European Journal of Education Studies
ISSN: 2501 - 1111
ISSN-L: 2501 - 1111
Available online at: www.oapub.org/edu

DOI: 10.46827/ejes.v10i5.4770 Volume 10 │ Issue 5 │ 2023

THERMAL CONCEPTS AND PHENOMENA IN EARLY CHIDHOOD SCIENCE EDUCATION: A LITERATURE REVIEW

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Abstract:
In the current study, an attempt is made to bring together and synthesize research data on the way early childhood children approach thermal phenomena and concepts. In this pool of data, the mental representations of young children, the barriers to the conceptualization of these phenomena and the effectiveness of specialized teaching interventions are highlighted and discussed. Going through a series of empirical studies the paper focuses on critical aspects of thermal phenomena and concepts such as thermal conductivity in solid and liquid materials, expansion and contraction of metals, thermal insulation, use of a thermometer etc. A considerable part of these studies prominently deals with the changes in the state of materials and in particular water and the water cycle in the natural environment. The literature review presented here provides a detailed overview and a classification of these studies as well as highlights the need to foreground the systemic character of phenomena and the unifying character of the concepts when approaching or researching about thermal phenomena in early childhood educational settings.

Keywords: science education, early childhood, mental representations, thermal concepts, thermal phenomena, literature review

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1. Introduction

In the broad field of research on young students' thinking about concepts and phenomena in science and the development of related teaching interventions, an important part of the spectrum covers issues related to thermal phenomena in the natural environment as well as touches upon concepts that were constructed in the context of physics. Thermal phenomena and concepts are very often encountered in children's everyday life as real-life experiences and everyday understandings. For example, children watch vapor coming out of a saucepan when their parents are cooking, experience the melting of snow, or they use insulated lunch boxes to keep their meals warm at school. The spectrum of thermal concepts and phenomena, although encountered frequently in children's everyday life, has a particular complexity and breadth, given that it involves the phenomenology of the macrocosm with the interpretive assumptions for the microcosm, bodies, systems, and their interactions. This complexity evolved historically and gradually condensed into a strong theoretical framework, of which didactic transposition for education is always an important research field.

Early Childhood Science Education, addresses a wide range of issues in approaching phenomena of the natural world such as electricity and magnetism (Calo Mosquera et al., 2021; Kalogiannakis et al., 2015), energy (Koliopoulos et al. 2009), floating and sinking (Canedo Ibarra & Gómez Galindo, 2022; Elmalı & Laçin Şimşek, 2021), light and the phenomena that it causes (Gallegos Cázares et al., 2009; Pantidos et al., 2017), etc. Literature reviews in early childhood science education (Akerson, 2019; Hadzigeorgiou, 2015; O'Connor et al. 2021; Plakitsi, 2011; Ravanis, 2021, 2022; Siry et al., 2023; Trundle & Saçkes, 2015) have provided us with the big picture of the research around thermal phenomena and concepts as part of the research about teaching and science during the early years. However, thermal phenomena have specific particularities as they either have a strong empirical content of physical processes, such as for example the rapid liquefaction during the melting of a material that is intensely heated, or they have a weak perceptual content such as the coagulation during the cooling of liquid materials in the non-visible interior of typical cooling systems such as for example refrigerators. The critical role of these particularities in teaching and learning about thermal phenomena and concepts needs to be better explored and understood as a whole.

The present study seeks to highlight research data on thermal phenomena such as the change of state of materials and especially water, the heat transfer and conductivity in materials, the expansion and contraction of metals, the thermal insulation, and the use of thermometer. Within this data, both mental representations as well as obstacles to young children's thinking are approached. Thus, a conceptual space is created that allows the formulation of hypotheses for more comprehensive approaches, that is, the transition from punctual explorations and teaching activities that emphasize materials and their changes, to broader changes with a common background in which the systemic character of the phenomena and the unifying character of the concepts prevail. In this perspective, the question of the possibilities of a systematic approach and understanding of the transition from discrete changes in the state of water in the water cycle in nature is highlighted.

