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The transformation of children's mental representations of 5-6 year olds for coagulation: precursor models through a storytelling approach

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Abstract. The current study presents the results of a qualitative research on the mental representations of children aged 5-6 years regarding the coagulation of everyday materials. Initially, children's representations on coagulation of butter and chocolate were studied in a pre-test through three different tasks. Subsequently, a teaching intervention was implemented based on a storytelling approach, which is embedded in a socio-constructivist perspective with the aim of establishing a precursor model in children's thinking about coagulation. Finally, in a post-test, children's representations after the teaching intervention were studied. The results of the research showed that children have made significant progress in the post-test as the majority of them recognize cooling as a factor in the coagulation of the above materials.

1. Inroduction

The issue of introducing children aged 3-8 years to the phenomena of the natural world has been studied in recent decades by a raising field of research known in the academic literature as Early Childhood Science Education [1–6]. Along this context a long series of research in different cognitive fields such as astronomy [7], plant growth [8], human body [9], state of matter [10], electricity [11], floating and sinking [12], have been carried out with the aim of capturing the initial children's mental representations, their distance from school scientific knowledge, the obstacles encountering by children's thinking regarding the transformation of these representations as well as effective processes for developing teaching activities and learning. The issue of identifying naïve representations is important because it enables us to obtain an initial mapping of early forms of thinking. However, since representations are unstable entities usually at odds with school scientific knowledge due to some systematic barriers of children's thinking, the research was led to overcome these barriers [13–17].

In recent years, especially for the level of early childhood education, narrative and storytelling approaches are often used in the development of teaching activities that create a favorable environment as they stimulate the interest of young children and favor learning [18–22]. Along

this direction, it was found that through specialized teaching interventions, young children are able to construct mental entities about natural phenomena that are compatible with certain characteristics and functions of school scientific knowledge such as the description and prediction of the evolution of phenomena. These entities, which show stability in different settings and utilize the same criteria for formulating arguments and reasoning, have been called precursor models and in recent years have been objects of systematic research [23–26]. In the current study we present an attempt to construct a precursor model for the phenomenon of coagulation with 5–6-year-old children.

The conceptualization of thermal phenomena is a well-developed field of research in Early Childhood Science Education. Indeed, since many physical changes frequently encountered in everyday life are accomplished by simple states of heating or cooling of materials, thermal phenomena are a favorable area for initiating young children into the world of Physics. The main part of the relevant research is related to the study of young children's mental representations of changes in state of matter. However, relevant research on children of early childhood education ages is scarce and is often confined to the water cycle in nature or to particular changes of state.

In a series of studies on the conceptualization on evaporation and condensation, the findings have highlighted important limitations associated with aspects of "prelogical" thinking that typically dominate children's intelligent at this age [27]. Thus, young children do not recognize that the amount of water is conserved and therefore the representation that water ceases to exist occurs frequently, while at other times they believe that water that has become water vapor is stored in various places such as furniture or soil [28–31]. Based on these findings, attempts were made to construct teaching activities aimed at transforming these representations. In research with this orientation, teaching environments were designed in which young children were shown to be able to approximate the changes from the liquid to the gas phase and vice versa, as they were assisted by certain centrations in the setups in which the simple experiments were carried out. For example, the bubbles during boiling and their movement from bottom to top or the observation of the transition of water vapor from the containers to the air, allow the transformation of their mental representations [32–34].

Research related to melting and coagulation in early childhood education context is clearly limited. In particular, in research conducted through the process of prediction and confirmation in experiments of state changes with everyday materials such as ice cubes and chocolate [33] it was highlighted the ability of very young children to recognize that changes in the "hardness" of solids and the "fluidity" of liquids are due to heating and cooling. In another study, both children with learning disabilities and typical development children were asked to make estimates of melting and coagulation in a specially created digital environment. The results showed that the majority of children of both groups made correct predictions [35]. Similar data was recorded in another study in which children participated in a special inquiry-based learning sequence. After completing this process, the vast majority of children were able to link the ice with water, to identify that ice is a form of water, to understand why and how ice becomes water and to solve real-life problems or other challenges using the new knowledge [36]. In research on the water cycle, simple experiments were used to study melting and coagulation based on children's predictions and explanations [37,38]. Findings of these research highlighted a series of difficulties in children's thinking derived from everyday life. However, through the experimental procedures the possibility of constructing a precursor model was emerged.

