Research on Preschool and Primary Education
https://ojs.luminescience.cn/RPPE

LUMINESCIENCE
https://luminescience.cn

Original Research

5-6 years old children's mental representations of water in plants

George Kaliampos[1], Michalis Ioannou[1], Panagiotis Pantidos[2], Konstantinos Ravanis[1*]

[1]Department of Educational Sciences and Early Childhood Education, University of Patras, Greece
[2]Department of Early Childhood Education, National and Kapodistrian University of Athens, Greece

[*]Correspondence to: Konstantinos Ravanis, ravanis@upatras.gr

Abstract: The concept of water holds a central position in almost every curriculum that is developed within early childhood education. The current study presents the findings of research on the way 5–6 year old children deal with the issue of the existence of water in plants. The research was qualitative and was conducted through semi-structured interviews with 66 children. The data was analyzed using content analysis based on the transcripts of the interviews. The results showed that only a small number of children were able to conceptualize the existence of water in plants, however these children were able to describe and make predictions that were in line with school knowledge. Consequently, this field constitutes an interesting area for further research and development of properly designed activities. Limitations of the current research were the restricted and convenient sample as well as the choice of descriptive analysis.
Keywords: Early childhood, Mental representations, Water, Plants

1. Introduction

In recent years, introducing children aged 3 to 8 to the natural world and the natural sciences has been an issue that seems to attract the interest of diverse fields such as early childhood education, science education, and various streams of psychology that focus on learning issues (Akerson, 2019; Barenthien & Steffensky, 2023; Christodoulakis & Adbo, 2024; Hsin, C. T. et al., 2024; Ravanis, 2022; Siry et al., 2023).

One of the main issues that always preoccupies researches on learning and teaching of natural sciences is the identification and categorization of students' mental representations. Particularly, the aim is, on the one hand, to detect the causes that lead to each form of thinking and, on the other hand, to examine to what extent these representations are consistent with school scientific knowledge. This research dimension has a strong imprint within the context of early childhood science education since collecting data regarding the difficulties of young children's thinking enables the possibility of planning and adjustments at many levels: in the organization of curricula, in the designing of teaching activities, in the choice of teaching strategies, in the selection of teaching materials.

In recent years, a large number of studies have highlighted the mental representations of 3–8-year-old children in various fields of natural sciences. Examples regarding three distinct fields of natural sciences, namely Physics, Biology, and Astronomy are given below. Particularly, in the broader context of Physics, Elmalı and Laçin Şimşek (2021) found that young students used terms such as "heavy-light", "soft-hard", "big-small", "thin-thick" to explain floating and sinking bodies in water. In addition, Kaliampos and Ravanis (2019) identified that the dominant representation of heat propagation in metals is that propagates through the air that surrounds them, while Kampeza and Delserieys (2020) found children's visual representations of both melted objects (e.g. drops, lines, flow, puddle) and the melting process (e.g. increased number of drops, decrease in size). Finally, Ravanis et al. (2005) observed that the representation of shadow formation is based on the recognition of entities such as the light source and objects

Received: Sep.20, 2024; Revised: Nov.1, 2024; Accepted: Nov.15, 2024; Published: Nov.26, 2024

DOI: https://doi.org/10.55976/rppe.3202513061-8

and does not include the interaction of light with opaque objects. In the field of Biology, Ergazaki and Zogza (2012) showed how young children's representations can be used in "life cycle of plants", "growth factors of plants" or "decomposition & recycling", while García-Rodeja et al. (2024) followed the same line of research for woodlice. Jégou et al. (2022) in their research on variations within populations, found the dominance of a "typological" representation which highlights the possibility of "essentialist" bias in their reasoning. Finally, in elementary astronomy, Hu et al. (2021) reported that a significant number of children tended to use everyday representations of celestial bodies such as the Sun and stars, while Jelinek (2024) and Raviv and Dadon (2021) found that a significant number of children used a representation of the movement of the Sun at night in the sundown, behind the Moon or covered in clouds. Quite interestingly, Kampeza and Ravanis (2012) identified that a significant number of children used the flat earth representation.

It should be noted that analysis of empirical data becomes purposeful only within the context of specific theoretical frameworks, so that it gains a clear and systematic perspective of utilization. In the current study, we tried to explore the mental representations of children aged 5 to 6 years on the existence of water in plants. These representations are studied in a perspective that draws theoretical support from the notion of precursor models which are entities of children's thinking compatible with school-specific scientific models designed for teaching.

