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Teaching activities for the construction of a precursor model in 5- to 6-year-old children's thinking: the case of thermal expansion and contraction of metals

Konstantinos Ravanis[a], Maria Papandreou[b], Maria Kampeza[a] & Angeliki Vellopoulou[a]

[a] Department of Educational Sciences and Early Childhood Education, University of Patras, Patras, Greece

[b] Department of Early Childhood Education, Aristotle University of Thessaloniki, Thessaloniki, Greece
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Teaching activities for the construction of a precursor model in 5- to 6-year-old children's thinking: the case of thermal expansion and contraction of metals

Konstantinos Ravanis[a]*, Maria Papandreou[b], Maria Kampeza[a] and Angeliki Vellopoulou[a]

[a]*Department of Educational Sciences and Early Childhood Education, University of Patras, Patras, Greece;* [b]*Department of Early Childhood Education, Aristotle University of Thessaloniki, Thessaloniki, Greece*

ABSTRACT: This article presents the results of empirical research on the construction of a precursor model of the phenomenon of thermal expansion and contraction of metals in preschool children's thinking, which is compatible with the model used in science education. The research included 87 children aged 5–6. It was conducted at four stages, during which predictions and explanations for simple cases of thermal expansion and contraction were sought. The discussions with the children demonstrated that a considerable number of preschoolers are able to take advantage of their involvement in the specific teaching processes and construct a stable precursor model of the phenomenon.

RÉSUMÉ: Cet article présente les résultats d'une recherche empirique sur la construction d'un modèle précurseur du phénomène d'expansion et de contraction thermique des métaux dans la pensée des enfants d'âge préscolaire, compatible avec le modèle utilisé dans l'enseignement des sciences. La recherche comprend 87 enfants de 5–6 ans. Elle a été réalisée à 4 étapes, au cours desquelles ont été étudiées des prédictions et des explications pour les cas simples de l'expansion et la contraction thermique. Les discussions avec les enfants ont démontré qu'un nombre considérable d'enfants d'âge préscolaire sont capables de tirer profit de leur implication dans les processus d'enseignement spécifiques et de construire un modèle précurseur stable du phénomène.

ZUSAMMENFASSUNG: Die vorliegende Studie präsentiert die Ergebnisse einer empirischen Forschungsarbeit über den Bau eines Vorläufer-Modells zum Phänomen von thermischer Expansion und Kontraktion von Metallen im Denken von Kindern im Vorschulalter, das kompatibel ist mit dem Modell, das im späteren naturwissenschaftlichen Unterricht verwendet wird. Die Untersuchung umfasste 87 Kinder im Alter von 5–6 Jahren. Sie wurde in 4 Phasen durchgeführt, in denen Prognosen und Erklärungen für einfache Fälle der thermischen Expansion und Kontraktion gesucht wurden. Die Gespräche mit den Kindern haben gezeigt, dass eine beträchtliche Anzahl von Kindern im Vorschulalter in der Lage ist, aus ihrer Beteiligung an den spezifischen Lehr-Prozessen so zu profitieren, dass sie in der Lage sind, ein stabiles Vorläufer-Modell des Phänomens in ihren Gedanken aufzubauen.

*Corresponding author. Email: ravanis@upatras.gr

RESUMEN: En este artículo se muestran los resultados de un estudio experimental sobre la construcción de un modelo precursor de los fenómenos de expansión térmica y de contracción de metales en el pensamiento de niños en edad preescolar. Este modelo es compatible con el modelo empleado en la educación de las ciencias. La investigación se realizó sobre 87 niños de 5–6 años, en cuatro fases, durante las cuales se formularon predicciones y explicaciones para casos simples de expansión térmica y contracción. Las entrevistas con los niños demostraron que un considerable número de preescolares puede beneficiarse de su participación activa en los procesos de enseñanza específicos y construir un modelo precursor estable de estos fenómenos.