The current study presents the research findings on coagulation in the thinking of children aged 5-6 years. The ability of children of this age to deal with this phenomenon has been established both in studies that aimed to capture mental representations [33, 35] as well as in other studies that investigated the issues of constructing a precursor model for water state changes in young children's thinking [37, 38]. The innovative element of this research is the attempt to utilize a storytelling approach to construct a precursor model. This choice was

made not only because it enriches the teaching perspectives, but also because it is consistent with the context of pedagogical practices that are often adopted in preschool education classroom. Specifically, having explored children's mental representations, a storytelling teaching intervention was implemented in order to overcome the difficulties identified. Thus, the following two research questions were formulated:

1. What are the mental representations of pupils on coagulation?
2. After a storytelling teaching intervention, were the children's mental representations transformed into a precursor model compatible with school knowledge?

2. Methodological framework

2.1. Research design

The current research is qualitative in nature and was conducted in three sub-sequent phases: the pre-test, the teaching intervention and the post-test [39,40]. Data in the pre- and post-tests were collected through individual semi-structured interviews. During the pre-test, children were asked for predictions and explanations in three tasks. The two of them were related to the coagulation of a cube of butter in liquid form which was observed melting on a gas stove while the third task was related to the coagulation of a melted chocolate which was also observed melting on the gas stove. Based on the findings of the pre-test, after two weeks period, a teaching intervention took place in which the issue of water coagulation in the natural environment under conditions of strong cooling was highlighted through the narration of an improvised fairy tale. In the post-test, two weeks after the teaching intervention had taken place, the same tasks that were given in the pre-test were presented to children who were asked for predictions and explanations.

The research was conducted in 6 kindergarten classes in an urban area of the city of Patras (Greece). The implementation of the pre- and post-test took place during the winter period in a special area of the schools outside the classroom. The teaching intervention took place in the same school areas in groups of 4-5 children. All the discussions with the children were recorded and the analysis was done from the transcripts. Non-verbal behaviours were also recorded through the use of a specific written protocol. The children's responses were classified into the same categories for the pre- and post-test and their data were studied comparatively.

For the current research, the consent of the children's parents was requested according to The Ethics Committee of the Department of Educational Sciences and Early Childhood Education of the University of Patras approved the study and consent procedures (the approval No: 4 / 21.2.2022)

2.2. Participants

In the current study participated 99 children (47 boys and 52 girls) with a mean age of five years and five months (S.D. 2 months). A large number of children aged 5-6 years old, that were enrolled in Greek primary schools, were invited to play with the researcher and listen to a story. Those who responded positively to this invitation were finally included in the research sample.These children had not come across to any school activity related to state of matter changes.

2.3. Task in the pre- and post-test

Three tasks were used to explore children's representations of the coagulation of two everyday materials.

Task 1. We put a cube of butter on a metal tray and then we place that tray on the flame of a camping gaz. We also put half of the amount of melted butter on a plate which we place on a table in the room. We ask the children to tell us whether the butter will stay

hard as it was before heated or stay melted as it appears after heating as soon as it we let it outside during the whole cold night.

Task 2. We put the rest of the melted butter in another dish which is placed in the fridge. We ask the children whether the butter will remain as hard as it was before we melted it on the fire, or it will stay melted as soon as we take it tomorrow out of the fridge.

Task 3. We put a piece of chocolate in a transparent container and heat it in the camping gaz until it liquefies. We ask the children to tell us whether we will be able to drink the melted chocolate tomorrow morning as soon as we let it in the classroom during the whole night.

2.4. The teaching intervention

Based on the pre-test findings, a storytelling teaching approach was designed and implemented. Since the important issue that emerged was the difficulty in recognizing the role of the environment as a cooler system compared to a liquid in that environment, a story was created in which the main idea was that the environment can resemble a large refrigerator.