2. Theoretical framework

Quite often in literature, the concept of water, with its properties, interactions and phenomena related to it, constitutes an important field of research and the development of activities in the natural sciences for early childhood education. Moreover, since water is a physical entity that has a strong presence in the natural environment, in social life, in health care and the production of goods in general, it often holds a central position in almost every curriculum (for example, Australian Government, 2010; Greek Ministry of National Education and Religious Affairs, 2002; Irish Government, 2009; UK Government, 2017). In Early Childhood Science Education research, we have been encountering for decades many fields of study that aim to familiarize young children with water and help them conceptualize the basic properties of water that are found in the natural and social environment (Begacarslan et al., 2021; Ioannou et al., 2023; Jelinek, 2022; Ouabich et al., 2024; Yurt Tarakcı et al., 2020; Wei & Karpudewan, 2018).

A fundamental strand of research on water is concerned with investigating young children's mental representations of water state changes, such as boiling and evaporation or melting ice. These studies record children's "local" difficulties with diverse phenomena and highlight important issues of a more general nature, such as the significant influence of everyday experience or the prevalence of prelogical forms of thought and especially the conceptualization that the changes are not due to heat but instead are attributed to the nature of the materials. A small group of studies investigated the degree to which specific pedagogical interventions managed to transform children's mental representations to become compatible with school scientific knowledge (Amorín de Abreu et al., 2022; Cruz-Guzmán et al., 2017; Ioannou, 2023).

In a second direction of water-related research, the studies focus on cases where water is involved in the creation or occurrence of natural phenomena at different levels. Here research often turns to the study of young children's representations or the organisation of teaching interventions on various natural phenomena. Within this research orientation, Canedo-Ibarra et al. (2010) and García-Rodeja, et al. (2023) showed that young children identify weight, size, and volume as the main factors for sinking or flotation. In addition Christidou (2006) found that most children attributed the occurrence of dissolution to certain intrinsic properties of the substances or objects that were involved in the process, while Fragkiadaki and Ravanis (2016) recorded that children believe that clouds are made up of dust, vapour or smoke that rises into the sky from chimneys, and they often invoke some kind of mechanical creation and synthesis of materials such as cotton and foam.

Finally, in a third direction of water-related research, the studies deal with the concept of water in a broader perspective related to its existence and importance in nature, either focusing on the water cycle in nature or on the connection of water to environmental and sustainability issues. Indeed, Smith and Samarakoon (2017) showed that children can be introduced to the water cycle in nature through the use of cultural tools such as plays. In addition, Tetik and Tetik (2024) studied the effectiveness of educational programs aimed at promoting young children's awareness of water conservation, while Ursavaş and Aytar (2018) were able to cultivate positive attitudes among young children towards water conservation and sustainability by implementing a project on water-related phenomena.

In the current study we tried to deal with the issue from a different research orientation, which is the existence of water in organisms and especially in plants. This is a particular dimension that illuminates another aspect of the presence and great importance of water for humans and living organisms, and therefore seems quite interesting to explore the way young children approach this topic.
Undoubtedly, conceptualizing the existence of water in living organisms has different dimensions in the minds of students of different ages. Therefore, this issue, as far as children 5-6 years old are concerned, is posed in terms of the possibility of constructing a "precursor model" in their thinking, as found in modern literature. Precursor models are mental entities that allow children to formulate ways

of reasoning whose basic characteristics are compatible with those of school scientific knowledge (Ravanis & Boilevin, 2022). Thus, if we assume that the functions of models, concepts and phenomena in the Natural Sciences (a) describe the natural world in a non-empirical way (b) predict the evolution of phenomena and (c) provide explanations in a (pre) scientific context, we can claim that a precursor model has been constructed in child's mind as soon as some of the above-mentioned points are satisfied (Ravanis, 2020).

Thus, in the current study, the key research question is mainly concerned with the way young children deal with the existence of water in plant organisms. Based on the theoretical perspective of the precursor model, it could be considered satisfactory to describe and predict the existence of water in both the solid and liquid forms of plant substances. It is worth noting that 5-6 year old children are often unable to give a proper explanation, as this requires a mental process that refers to the microcosm, which is far from the capabilities of children of this age.