Keywords: expansion; contraction; precursor model; teaching activities; kindergarten

1. Theoretical framework

In the last 20 years the three distinct fields of Early Childhood Education, Science Education and Developmental Psychology, have displayed a strong research tendency to study the construction processes used by 4- to 8-year-old children's thinking for the phenomena of the natural world and natural science concepts. Thus the question of the construction of mental representations in young children's thinking regarding the natural world seems sufficiently studied from a didactical, psychological and epistemological point of view (Piaget 1975; Rayna, Sinclair, and Stambak 1982; Karmiloff-Smith 1992; Baillargeon 2000). Research in this area, and also the various teaching strategies, can be categorised into three theoretically distinct groups (Ravanis and Bagakis, 1998): those based on empiricist ideas of learning, those arising from the Piagetian paradigm, and, finally, those which combine both post-Piagetian and Vygotskian views of learning in a sociocognitive or a sociocultural perspective.

In this context, various research questions are posed, whose investigation requires that the research conducted involve and lead to interdisciplinary approaches created with the contributions of all three fields above. Thus, the use of different theoretical background, methods and pedagogical practices has shown that young children can approach systematically the natural world and construct in their thinking pre-concepts compatible with those of natural sciences, in several cognitive learning fields of natural sciences, such as biological phenomena (Zogza and Papamichael 2000; Christidou and Hatzinikita 2006; Ergazaki, Saltapida, and Zogza 2010), optical phenomena (Resta-Schweitzer and Weil-Barais 2007; Gallegos-Cázares, Flores-Camacho, and Calderón-Canales 2008; Ravanis 2010), astronomical phenomena (Kampeza 2006; Papandreou and Terzi 2011), properties of matter (Ravanis, Koliopoulos and Hadzigeorgiou 2004; Hatzinikita 2006; Vellopoulou and Ravanis 2010) electric and magnetic phenomena (Tsatsaroni, Ravanis, and Falaga 2003; Papadopoulou and Poimenidou 2008).

The development of educational activities in this direction exploits young children's everyday experiences by means of processes that offer them the necessary tools through which they understand, communicate and interact with nature and, as a result, they acquire new knowledge, competencies and skills. The above mentioned research detects children's ability to form cognitive constructs with constant characteristics, allowing the achievement of an equally constant cognitive performance.

These very elements form a kind of model in children's thinking. Science models used in education are constructions of human thinking, which enable three functions: descriptions, explanations and predictions compatible with scientific models (Genzling and Pierrard 1994). All three functions require the use of common reference frameworks, tools and descriptors. However, according to relevant research (Ravanis, Koliopoulos, and Boilevin 2008), it is extremely difficult for the children, during their developmental stages, to become familiar with all the characteristics necessary for these three functions. Indeed, when children approach the natural world, they come up against multiple empirical, cognitive, psychological and logical obstacles. Therefore, when they are engaged into relevant teaching processes, they organise cognitive constructs for approaching phenomena, and formulating reasoning and thinking. These constructs remain constant in the different situations and are compatible with those of natural sciences. Such cognitive constructs are called 'precursor models' and their construction is considered a precondition for the scientific literacy that may follow (Weil-Barais 2001). Precursor models keep some basic characteristics from those recognised in mental models by different currents of Cognitive Psychology, for example the stable structure and the possibility to be used in different situations. However, the nature of precursor models does not refer solely to children's or more generally human's thinking – like mental models – but furthermore to school science (Resta-Schweizer and Weil-Barais 2007; Ravanis 2010).

The way in which children of different ages understand the phenomenon of thermal expansion and contraction of metals is not extensively studied. Although this phenomenon offers easy experimental confirmation at macroscopic level and, as a readily observable result, is of empirical interest, its explanation pertains to the changes in the complicated movement of the structural elements of the microcosm, a significant obstacle for the understanding of this phenomenon even for older children (Lee et al. 1993; Gómez Crespo and Pozo 2004). Therefore, the relevant research is mainly focused on studying the representations at microscopic or macroscopic level and the introduction of teaching interventions achieving cognitive progress. However, the younger the children, the more difficult it is for them to construct in their thinking an interpretative pattern fully compatible with the scientific model; thus, the concept of the precursor model can exemplarily be implemented here. Working with children aged 11–12, Lee et al. (1993) found that their original ignorance of the phenomenon is easily dealt with at macroscopic level, while the obstacles remain serious when the discussion turns to microscopic level. In other words children can easily understand heating/cooling as the cause of metal expansion/contraction but they can hardly provide explanations based on the molecular movement. Gómez Crespo and Pozo (2004) stress the fact that students between 12- and 18-years-old are able to use microscopic terms in their discussions on the phenomenon, but their interpretations are often confined to attributing macroscopic properties to microcosmic particles; that is they consider particles' movement to be like the movement of a small sphere in everyday life, which is obviously approached with totally different models. According to similar research findings, Solomonidou and Kalantzis (2008) construct a digital microcosm on which they work with children aged 13–14 years. The systematic work that was based on the specific obstacles encountered by the pupil led several children to adapt their thinking to the scientific model. There is only one relevant research paper dealing with the issue of thermal expansion in preschool children (Ravanis, Antoniou, and Nasti 2000). In this research, children's prior knowledge of the phenomenon was studied during a pre-test with the use of a metal sphere. Having identified children's relevant difficulties, a teaching intervention took place, which consisted of an experiment for expansion and contraction of metallic bodies using two materials, a metal sphere and a metal bar, along with an analogy from children's everyday experiences of heat and cold. Finally, a meta-test was carried out using a metal disc. The research results showed that children of 5- to 6-years-old are able to approach the phenomenon but it was difficult for the researchers to discern whether this effect was due to the use of the analogy or due to the use of the systematic experimentation, since children's responses during the meta-test did not confirm any systematic or stable reasoning based on the utilisation of the analogy.