The narrative begins with a very cold winter day in a house near a lake. The parents of a disobedient child have forbidden him to take the boat in the cold afternoon and go for a ride on the lake as the whole family used to do together, because at night the air in the lake is cold as it is in the refrigerator and its water is likely to turn into ice. The child disobeys the parents because he did not believe that the water in the lake will turn to ice. He secretly took the boat and went into the lake. When the sun went down it started to get very cold, and the child felt like he was in the refrigerator. The water froze, the boat got stuck in the ice and could not move forward or backward. After many hours in the lake, the parents searched for the child and with large fires melted the ice and the boat became unstuck. When the parents scolded him for disobeying, he apologized telling them that he could not believe that the air in the lake around the boat would be as cold as the refrigerator to cause the water to freeze.

The narrative was dialogic and interactive in nature. The researchers answered every question and built on every observation made by the children, with the emphasis given on the relation between cold air and refrigerator. During the discussion the children were shown pictures of trapped boats in frozen lakes (figure 1).

Figure 1. Boats on frozen lakes.

2.5. Data analysis

The children's responses, which correspond to different mental representations, were classified into three distinct categories based on their distance from the school scientific knowledge. In particular, they were classified into the following three categories: (a) sufficient, (b) intermediate

and (c) insufficient. In 'sufficient' category were classified those responses that were compatible with school scientific knowledge, i.e. attribute coagulation to cooling. Answers in which the children's reasoning had shortcomings or contradictions were characterized as 'intermediate'. Finally, answers that had nothing to do with school scientific knowledge were described as 'insufficient'.

The analysis and classification of responses before and after the teaching intervention were evaluated by two different researchers, among whom there was more than 90

3. Results

The frequencies of children's responses to the three tasks in the pre- and post-test as well as the categories of responses along with typical examples that were given by the children are presented below. Children were numbered from 1 to 99. It should be noted that as there were found no differences with regard to children's gender, the presentation refers to the whole sample.

Table 1 presents the results in all three tasks for the pre- and post-test.

Table 1. Frequencies of pupils' responses.

	Task 1		**Task 2**		**Task 3**	
	Pre-test	Post-test	Pre-test	Post-test	Pre-test	Post-test
Sufficient responses	–	51	17	76	4	69
Intermediate responses	31	19	73	21	56	20
Insufficient responses	68	29	9	2	39	10

3.1. Responses to Task 1: the melted butter in the environment

Children's responses to Task 1 were classified into three categories.

Sufficient responses. Here were classified those responses in which it was recognized that the butter will congeal during the cold night. Quite interestingly, sufficient responses were obtained only during the post-test. For example, Student 33 (S33), post: '*The butter will become hard again as it was before we melted it in the fire...* [Resesarcher (R): Why? How do you think that?] *... It will cool down during the cold night'.*

Intermediate responses. Here were classified those responses that while acknowledged that the melted butter will get cool, they did not link cooling to possible coagulation. For example, S71, pre: '*If left overnight in the classroom the butter will get very cold... It's cold in here in the morning when we come in...*'.

Insufficient responses. Here were classified those responses that did not referred to the thermal condition of the environment at all. For example, S4, pre: '*There will be butter on the table. In the morning we will take it from there... that's where Maria sits...*'.

3.2. Responses to Task2: the melted butter in the fridge

Children's responses to this Task were also classified into three categories.

Sufficient responses. Here were classified those responses that acknowledged that the butter would congeal when placed in the fridge. For example, S54, post: '*The butter will freeze in the fridge... it will turn to stone...*'.

Intermediate responses. Here were classified those responses that while acknowledged that the melted butter will cool, they did not make any reference to coagulation. For example, S11, pre: '*In the refrigerator the butter will cool down a lot... but I am not sure if it will get hard like before...*'.

Insufficient responses. Here were classified those responses that did not refer to the cooling of butter at all. For example, S47, pre: '*In the fridge it will stay the same... (R: Why?) ... I don't know...*'.

3.3. Responses to Task 3: the melted chocolate in the environment

Children's responses to this Task were also classified into three categories.