3. Methods

3.1 The procedure

The research was qualitative in nature and data collection was conducted through individual, semi-structured interviews drawn from three different tasks. This research method was chosen because the conversations with the children around selected tasks allow the emergence and recording of their representations. The interviews took place in a specially designed area of the kindergartens and lasted approximately 15 minutes. In all tasks, different contexts were used to investigate how children conceptualize the existence of water. The interviews were audio-recorded and transcribed while a protocol was created to observe non-verbal behaviors during the conversations with the children.

3.2 Participants

Sixty-six children (34 girls and 32 boys, average age: 5 years and 7 months) aged 5-6 years, attending four kindergarten classes in the urban area of Patras, Greece, participated in the survey. All socio-economic levels (low, medium, and high) were equally represented in the sample. The participants were randomly selected, and the children were asked to "play" with the researchers and therefore those who accepted participated voluntarily. Seven children did not agree to "play" and therefore did not participate in the survey. The permission of directors and teachers of the kindergartens was also sought while the schools asked for parents " consent. It should be noted that the participants had already attended water vaporization and vapor liquefaction activities in their classrooms as part of their education by their own teachers. The children in the sample met the researchers who worked for a few days with their teachers in their classrooms.

3.3 The tasks

In an attempt to study whether and how young children detect the existence of water in plant organisms, we carried out three different tasks.

In the first task, the children were presented with three static situations: a glass full of water, a well-wetted sponge and fresh cabbage leaves. They were asked to specify whether they contained water. In the case of the glass, the existence of water was immediately understood without difficulty, so that the answers did not have to be categorized. The use of the sponge was an attempt to create a reference base for all the subsequent experiments, as it familiarized the meaning of the sentence "Does it contain water" with which children had to deal in all remaining tasks.

In the second task, the children were presented with two dynamic situations: (a) making and concentrating orange juice in a glass, a process that was carried out in front of them by squeezing two oranges and (b) opening a transparent bottle of lemonade and concentrating it in a glass. In both situations, it was discussed with the children whether water was present in the orange and lemon juices in the glasses.

In the third task, pieces of fresh apples and vegetables were placed on the classroom radiator and after a few hours of operation they were scrutiny examined while change in their appearance was discussed without reference to possible water loss.

3.4 Analysis of data

The materials of the transcribed interviews were approached by content analysis. This analysis identified children's mental representations of the existence of water in different materials. The coding of children's responses was based on the degree they were consistent with school scientific knowledge, regarding the existence of water in plant organisms. Across all tasks, three broad categories of representations were identified in the dialogues with the children.

1. In the category of "sufficient" responses were classified as those in which children recognized the existence of water in plant organisms.

2. In the category of "intermediate" responses were classified as those in which inconsistencies were detected during the discussions with the children.

3. In the category of "insufficient" responses were classified as those that did not recognize the existence of water in plant organisms.

4. Results

In the following section, the results drawn from data analysis are presented. In particular, categories of children's responses along with typical answers and dialogue excerpts are given for each task. In addition, frequency tables of responses that depict the general trends in children's representations are given. The comparison between boys' and girls' responses suggested no statistically significant difference and showed no trend of differentiation.

4.1 Task 1

In the first task, the children had to deal with three distinct contexts: a glass of water, a wet sponge and fresh cabbage leaves. The glass of water was used simply to lead to the first approach of "Does it contain water", used consistently throughout the interview for all tasks. Indeed, all children answered the question "Does the glass contain water" positively and without any difficulty. The same subject was then discussed successively with the other two situations.
Regarding the sponge, the situation was presented as follows: "On the plate, there is a sponge. I would like you to tell me if there is water in this sponge". Children's responses were divided into three distinct categories (see Table 1):

Sufficient responses. In this category, the majority of children's responses recognized that the sponge contains water. Here, the children touched the sponge and immediately responded positively. In cases such as this one, the embodied dimension of some children's engagement with objects was highlighted. For example, S. 16 (S for Student): "*It has inside (water)… yes… it is wet (touches it)*". In some cases, children were just asked whether the sponge was wet. For example, S. 32: "*Have you got the sponge wet*?" R (R for Researcher): "*Yes*". S.32: "*Then it will have water… it goes through the holes and holds the water*".

Intermediate responses. In this category were classified responses where inconsistencies were detected. For example, S. 41: "*If you dipped it into the water it may have stayed… (touches the wet sponge) … but here it hasn't been collected somewhere… it probably can't hold it because it has the holes and it's going away*".

Insufficient responses. Here were classified responses that did not recognize the existence of water in the sponge unless it is kept submerged in a wet environment. For example, S. 7: "*There is no water in the sponge. It will only have it if we put it in a basin of water and keep it submerged*".