In the present article we studied the progress of children's thinking regarding descriptions, predictions and explanations of the phenomenon of thermal expansion and contraction of metal materials during a systematic sequence of educational activities, as well as the influence of these activities on the construction of a precursor model of this phenomenon.

2. Methodological framework

2.1 *Sample*

The research sample included 87 children (42 boys and 45 girls) with an average age of 5 years and 3 months (S.D. 2 months), from eight classes of six public kindergartens. The children were randomly sampled among those willing to cooperate. The children that took part in the research had not previously attended any organised teaching activity on the phenomenon of thermal expansion and contraction.

2.2 *Material*

In order to study volume expansion, we used a metal sphere hanging from a chain, which at ambient temperature scarcely passes through a ring, while when it is heated it cannot pass (Figure 1). A small portable gas stove was also used for heating the metal sphere, as well as a pot of water at ambient temperature for cooling the sphere.

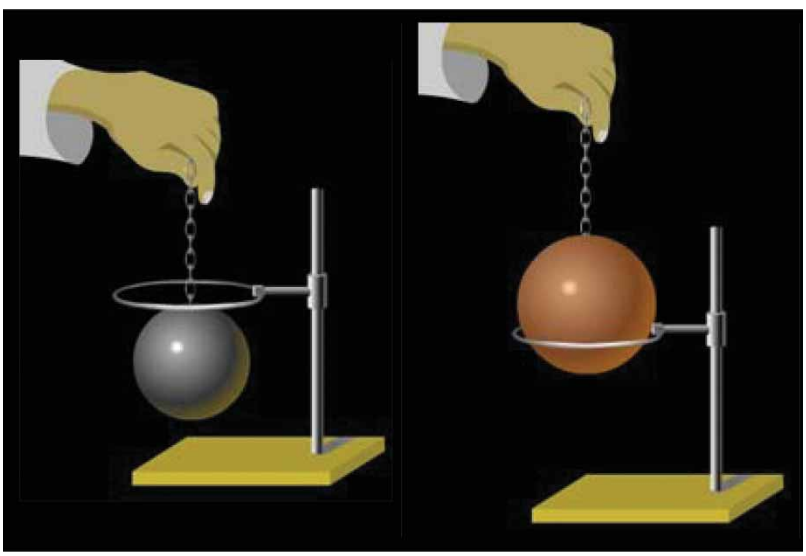

Figure 1. Schematic representation of the thermal expansion and contraction of metals.

2.3 *Design*

The research consisted of four stages. Children–researcher interactions included descriptions and predictions of the phenomenon as well as explanations of their reasoning. The semi-directed individual interviews between the researchers and the children were taped-recorded and special protocols including non-verbal reactions were also filled.

At the first stage we detected whether the children had any empirical mental representations of the phenomenon of thermal expansion. The children were provided with the metal sphere, were encouraged to check if it can pass through the ring and describe what was happening. After they found it possible, they were asked to predict if the sphere would once again pass through the ring when heated intensely by the gas flame: 'If we heat this sphere intensely, will it pass through the ring?' Then the children were asked to explain their reasoning, and a discussion followed aiming to make children's thinking explicit.