Sufficient responses. Here were classified those responses that acknowledged that that the chocolate will congeal as soon as it would be left in the cold environment. For example, S54, post: '*We won't be able to drink the chocolate... it will become normal chocolate again in the cold. Then we can eat it*'.

Intermediate responses. Here were classified those responses that while acknowledged that chocolate will cool, they did not make any reference to coagulation. For example, S70, post: '*The chocolate will freeze during the night... your throat will get cold when you drink it in the morning.*'

Insufficient responses. Here were classified those responses that did not refer to chocolate cooling. For example, S82, pre: '*The chocolate will be a hot drink...* (R: The next morning will be a hot drink too?) ... *Less, since it's been so long*'.

4. Discussion

In the current qualitative research, mental representations of 5-6 years old children about coagulation as well as the possibilities of their transformation after a storytelling teaching approach were studied.

With the first research question we tried to record the various mental representations of young children in three different settings. The research data highlighted the difficulty of children to conceptualize coagulation phenomena, a fact that is in line with the limited international literature in this area [33, 35]. This particular difficulty was not only confined into situations where coagulation occurred in the physical environment, as in Task 1 and 3, where it was almost impossible for children to conceptualize it as a source of receiving the heat to which the coagulation of butter and chocolate took place. In contrast, it was also found in Task 2 where the source of cooling was a well-known machine from everyday life such as a refrigerator. Indeed, as it was found only 17% of the children recognized that in the fridge the liquid butter will transformed into the solid state.

In the second research question, an attempt was made to capture the effect of the storytelling teaching intervention on children's mental representations. Evidently, engaging children in storytelling had a significant effect on their thinking since more than half of them associated in each task cooling with coagulation. In particular, in Tasks 1 and 3, almost 51% (vs. 0% in the pre-test) and 70% (vs. 4% in the pre-test) of children recognized that both melted butter and chocolate will return to their original solid state as soon as they left in a cold environment for a few hours. In Task 2, almost 77% of children (vs. 17% in the pre-test) identified the refrigerator as an environment that causes melted butter to coagulate. This finding is of particular interest as it seems that the function of an appliance that falls within the children's everyday experience begins to act not only as a familiar cooling-preserving/storage space for food, but also as a system involved in thermal exchanges.

The recognition of the refrigerator as a tool that causes coagulation is probably linked to the understanding of the wider environment as a space that has analogies with the refrigerator, since this analogy was reinforced in the narrative by the reference to the air around the boat that was persistently characterized as a refrigerator. However, the consistency of this type of reasoning that was found across all Tasks in the post-test acts as a precursor model in children's thinking as it enables them to predict and describe coagulation processes of liquid materials found in environments to which strong cooling potential is attributed. In this respect, it was

apparent that early childhood children are capable of constituting precursor models regarding liquid coagulation. Indeed, in the relevant literature [37,38], it has been pointed out that through appropriate teaching interventions, young children are able to overcome the obstacles that naïve mental representations create for them and to be led to entities that produce stable reasoning, compatible with school scientific knowledge.

It should be noted here that the precursor model does not include the mechanism of interaction between hot and cold systems, i.e. the issue of thermal equilibrium. The concept of thermal equilibrium requires high abstraction and is combined with heat as a concept and therefore far exceeds the thinking capabilities of children of this age.

The storytelling approach used in this research is an alternative approach to guide young children's thinking to critical transformations. It is one of the several approaches that are based on different socio-cultural aspects of children's everyday life and education, such as the use of play and imagination [41–44], modern digital technologies [45, 46]. In recent years, significant research efforts have been directed along this line, which gradually constitute a broader area of theory, research and pedagogical applications well known as Early Childhood Science Education.

5. Study limitations

The small sample which was consisting of children recruited from a small number of schools, undoubtedly serves as a major limitation of the study. This is also the case for the qualitative approach which was confined into the usage of familiar materials. Undoubtedly, data of quantitative approaches combined with the comparison of children's reasoning between familiar and non-familiar materials will allow to study the stability of precursor models.

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