Regarding the cabbage leaves, children's responses were also divided into three distinct categories.

Sufficient responses. Few children here recognized that cabbage contains water. S. 1: "*I think it has water… You don't see it like in the glass…*". R.: "*Why do you think it has?*". S. 1: "*If you bite it water runs in your mouth… as if the water cools you down…*".

Intermediate responses. Here were classified those responses that were unstable and contradictory. S. 51: "Cabbage has water". R.: "How do you think about that?". S 51: "Because when we take it out of the fridge it's wet…" R.: "What if we don't put it in the fridge?" S. 51: "If we don't put it in the fridge then there is no water. Only if we wash it…" R: "Does it have water in it?" S. 51: "It might have water in it… But I'm not sure…"

Insufficient responses. Here were classified those responses that were dominated by a clear representation of the absence of water. For example, S. 27: "*No, it doesn't have water… where could the water have been?*". R: "*Maybe inside it?*" S. 27: "*To have a kind of bag.*" R: "To have it everywhere inside." S. 27: "*I don't see any water… no!*"

Table 1. Frequencies of children's responses to Task 1

Responses	Existence of water in the sponge	Existence of water in cabbage leaves
Sufficient	52 (79%)	6 (9%)
Intermediate	9 (14%)	12 (18%)
Insufficient	5 (7%)	48 (73%)

As Table 1 shows, there is a great difference regarding the existence of water among the two situations. It seems that the mechanical processes to which children attribute the existence of water in the sponge lead their thinking to representations which identify it as a "storage" of water. In contrast, in the case of the cabbage leaves, where there is no mental mechanism for transporting water, there is great difficulty in recognizing the existence of water.

4.2 Task 2

In the second task, the children had to deal with two dynamic situations: In the first, two oranges were squeezed and the contents were poured into a glass, while in the second one, the contents of a ready-made lemon juice from a store were poured into a glass. In both situations, the children had to point out whether there was water in the two glasses.

In the first situation, the orange juice was made in front of the children and poured into a glass while children were asked whether there was water in it. The children's responses in this experimental situation were divided into three distinct categories (see Table 2).

Sufficient responses. This category included those responses where children recognized that water exists within orange juice. For example, S. 12: "*It is an orange juice that has orange balls and water*". R: "*Where did that water come from?.*" S. 12: "*The oranges have it in them…*

that's why the orange juice is like water in a glass…"

Intermediate responses. This category includes the responses that were unstable and contradictory. For example, S. 31: "*There is probably water in the orange juice because… it is like water (the child shakes the glass to show that it contains liquid)*". R: "*How did the water get into the orange juice?*" S. 31: "*We may put it in it …*" R: "*But how, since the glass was empty…*" S. 31: "(thinking) *I think there is no water in it. Since oranges don't have water…*".

Insufficient answers. Here were classified responses that did not recognize the existence of water at all. For example, S. 17: "*No, we put orange juice in the glass.*" R: "*Does the orange juice have water in it?*" S. 17: "*No, we just put orange juice in it… the glass was empty*".

In the second situation, the contents of a ready lemon juice from a commercial glass bottle was poured into a glass while children were asked whether there was water in it. Again, children's responses were divided into three distinct categories.

Sufficient responses. In this category were those responses where children recognized that water exists within the lemonade. For example, S. 12: "*There is (water)… lemonade is made from lemon and water… and we drink it.*"

Intermediate responses. In this category were unstable responses which correspond to representations of everyday life. For example, S. 11: "*It might have, if they had poured (water) in the bottle… in the factory…*". R. "*What if they had not poured water in the factory*?" S. 11: "*You mean if it had been done by squeezing lemons like oranges before?*" R: "*Yes.*" S. 11: "*Probably not… it would not have (water)… unless the lemon had water in it…*" R: "*What do you think?*" S. 11: "*… I don't know…*".

Insufficient responses. Here were those responses that did not recognize the existence of water in the juices at all. For example, S. 60: "*There would not be water… there would be only the lemonade you put in.*" R: "*Does the lemonade have water in it?*" S. 60: "*No, since we put only lemonade….*"

Table 2. Frequencies of children's responses to Task 2

Responses	Orange juice	Lemon juice
Sufficient	4 (6%)	16 (24%)
Intermediate	16 (24%)	10 (15%)
Insufficient	46 (70%)	40 (61%)

In the second task, the representations of the majority of children lead them to responses that do not recognize the existence of water in the juices. The small discrepancies in "sufficient" responses between the two situations are exclusively related to the consistently expressed belief that lemon juice in the lemon juice industry is made by adding water to the lemon squeezed, i.e. by a mechanical process of adding water.