At the second stage, after the sphere was heated by the flame, the children were asked to watch carefully and to describe 'what happens?' (it cannot pass through the circular opening) and after that to explain 'why is this happening?' aiming at finding whether and how they connect heating with the expansion of materials.

At the third stage of the research, the children were asked to predict whether the sphere would pass through the opening 'after it is cooled inside a pot of cold water' and to explain their responses.

At the fourth stage, after the sphere was cooled in a pot of water and we all found that it once again passed easily through the opening, the children were asked to provide their descriptions and explanations for this change.

2.4 *Criteria of evaluation*

The analysis performed follows the four stages of the experimental process. At all process stages, children's responses are classified into three categories: sufficient, intermediate and insufficient.

(a) *Sufficient* responses are those provided by children who predict and explain changes (expansion or contraction of the sphere), associating them with temperature fluctuations on a qualitative scale (major-minor), that is to say, in the way these changes can be appreciated by children of this age.
(b) *Intermediate* responses are those provided by children who make correct predictions referring to a kind of change associated with temperature, although their explanations fail to convey changes occurring in mental representations of expansion or contraction.
(c) *Insufficient* responses are those provided by children who fail to offer correct predictions and when the children are asked to give explanations after the experimental activities, they do not express concrete ideas.

3. Results

The data collected during the four stages of the research process is presented below. Categories and frequencies of responses as well as typical examples of children's thinking are presented.

3.1 *First stage: predictions about the sphere passing through the ring after it has been heated*

At first the children tried themselves and confirmed that when the sphere is at ambient temperature, it passes through the ring. Then they were asked for their predictions as to whether in case the sphere was heated, it could still pass through the opening. They were also asked to provide their reasoning about their predictions. Three categories of responses resulted from the discussion held on children's original predictions.

(a) *Sufficient*. Four children predict that when the sphere is heated, it will not be able to pass through the ring. They say, for example, 'It will swell because of the fire and will not pass through…it will be bigger, not like it was before' (Subject 58); '…it will not pass through because it will have become fatter due to the heat…when heated, it becomes larger.… I have seen it happening in our kitchen' (Subject 68).

(b) *Intermediate*. This category includes the responses of 20 children who predict that the sphere will not be able to pass through the ring after it is heated, though no reference to expansion is made. They say, for example, 'It will not pass… not now… [Researcher: Why not now?]. It is changing and it can't happen… [R. What is it that is changing?]. It is changing; I don't know what else is happening...' (S. 14). 'When we heat it, it will find difficulty in…it won't be able to pass through the ring… [R. Why?]. Because we have heated it' (S. 75).

(c) *Insufficient*. This category includes the responses of children declaring 'I don't know' (four subjects) and of children predicting that the sphere will pass through the ring (59 subjects). The latter's responses show that they do not attach any importance to the sphere being heated. They say, for example, 'It will pass…just like it passed before' (S. 40), 'In the way I put the sphere before, I am going to put it now…' [Researcher: I say, is there a case of anything changing now that we have heated it?)]. No, nothing changes…it will pass even though it is heated' (S. 86).

3.2 *Second stage: explanations concerning the inability of the sphere to pass through the ring after it is heated*

After we heated the sphere and, together with the children, tried to pass it through the ring, we realised that this was impossible and, therefore, we challenged them to explain the phenomenon. The discussion with the children after the experimental process led to the classification of the responses into three levels.

(a) *Sufficient*. The category includes the responses of 44 children. Among them are the four children that provided sufficient responses at the first stage. Furthermore, the confirmed predictions of the children that were previously classified into the intermediate category (b) now seem to lead them to integrate their empirical data in their thinking, thus identifying the heating of the sphere as the cause and its expansion as the effect. Finally, the inconsistence between the original predictions of the children whose responses during the first stage were classified in the third category (c, '*insufficient'*) and the result of the experimental process of the second stage leads several of these children to a sort of cognitive conflict. They say, for example, 'Since it cannot pass through, it has swollen…' [R: Why?]. 'I guess because we have heated it…it seems that it has swollen because we have heated it…' (Subject 47), 'While we are burning it, it becomes hotter and swells. I mean…as if it became fatter because of the heat…' (S. 69).