2. Methodological approach

The literature review was based on the analysis of texts presenting research on the approach of thermal concepts and phenomena by children aged 3 to 9-years-old. The investigation was carried out on the Google Scholar database, covering the last 35 years and limited to research in which purely mental representations were recorded. The papers were selected according to the research topic. The works were approached based on the research object and given that in some cases more than one concept or phenomenon is necessarily addressed, the main dimension of the research questions and findings was selected.

3. Literature review

By examining the relevant literature, we found that it mainly includes a relatively small number of studies with a heterogeneous distribution in terms of research topics. Most of them are related to changes in the state of matter, especially water, while few investigations are carried out in other directions. Therefore, we will present the findings of the analysis at two distinct levels. Firstly, thermal concepts and phenomena that are not directly related to changes in the state of matter. Secondly, thermal concepts and phenomena that are directly related to changes in the state of matter.

3.1. Thermal concepts and phenomena that are not directly related to changes in the state of matter

In the last 30 years, a small number of studies with children aged 3 to 9-years-old dealt with issues such as the heat transfer phenomena, the thermal conduction, the temperature, the thermal expansion and contraction, the thermal insulation, and the use of thermometer. Throughout this range of studies, the difficulties in learning, the barriers to conceptualize the phenomena and in some cases the strategies for overcoming these difficulties are highlighted.

A study conducted by Kaliampos and Ravanis (2019) examined the mental representations of 5–6-years-old children regarding thermal conductivity in metals. Children were asked to make predictions and macro descriptions of phenomena depicted in 3 different tasks during which simple thermal conductivity experiments with everyday and non-ordinary materials were performed. The results of the study showed that the vast majority of children express mental representations that are far from the scientific models used in education. Moreover, many children can make predictions about thermal conductivity without being able to provide explanations. Finally, differences in their ideas about heat conduction were found in familiar and unfamiliar materials used by children. The same results were obtained by Katsidima et al. (2023), who studied how children aged 4-9-years-old with and without learning disabilities approach the phenomenon of thermal conductivity in objects. Similar results with familiar objects are obtained by Paños et al. (2021). After a teaching intervention, it was found that students were able to apply what they had learned to other everyday situations, but they faced significantly greater challenges a year later. In another study, which, among other things, investigated the heat transfer in water, some children were able to state that the water became progressively hotter or colder without providing specific explanations about heating as a process (Pahl et al., 2022). For example, expressions such as 'you have to wait' were interpreted as indicating an understanding that temperature changes are not instantaneous but take some time.

Gerhátová et al. (2021) studied the understanding of the temperature measurement process by 8 to 9-years-old students participated in a learning program with inquiry-based learning activities. This is carried out through a process of group and individual 'guided research' using on-site and remote experiments, as well as electronic study materials. Research data showed that the learning outcomes of these activities are significantly better than those of traditional teaching, because children developed a satisfactory conceptual understanding of temperature. In research on the approach to certain thermal phenomena, working with children aged 4 to 6-years-old with specialised tasks, it was recorded that they do not use the word "heat" or interpret change using this concept, but can relate changes in water temperature to certain phenomena (Pahl et al., 2022). In a similar orientation, Hindarti et al. (2021) found that children aged 6 years can intuitively recognize the importance of different temperatures in everyday phenomena.

Relevant research explored predictions and explanations for simple cases of thermal expansion and contraction of a metallic sphere (Ravanis et al., 2013). Discussions with the children showed that a significant number of preschool children are able to take advantage of their engagement in the different phases of the teaching-experimental process and to construct a stable precursor model for expansion and contraction., i.e., a model compatible with the model used in the school-level Science models (Boilevin et al., 2022). In another study with children aged 4-7-years-old with and without learning disabilities, regarding the extension and contraction of metal objects, a notable percentage of the sample predicted that a metal sphere would not pass through a ring and a metal tube will be elongated after being heated, even though no mention was made of any kind of expansion (Katsidima et al., 2023).