4.3 Task 3

In the third task, fresh pieces of fruit and vegetables were presented on a plate in front of the children, who had to identify them individually. They were then placed on a radiator, which was in operation, and after lying there for about 2 hours, they were shown to the children, who discussed about them. The pieces of fruit and vegetables were deformed due to the evaporation of the water they contained. After noticing the change in the shape of the objects, the children were asked to give their opinions on what they thought caused the change.

Only two types of representations were identified in this task, leading to two distinct categories, "sufficient" and "insufficient" responses.

Sufficient answers. In this category were 7 (11%) responses which invoked the evaporation of water that is involved in fruit and vegetables. S. 1: "*The heat from the radiator caused the water to evaporate.*" R: "*Which water*?" S. 1: "*The water in the apples… and the other fruits…*". R: "*Do apples and the rest fruits have water*?" S. 1: "*Yes, that's how nature makes them… and as the apple heats up in the radiator the water turns to smoke… just as it does with the clothes we dry in the radiators…*"

Insufficient responses. In this category were 59 (89%) (responses that did not associate the change in the image of plant objects with the existence of water at all. For example, S. 66: "*The radiator burned them…*" R: "*What do you mean that the radiator burned them?*" S. 66: "*It is from the heat…*" R: "*And why did they become wrinkled and smaller*?" S. 66: "*As I told you, the radiator puts out heat that spoils them…*"

Judging from the above, although children had carried out activities related to water evaporation in their classrooms, a small number of them were able to link the shrinkage of plant organisms to water evaporation due to heating. However, this requires the recognition of the existence of water in plants, which as we saw in the first task is only possible for a small number of children. It seems that the usual activities of changing the state of water by boiling, which is an intense phenomenon, cannot act as an analogous scheme for conceptualizing evaporation and even quantities of water that are not visible.

5. Discussion and conclusions

In the current study, we tried to explore the way children aged 5-6 years conceptualize the existence of water in plant organisms, by using specific tasks that deal with the issue from different angles. As the results showed, very few of the children in the sample were able to identify water as a component of plants, regardless of whether they appear in solid or liquid form. In addition, there was a fairly strong representation related to mechanical processes by which water is "added" to plant matter. Thus, in the minds of young children, standard lemon juice contains water because it is produced in the factory by adding water to the material we extract from lemons, just as a sponge is wet when immersed in water. In contrast, orange juice produced from natural oranges in front of children's eyes does not contain water as it is not obvious that water is added to the juice during the process.

These results are consistent with data from studies that examine young children's thinking about similar water-related issues. Indeed, in these surveys we saw that children's representations are fragmentary (Impedovo et al., 2017), often attribute the properties of water to which they refer to objects or substances (Christidou, 2006) and are usually not consistent with school knowledge (Amorín de Abreu et al., 2022). However, the fact that a small number of children responded satisfactorily to the tasks allowed us to hypothesize that these children were approaching the formation of a precursor model, i.e. a cognitive entity that has stable characteristics and gives responses compatible with the school scientific knowledge. Therefore, the issue of the existence of water in plants is a potential extension of children's field of reference in early childhood education, since our finding that a few children in the sample spontaneously discovered could become a matter of learning for the rest of them with appropriate teaching activities.

Therefore, with regard to the development of activities on water in preschool institutions, such as kindergartens in the Greek educational system, the issue of the existence of water in the tissues of plant organisms is a demanded conquest of young children's thinking and not a given that we can rely on. Undoubtedly, the way we are driven to the reconstruction of children's thinking on this subject is a more general issue of developing teaching strategies for introducing early childhood children to science. This issue has been discussed both from the perspective of children and their differences (Fragkiadaki, 2020; Kaliampos, 2021; Ravanis, 2021) as well as from the perspective of teachers (Ampatzidis & Tsevreni, 2024; Draganoudi et al., 2023; Papantonis Stajcic & Nilsson, 2024) and there is already a range of proposals leading to different possible approaches.

