cognitive obstacles that should be overcome in order to formulate pre-energy reasoning, etc.), but also to test the hypothesis that it is possible to introduce energy-related themes in science activities addressed to preschool children.

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Appendix

Interview scheme and rationale

Questions	***Justification of the question / comments***
Phenomenological situation I	**Movement of the battery-operated toy car**
I. A. Presenting the objects	*Questions to confirm that the children know and name the objects involved in the situation correctly.*
1. What is this? (toy car) 2. What is this? (battery)	
I. B. Asking for predictions	*Questions that may lead to the use of mental representations of the objects in terms of function*
1. What do we need the battery for? 2. How can we find out if there is a battery inside the box without opening it? 3. What should be done in order to move the car? 4. What do you think will happen if I put batteries in the box and let it?	1. Question to check the children's familiarity with batteries. 2. Question possibly leading to an initial explanation of the toy car movement. 3. Question which will help the children who didn't answer the previous questions. 4. Question to check if responses to previous questions were randomly given.
I. C. Asking for justification of the predictions.	*Question that may lead to the use of mental representations of the objects in terms of distribution.*
1. Why do you think this happens?	
I. D. Doing the experiment and asking for explanations	*Questions that may lead to the use of mental representations of the objects in terms of function or distribution.*
1. What happened? 2. Why did this happen? 3. Why didn't this happen without the batteries? 4. What should I do so as to make the car run faster? 5. Why? What does the battery give to the toy car? What is in the battery?	1. Question to yield descriptions of what they perceived. 2. Question to yield explanations of the experimental situation 3. Question to verify that their responses are consistent with the previous ones. 4. Question to verify that their responses are consistent with the previous ones. 5. (If question 4 is answered in terms of pre-energy reasoning) to obtain more information about their way of thinking.

Appendix

Interview scheme and rationale

Questions	***Justification of the question / comments***
Phenomenological situation II	**Movement of the spring-operated toy car**
II. A. Presenting the items	*Questions that certify that the children know and name the objects involved in the situation correctly.*
1. What is this? (toy car) 2. What is this? (spring)	
II. B. Asking for predictions	*Questions that may lead to the use of mental representations of the objects in terms of function*
1. What do we need the spring for? 2. What do we have to do to move the car? 3. What do you think will happen if I press the spring with the toy car against the wall?	1. Question to check the children's familiarity with springs. 2. Question possibly leading to an initial explanation of the toy car movement. 3. Question to check if responses to previous questions were randomly given.
II. C. Asking for justification of the predictions	*Question that may lead to the use of mental representations of the objects in terms of distribution.*
1. Why do you think this happens?	
II. D. Doing the experiment and asking for explanations	*Questions that may lead to the use of mental representations of the objects in terms of function or distribution.*
1. What happened? 2. Why did this happen? 3. Why didn't this happen without pressing the spring? 4. What should I do to make the car run faster? 5. Why? What does the pressed spring give to the toy car? What does the pressed spring have?	1. Question to yield descriptions of what they perceived. 2. Question to yield explanations of the experimental situation 3. Question to verify that their responses are consistent with the previous ones. 4. Question to verify that their responses are consistent with the previous ones. 5. (If question 4 is answered in terms of pre-energy reasoning), to obtain more information about their way of thinking.

Appendix

Interview scheme and rationale

Questions	***Justification of the question / comments***
III. Comparison of the phenomena	*Questions that may lead to the use of mental representations of the objects in terms of function or distribution*
1. What do the battery-operated and the spring-operated car movements have in common? 2. What should I do in order to make the two toy cars run faster?	Questions to check if they consistently use naturalistic reasoning entailing the objects involved in terms of function or distribution.