In another research on the study of insulation and the methodological choice of creating theatre play conditions with 5 to 6-years-old children, it was shown that children developed basic arguments to express their thinking about the phenomenon (Fragkiadaki et al., 2021). They also related the phenomenon to the thermal state and temperature changes, identified materials and objects with insulating properties and distinguished them from others with non-insulating properties, and concluded that the use of enhanced insulating materials can lead to better insulation results.

A survey by Kampeza et al. (2016) studied whether children aged 5 to 6-years-old perceive a familiar object such as a classic mercury thermometer as a specialised technological tool linked to thermal exchanges. The interviews with children showed that most of them were not able to distinguish the thermometer as a special technological artefact whose function is linked to thermal processes. In recognition of this difficulty (Cain, 2019), Cain & Lee (2020) created a specialised thermometer, the "Early Childhood Thermometer", which includes designed features that make it easier for young children to read (e.g., distinct measuring boxes).

3.2. Thermal concepts and phenomena that are directly related to changes in the state of matter

The issue of changes in the state of matter in the minds of young children is usually studied in terms of water changes. By attempting a classification of the relevant research, we can distinguish two research orientations. The first includes research that approaches discrete phenomena such as evaporation or melting. In the second orientation, an attempt is made to integrate these discrete phenomena into the study of the water cycle in nature.

3.2.1. Distinct changes in the state of matter

Children between the age of 6 to 8-years-old can understand that when the water boils steam is generated, and the quantity of the water is decreased because steam consists of water, while they refer to scientific notions (Bar & Travis, 1991). However, most children of this age face difficulty to comprehend the phenomenon of evaporation and they are not able to justify this procedure (Bar, 1989). Most children aged 5 to 7-years-old cannot describe the transformation of a liquid into another state of matter, while one-third of the children do not mention water conservation (Russel et al., 1989).

Other research studied the mental representations of children 6 to 7-years-old regarding evaporation and condensation (Tytler, 2000) and the mental representations of young children, 2 to 4-years-old, through a process of predictions and experiments about the change of the matter in daily material (Cruz-Guzman et al., 2017). Similar results were also obtained by Tin (2022) studying water evaporation with 6-years-old children. Quite interestingly, whenever another everyday solid material such as salt is used instead of ice, 5 to 6-years-old children seem to have great difficulty in predicting melting and freezing (Ravanis, 2014).

Ravanis and Bagakis (1998) aimed to record the knowledge barriers that can be found in the children's experienced mental representations about the vaporization of water. More specifically, they conducted interviews with 5 to 6-years-old children, and they found that it is feasible for children of preschool age to approach the change of the matter from a liquid to a gas form.

Acher, Arca and Samnarti (2007) investigated children's, aged 7 to 8-years-old, ideas about changes in the state of matter for continuous materials such as water. Using the 'parts model', the children created a modelling process based on a kind of discrete vision of the material. The children gradually manage to satisfactorily connect the visible continuum of water with an invisible imaginary shape.

Kambouri-Danos et al. (2019) and Ravanis et al. (2022) studied quantitatively and qualitatively the structure of a precursor model that can support the scientific thinking of the children about the phenomena engaged in the water state changes. In this research participated 5 to 6-years-old children and it seemed that a significant number of them were able to structure a stable precursor model that could support the understanding of the states of water.

Karlsson (2017) utilized embodied illustrations to examine the notion of evaporation in preschool children aged 5 to 6-years-old. Children could express themselves and describe the specific phenomenon with their bodies, even without using the scientific term “evaporation”. Also, in a sociocultural perspective where everyday situations emerge, it seems that children more easily recognize the changing state of water and other materials (Kampeza & Delserieys, 2020).