In general, this research is an initial contribution to the literature on how young children approach the issue of water in plants. This topic is interesting as it can allow children to connect water with living organisms in a more concrete way and thus introduce them to a fundamental aspect of the idea of sustainability. At the theoretical level, the research confirms the importance of mental representations in the issues of natural sciences learning as they create barriers that young children have to overcome. It also highlights the importance of the orientation towards the formation of precursor models in children's thinking as these can prepare the formation of school scientific models that are foreseen in the curricula. At the level of everyday teaching practices, the data from this research could provide teachers with a general picture of the difficulties young children face in this subject in order to create appropriate and effective activities.

The research presented here certainly has its limitations. On the one hand, the selection and orientation of the tasks and on the other hand, the limitations of the volunteers' participants which lead to a qualitative approach to a specific age group of children, delineate a first framework for approaching the central question of the research. The development of qualitative and quantitative research with a representative sample in this area can provide not only a more detailed map of children's representations but also concrete developmental perspectives.

Authors' contribution

All authors contributed equally to all phases of the research: research design, data collection, analysis, writing the article.

Conflict of interest

We declare no conflict of interest.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

References

Akerson, V. L. (2019). Teaching and learning science in early childhood care and education. In C. P., Brown, M. Benson McMullen & N. File (Eds.), *The Wiley Handbook of Early Childhood Care and Education* (pp. 355-376). Medford MA, USA: John Wiley & Sons, Inc.

Amorín de Abreu, T., Lorenzo Rial, M. A., Álvarez Lires, M. M., & Álvarez Lires, F. J. (2022). Jugando con el agua en un aula de Educación Infantil para explicar cambios de estado. *Revista Eureka sobre Enseñanza y Divulgación de las Ciencias*, 19(3). https://doi.org/10.25267/Rev_Eureka_ensen_divulg_cienc.2022.v19.i3.3203.

Ampatzidis, G., & Tsevreni, I. (2024). Investigating early childhood education students' ideas about microorganisms. *International Journal of Science Education*, 1-13. https://doi.org/10.1080/09500693.2024.2400316.

Australian Government, Department of Education, Skills and Employment. (2010). *Belonging, Being & Becoming - The Early Years Learning Framework for Australia*. https://bit.ly/2yCuGTb.

Barenthien, J., & Steffensky, M. (2023). Übersichtsartikel: Interventionsstudien zu naturwissenschaftlichen lernumgebungen im kindergarten: empirische zugänge und befunde. *Psychologie in Erziehung und Unterricht*, 70(4), 257-292. http://dx.doi.org/10.2378/peu2023.art17d.

Begacarslan, E., Azahin, F., Azenel,B., Kazmaz, E., & Burasin, Z. (2021). Developing STEM skills with water games in early childhood. *International Journal of Learning and Teaching*, 13(4), 184-203. https://doi.org/10.18844/ijlt.v13i4.5407.

Canedo-Ibarra, S. P. Castelló-Escandell J., & García-Wehrle P. (2010) Enseñanza-aprendizaje de las ciencias en educación infantil: la construcción de modelos científicos precursores. *Revista d'Innovació i Recerca en Educació*, 3(1), 29-45. http://www.raco.cat/index.php/REIRE.

Cruz-Guzmán, M., García-Carmona, A., Criado, A. M., (2017) Aprendiendo sobre los cambios de estado en educación infantil mediante secuencias de pregunta–predicción– comprobación experimental. *Enseñanza de las Ciencias*, 35(3), 175-193. https://doi.org/10.5565/rev/ensciencias.2336.

Christidou, V. (2006). Accounting for natural phenomena. *International Journal of Learning*, 12(8), 22-28. https://doi.org/10.18848/1447-9494/CGP/v12i08/48022

Christodoulakis, N., & Adbo, K. (2024). An analysis of the development of preschoolers' natural science concepts from the perspective of framework theory. *Education Sciences*, 14, 126. https://doi.org/10.3390/educsci14020126.

Draganoudi, A., Lavidas, K., Kaliampos, G., & Ravanis, K. (2023). Developing a research instrument to record preschool teachers' beliefs about teaching practices in natural sciences. *South African Journal of Education*, 43(1), 2031. https://doi.org/10.15700/saje.v43n1a2031.

Elmalı, Ş., & Laçin Şimşek, C. (2021). Pre-school children's opinions about the concepts of floating and sinking and the effect of in-class interactions on their opinions. *Hacettepe University Journal of Education*, 36(1), 227-238. https://doi.org/10.16986/HUJE.2020058755.