(b) *Intermediate*. The category includes the responses of 31 children, where once again the reasoning formulated shows that they do not realise that the expansion of the sphere is due to heating. They say, for example, 'The ball stuck…when we heated it…it stuck into the circle…' [R. Why did it stick?]. 'Because it became very hot' (S. 66). 'Just like I told you before…it won't pass if we overheat it…' [R. Why?]. 'Since it burns, it cannot pass' (S. 73).

(c) *Insufficient*. Here are 12 responses of children stating 'I don't know' and some completely vague responses. They say, for example, 'Because we put it there, it cannot pass…' [R. But when you tried before, you passed it…]. 'I passed it before, but now it's impossible…it does not always pass' [R. Why?] 'I don't know' (S. 61).

3.3 *Third stage: predictions about the sphere passing through the ring after it has been cooled*

At this stage we studied children's reversible thinking and, therefore, the children were asked to provide predictions and explanations as to whether the sphere will pass through the ring when we cool it by immersing it into a glass of cold water. The discussion with the children following the initial question led to the classification of children's responses into three categories.

(a) *Sufficient*. At this stage 35 children use effectively the reversible reasoning, according to which they predict the contraction of the sphere by cooling. They say, for example, 'What if we cool it? … It should pass if it is cooled again…it becomes once again smaller, as it was when I passed it through… in the beginning' (S. 9). 'It will pass through again…because it has cooled and is smaller' (S. 64).

(b) *Intermediate*. This category includes the responses of 37 children, with the children predicting that the sphere will pass through the ring after it is cooled, although they do not refer to contraction. They say, for example, 'It will pass through when it cools again…now it is cold as it was before…' [R: Why should it pass now?]. '…when it becomes cool, it passes through the ring' (S. 53).

(c) *Insufficient*. Fifteen children are not able to predict the result of the cooling of the sphere. Two of them answered 'I don't know'. The rest of the children providing insufficient responses seem to remain adhered to the preceding empirical observation and, therefore, answer that the sphere will not pass through the ring. They say, for example, 'Now it cannot pass… should I try? (Researcher: Why do you think it won't pass?). Because you tried before and the ring stopped it…' (S. 54).

3.4 *Fourth stage: explanations concerning the ability of the sphere to pass through the ring after it is cooled*

After we cooled the sphere, the children were asked to try to pass it through the ring; they found that once again this was possible. During the ensuing discussion with them, we tried to find whether and in what way they represent the inverse process of the sphere passing through the ring after it is cooled in their reasoning. We classified children's responses into three (3) categories.

(a) *Sufficient*. This category includes the responses of 52 children. Several children had already from the previous stage formed in their mind the schema 'heating-expansion/cooling-contraction.' On the basis of this schema they had been able to predict and firmly describe the behaviour of the sphere during the previous stages. Furthermore, there are some children who, although in the previous stage had correctly predicted that the sphere would pass through the ring, after the sphere was cooled they did not mention of the sphere's contraction. It is likely that a considerable number of these children are led to form a schema concerning contraction caused by cooling, as a result of the completion of the circle of heating and cooling and the relevant empirical data on the sphere passing through the ring. Finally, as it happened in the trial after the sphere was heated, after the sphere was cooled there were children who were led to a kind of cognitive conflict, for their predictions at the third stage, according to which the sphere would not pass through the ring, contradicted the empirical data of the fourth stage. They say, for example, 'It passes… it becomes smaller and passes' [R. Why?]. When we put it into the fire, it swelled and when we cooled it, it became smaller' (S. 30), 'I thought it wouldn't pass but.… I see that…' [R. Why do you think it has now passed?]. I think because you cooled it in the water…when it cools…it seems to become smaller and passes' (S. 24).
(b) *Intermediate*. This category includes 28 responses, in which the descriptions of the sphere passing through the ring are associated with cooling rather than with some kind of change in the sphere's size. They say, for example, 'The ball can now pass because it has cooled…' [R. And what happened to the ball when it was cooled?]. 'It managed to pass' (S. 33). 'When you cooled the ball…the sphere…we can see that it passes once again' [R. Why?]. 'It passes because it is just as it was before, because we have cooled it' (S. 73).
(c) *Insufficient*. This category includes the responses of seven children, who answer either 'I don't know' or provide vague responses, for example, 'It passes if you place it well' [R. Why did it not pass before?]. 'It did not pass before…we did not place it well' (S. 87).