3.2.2. The water cycle in nature

Ahi (2017) examined whether the technique of “talking drawings” could enhance children’s mental models, about the water cycle. Both in pre- and post- drawings the children acknowledged rain and clouds as the most important elements of the water cycle, while the children connect these two elements. Also, water reservoirs appeared as important elements in the water cycle. Ahi (2017) also states that children face difficulties with evaporation and condensation notions.

To understand the water cycle or hydrologic cycle, students should first comprehend that vapor and drops of water have weight and obey in the free fall (Bar, 1989). Children aged 5 to 7-years-old believe that God is responsible for the rain and that the cloud is made of cotton or smoke. Thus, clouds and rain have no connection between them. Another idea is the coalition of the clouds, which are bags of water, and the creation of the rain. Also, at the age of 6 to 8-years-old children believe that clouds drink water from the sea, and from 6 to 9-years-old attribute to the sea and the heating by the sun which creates steam as the reason for clouds' creation. Moreover, clouds are treated like sponges with holes where the rain falls by children 7 to 10-years-old (Bar, 1989) or as water containers (Christidou & Hatzinikita, 2006).

Also, Savva (2014) examined the case of rainfall in young learners. He found that the older children were more likely to use notions related to the water cycle and as the above research children approach clouds as the source of the rain. However, 5-years-old children in comparison to 3-years-old children seemed to have a better understanding of some elements of the water cycle including water reservoirs such as rivers or the sea.

The issue of rain and cloud formation in the minds of 4-to 7-years-old children is understood as part of the water cycle in nature only by those who fully or partially associate water vapour with clouds and rain (Fragkiadaki & Ravanis, 2015; Georgantopoulou et al., 2016; 2022; Kikas, 2010). From a different standpoint, Fragkiadaki & Ravanis (2016) and Fragkiadaki et al. (2021) examined the development of scientific thinking in children (4,5 to 6-years-old) through acting in preschool. More specifically the aforementioned researchers mapped children’s thinking and ideas about the clouds and the rain focusing also on the contribution of the social, cultural, and material environment.

The research of Smith and Samarakoon (2017) aimed to determine if the integration of arts could be an effective teaching method to introduce the water cycle in preschool (5 to 6-years-old). The children could easily recognize some water state changes, but they were not able to connect them with the water cycle. When the water cycle was presented to them, they focused on one part of the cycle instead of describing the water cycle as a whole. They also faced some difficulties regarding the English words 'cycle', 'bicycle', and 'recycling'. However, in general, it seemed that the integration of art can help the introduction of the water cycle in preschool.

Finally, a study was conducted to examine the understanding of evaporation in 6 to 9-years-old children, using a narrative approach that presented incorrect information. The objective of this method was to determine whether the children would be able to identify the errors in the narrative, and to assess how effectively they could explain the process of evaporation (Jelinek, 2022). The data showed that half of the children knew that the cloud formation process was due to evaporation, but only a quarter of the children could detect errors in the narrative.

4. Discussion

Drawing from relevant research, an attempt was made in the current study to capture the mental representations of early childhood children about thermal phenomena and concepts. Traditionally, these studies have a limited scope which leads to a range of findings that collectively create the broader picture. In general, a limited number of children hold mental representations that are compatible with the scientifically accepted knowledge within the school context. These representations on one hand allow children who manipulate them to develop their thinking in a systematic way, and on the other hand serve as an indication that with appropriate teaching activities, we can lead other children towards similar cognitive paths.

Thus, a conceptual space for reasoning is created which allows the formulation of assumptions for more holistic approaches, i.e., the transition from the fragmentary explorations and teaching activities that emphasize materials, their changes and transformations, to broader changes with a common background, where the systemic nature of the phenomena and the unifying nature of the concepts prevail. In this perspective, perhaps the most characteristic example is the question of the possibilities of a systematic approach and understanding of the transition from the discrete changes in the state of water to the water cycle in nature. However, research aimed at such a large-scale intervention requires the creation of a comprehensive design of series of teaching activities whose development can be reflected in programs and over time.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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