Ergazaki, M., & Zogza, V. (2012). How does the model of inquiry-based science education work in the kindergarten: the case of biology. *Review of Science, Mathematics and ICT Education*, 7(2), 73-97. https://doi.org/10.26220/rev.2044

Fragkiadaki, G. (2020). Conflicts during science concept formation in early childhood: barriers or turning points? *Review of Science, Mathematics and ICT Education*, 14(1), 113-128. https://doi.org/10.26220/rev.3367.

Fragkiadaki, G., & Ravanis, K. (2016). Genetic research methodology meets early childhood science education research: a cultural-historical study of child's scientific thinking development. *Cultural-Historical Psychology*, 12(3), 310-330. https://doi.org/10.17759/chp.2016120319

García-Rodeja, I., Barros, S., & Sesto, V. (2024). Inquiry-based activities with woodlice in early childhood education. *Education Sciences*, 14, 710. https://doi.org/10.3390/educsci14070710.

García-Rodeja, I., Rodríguez Rouco, E. V., Lorenzo Flores, M., & Sesto Varela, V. (2023). Construyendo modelos precursores sobre la flotabilidad de objetos macizos a los seis años. *Enseñanza de las Ciencias*, 41(2), 137-154. https://doi.org/10.5565/rev/ensciencias.5718.

Greek Ministry of National Education and Religious Affairs - Greek Pedagogical Institute. (2002). *Cross-thematic curriculum framework for the kindergarten and curriculum for activities' development*. Athens: Greek Pedagogical Institute. http://www.pi-schools.gr/programs/depps.

Hsin, C. T., Wu, H. K., Tam Luu, D., & Wei, M. E. (2024). Fostering young children's scientific practices in urban and Indigenous areas: An investigation of instructional strategies. *International Journal of Science Education*, 1–25. https://doi.org/10.1080/09500693.2024.2343437.

Hu, J., Gordon, C., Yang, N., & Ren, Y. (2021). "Once upon a star": a science education program based on personification storytelling in promoting preschool children's understanding of Astronomy concepts. *Early Education and Development*, 32(1), 7-25. https://doi.org/10.1080/10409289.2020.1759011.

Impedovo, M. A., Delserieys-Pedregosa, A., Jégou, C., & Ravanis, K. (2017). Shadow formation at preschool from a socio-materiality perspective. *Research in Science Education*, 47(3), 579-601. https://doi.org/10.1007/s11165-016-9518-x

Ioannou, M. (2023). Ice melting in early childhood education: a case of the designing and implementing a STEAM project about water state changes. *Mediterannean Journal of Education*, 3, 164-175. https://doi.org/10.26220/mje.4478

Ioannou, M., Kaliampos, G., Fragkiadaki, G., Pantidos, P., & Ravanis, K. (2023). Thermal concepts and phenomena in early childhood science education: a literature review. *European Journal of Education Studies*, 10(5), 1-12. http://dx.doi.org/10.46827/ejes.v10i5.4770.

Irish Government (2009). *Early Childhood Curriculum Framework*. https://bit.ly/2VbzkyY.

Jégou, C., Gobert, J., Delserieys, A., & Ergazaki, M. (2022). A system to identify young children's reasoning about variations within populations. In J.-M. Boilevin, A. Delserieys, K. Ravanis (Eds.), *Precursor Models* *for Teaching and Learning Science During Early Childhood* (pp. 193-217). Springer, Cham. https://doi.org/10.1007/978-3-031-08158-3_11.

Jelinek, J. A. (2022). Dziecięca meteorologia. Rozumienie przez dzieci zjawisk pogodowych w różnych częściach świata. *Edukacja Elementarna w Teorii i Praktyce*, 17, 25-38. https://doi.org/10.35765/eetp.2022.1764.02.9.

Jelinek, J. A. (2024). From the spherical Earth model to the Globe: The effectiveness of a planetary model-building intervention. *Education Sciences*, 14, 761. https://doi.org/10.3390/educsci14070761.

Kaliampos, G. (2021). Early childhood special science education: setting the frame of a newly born and well-promising trend? *Review of Science, Mathematics and ICT Education*, 15(2), 61-76. https://doi.org/10.26220/rev.3795.

Kaliampos, G., & Ravanis, K. (2019). Thermal conduction in metals: mental representations in 5-6 years old children's thinking. *Jurnal Ilmiah Pendidikan Fisika "Al-BiRuNi"*, 8(1), 1-9. https://doi.org/10.24042/jipfalbiruni.v8i1.3737.