3.5 *The course of children's reasoning*

In the presentation of the results the four distinct stages of the research process were separately discussed. However, of particular importance is also the overall approach towards the course of children's reasoning at the successive stages, because this is a way to conclude whether there are any children constructing a precursor model of expansion and contraction in their thinking, in other words, whether constant cognitive progress was noticed after the first stage.

At first, the X^2 test performed for all three categories of reasoning at every stage (Table 1) shows that this differentiation is also statistically significant ($X^2 = 11.655$, $df = 2$, $p = 0.003$). Therefore, it emerges that the overall experimental procedure of the four stages finally led more children to form sufficient and intermediate

Table 1. Frequencies of pupils' representations ($n = 87$).

Representations	Stage 1 Subjects	f	Stage 2 Subjects	f	Stage 3 Subjects	f	Stage 4 Subjects	f
Sufficient	3, 58, 68, 80	4	1, 2, 3, 4, 5, ,9, 12, 13, 14, 15, 17, 18, 20, 22, 25, 26, 27, 30, 34, 35, 37, 40, 46, 47, 51, 52, 55, 56, 57, 58, 59, 60, 62, 63, 68, 69, 70, 74, 75, 79, 80, 84, 85, 86	44	1, 2, 3, 4, 5, 9, 13, 14, 15, 20, 22, 25, 26, 27, 34, 38, 40, 47, 56, 57, 58, 59, 60, 63, 64, 67, 68, 69, 70, 72, 74, 75, 80, 84, 86	35	1, 2, 3, 4, 5, 6, 9, 11, 13, 14, 15, 16, 18, 20, 22, 24, 25, 26, 27, 30, 34, 37, 38, 40, 41, 42, 47, 49, 55, 56, 57, 58, 59, 60, 62, 63, 64, 65, 67, 68, 69, 70, 72, 73, 74, 75, 79, 80, 82, 84, 85, 86	52
Intermediate	1, 2, 5, 9, 13, 14, 18, 20, 22, 25, 28, 30, 37, 47, 51, 59, 60, 70, 75, 84	20	6, 8, 10, 11, 16, 19, 21, 24, 28, 29, 32, 36, 38, 41, 42, 43, 44, 49, 50, 53, 64, 66, 67, 71, 72, 73, 76, 78, 81, 82, 83	31	6, 8, 11, 12, 16, 17, 18, 19, 21, 24, 28, 29, 30, 32, 35, 36, 37, 41, 42, 43, 44, 46, 49, 50, 51, 52, 53, 55, 62, 65, 66, 71, 73, 78, 79, 83, 85	37	8, 10, 12, 17, 19, 21, 23, 28, 29, 32, 33, 35, 36, 39, 43, 44, 46, 48, 50, 51, 52, 53, 66, 71, 77, 78, 81, 83	28
Insufficient	4, 6, 7, 8, 10, 11, 12, 15, 16, 17, 19, 21, 22, 23, 24, 26, 27, 29, 31, 32, 33, 34, 35, 36, 38, 39, 40, 41, 42, 43, 44, 45, 46, 48, 49, 50, 52, 53, 54, 55, 56, 57, 61, 62, 63, 64, 65, 66, 67, 69, 71, 72, 73, 74, 76, 77, 78, 79, 81, 82, 83, 85, 86, 87	63	7, 23, 31, 33, 39, 45, 48, 54, 61, 65, 77, 87	12	7, 10, 23, 31, 33, 39, 45, 48, 54, 61, 76, 77, 81, 82, 87	15	7, 31, 45, 54, 61, 76, 87	7

representations than those that formed insufficient representations. As a result, it may reasonably be supposed that this procedure facilitated the evolution of children's reasoning.

Then we identified groups of subjects whose responses remain invariable during the different stages. The two step cluster analysis we performed shows that three groups of children's cognitive performance are formed.

- The first group includes 14 children, which after the first stage continue using mainly insufficient or, more rarely, intermediate representations.
- The second group includes 37 children, which provide responses classified as intermediate representations.
- The third group includes 36 children, which, after the first stage, provide responses resulting from sufficient representations. Four of these children provided sufficient responses even at the first stage and, therefore, it can be concluded that the remaining 32 made a constant cognitive progress while processing the experimental data of the second stage.