Kampeza M., & Delserieys A. (2020). Acknowledging drawing as a mediating system for young children's ideas concerning change of state of matter. *Review of Science, Mathematics and ICT Education*, 14(2), 105-124. https://doi.org/10.26220/rev.3512.

Kampeza, M., & Ravanis, K. (2012). Children's understanding of the earth's shape: an instructional approach in early education. *Skholê*, 17, 115-120. Retrieved from https://www.researchgate.net/publication/236256493_Kampeza_M_Ravanis_K_2012_Children's_understanding_of_the_earth's_shape_an_instructional_approach_in_early_education_Skhole_17_115-120.

Ouabich, R., Tifroute, L., & Rafouk, L. (2024). Effectiveness of an inquiry-based science program on enhancing science process skills and knowledge among Moroccan preschool children. *International Journal of Educational Methodology*, 10(4), 543-558. https://doi.org/10.12973/ijem.10.4.543.

Papantonis Stajcic, M., & Nilsson, P. (2024). Teachers' considerations for a digitalised learning context of preschool science. *Research in Science Education*, 54, 499-521. https://doi.org/10.1007/s11165-023-10150-5.

Ravanis, K. (2020). Precursor models of the physical sciences in early childhood education students' thinking. *Science Education Research and Praxis*, 76, 24-31.

Ravanis, K. (2021). The physical sciences in early childhood education: theoretical frameworks, strategies and activities. *Journal of Physics: Conference Series*, 1796, 012092. https://doi.org/10.1088/1742-6596/1796/1/012092.

Ravanis, K. (2022). Research trends and development perspectives in early childhood science education: An overview. *Education Sciences*, 12(7), 456. https://doi.org/10.3390/educsci12070456.

Ravanis, K., & Boilevin, J.-M. (2022). What use is a precursor model in early science teaching and learning? Didactic perspectives. In J.-M. Boilevin, A. Delserieys & K. Ravanis (Eds.), *Precursor Models for teaching and learning Science during early childhood* (pp. 33-49). Springer.

Ravanis, K. Charalampopoulou, C. Boilevin, J.-M., & Bagakis, G. (2005). La construction de la formation des ombres chez la pensée des enfants de 5-6 ans : procédures didactiques sociocognitives. *Revue de Recherches en Éducation : Spirale*, 36, 87-98. https://www.persee.fr/doc/spira_0994-3722_2005_num_36_1_1327.

Raviv, A., & Dadon, M. (2021). Teaching astronomy in kindergarten: children's perceptions and projects. *Athens Journal of Education*, 8, 305-328. https://doi.org/10.30958/aje.8-3-4.

Siry, C., Trundle, K. C., & Saçkes, M. (2023). Science education during the early childhood years. In N. G. Lederman, D. L. Zeidler & J. S. Lederman (Eds.), *Handbook of Research on Science Education* (Vol. III, pp. 499-527). Routledge.

Smith, L. L., & Samarakoon, D. (2017). Teaching kindergarten students about the Water Cycle through arts and invention. *Journal of STEM Arts, Craft, and Constructions*, 2(1), 60-78. https://scholarworks.uni.edu/journal-stem-arts/vol2/iss1/5/.

Tetik, G., & Tetik, M. (2024). Measuring water saving awareness in preschool children. *Education Science and Management*, 2(2), 94-100. https://doi.org/10.56578/esm020203

Ursavaş, N., & Aytar, A. (2018). Analysing pre-school students' water awareness and water literacy development in a project-based study. *Journal of Research in Informal Environments*, 3(1), 19-45. https://dergipark.org.tr/en/pub/jrinen/issue/39907/400194.

UK Government, Early years foundation stage statutory framework. (2017). *Statutory framework for the early years foundation stage. Setting the standards for learning, development and care for children from birth to five*. https://bit.ly/3bTHcfd.

Yurt Tarakcı, O., Keleş, S., & Kolemen, E. B. (2020). Preschool teachers' science talks during picture storybook telling. *Journal of Baltic Science Education*, 19(6), 940-953. https://doi.org/10.33225/jbse/20.19.940.

Wei, A. S., & Karpudewan, M. (2018). Effects of social and emotional learning on disadvantaged year 1 pupils' understanding of sinking and floating concepts. *Eurasia Journal of Mathematics, Science and Technology Education*, 14(6), 2609-2622. https://doi.org/10.29333/ejmste/90258.