The last group includes the children that seem to be able to construct in their thinking a precursor model which they handle with remarkable invariability during the different stages of the research process.

4. Discussion

The present study investigated the possibility of introducing structured activities that may be incorporated into the framework of integrated curricula which aim at the construction of a precursor model of thermal expansion and contraction of metals in 5- to 6-year-old children's thinking. At first, we realised that children of this age are able to approach these phenomena within the framework of a systematic teaching intervention. The precursor model they construct allows them to describe and predict these phenomena, to explain their reasoning in a way compatible with the model used in education concerning the specific phenomenon. Moreover, in the cognitive repertoire of at least 36 subjects of the third group, both phenomena, the expansion and the contraction, are identified as inverse, as long as the first is associated with heating an object and the second with cooling it. In other words, a kind of reversible reasoning is achieved. As mentioned above, at the second and third stages almost half of the children are able to describe the change and explain their reasoning, based on the heating of the sphere, or predict the contraction and explain their reasoning, based on the cooling of the sphere, while at the fourth stage, 52 out of the 87 children (which is more than six out of 10) provide a sufficient response.

The question is where this cognitive progress occurring in children's thinking comes from. In contrast to Ravanis, Antoniou and Nasti (2000) research results, which were not explicit as to whether and how the activation of analogical thinking and the selected experimental settings influenced children's reasoning our results established that the teaching support offered to children's mental processing of the suitable empirical data was the 'heart' of the experimental activities. Indeed, at the early second stage, when the sphere was heated and the children were challenged to interpret its inability to pass through the ring, we observed that a large number of children are led to the formation of a satisfactory precursor model for the phenomenon. As a matter of fact, because their responses later improved, we may reasonably suppose that this model is established and expanded through further experimental processes. Indeed, the sharp disagreement between the result obtained after the sphere was heated (second stage) and the original children's predictions (first stage) sets the preconditions for a cognitive conflict, which, with the help of the researcher's suitable questions, enables the children to construct mental associations between heating and the expansion of the material, that is to say, associations that originate from experience and later go beyond it as they afterwards allow a reversible reasoning concerning predictions and explanations for contraction as well. Precisely for this reason several children predict the association between cooling and contraction without the need of experimental confirmation. On the contrary, other children who do not predict this relation (third stage) failed to provide sufficient responses even after they had observed the experiment (fourth stage). It seems that the experimental procedure and the individual interviews did not provide the ideal conditions for these children in order to unfold their ideas and to enable the development of their cognitive reasoning (Papandreou and Terzi 2011). This failure should direct us to the development of relevant educational activities that will utilise different didactic strategies.

On the whole, the findings of this research paper, which is part of wider research projects aiming at the empirical study of the conditions under which preschool children are initiated into properties and phenomena of the natural world and science concepts, lead us to formulate some broader working hypotheses. A first finding concerns the cognitive readiness of the children when they approach natural phenomena and concepts. As long as we agree that the cognitive development of the children is also important within the framework of preschool education institutions, from an educational point of view there is still an important issue not dealt with herein but already supported by other researches, namely the development of relevant science learning activities corresponding with both the research results and the limits of the actual work framework in the kindergarten (Resta-Schweitzer and Weil-Barais 2007; Kampeza and Ravanis 2009; Ergazaki, Saltapida, and Zogza 2010; Papandreou and Terzi 2011).

In the present research, the methodological design was not developed in a sequence of teaching interactions focusing on children–teacher interaction, as usually suggested in recent years according to the current socio-cultural or socio-cognitive approaches (Fleer and March 2009; Robbins 2009). In our study the focus was placed mainly on the successive stages of science activities aimed to systematically elicit the reasoning formulated by the children on the association between the factors of heating or cooling a metal and the expansion or contraction of the metal, while communication issues were not emphasised. In other words, we studied not only descriptions, predictions and explanations offered by the children before and after the phenomenon of expansion and contraction, but also the course of their reasoning while they predict and observe the expansion and the contraction, and later verify or falsify their prediction and explain the observed changes.

This choice, namely approaching children's course of reasoning, is always the base for developing science learning activities. Such findings can be later integrated and exploited by a broader instructional design. In this educational perspective and in combination with the findings of other research mentioned above, it seems that thermal phenomena are a privileged field for empirical reference when working with preschool children.

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