Mental representations of children 4-6 years old about air in 'open' and 'closed' space

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ABSTRACT
A significant amount of research in the field of Early Childhood Science Education is oriented towards the study of young children's mental representations of entities, phenomena and concepts in the physical sciences. These representations can be proved as powerful tools for the development of activities in overcoming children's difficulties and constructing in their minds new representations compatible with Physical Sciences models. Despite the fact that air constitutes a fundamental physical entity of children's everyday life, it has been hardly studied in the international literature. In the current paper an attempt was made to study the mental representations of children aged 4-6 years old about air. In particular, we investigated children's representations about the existence of air in both indoor and outdoor environments. Forty-one children attending a kindergarten in Patras (Greece) took part in the study. Along individual semi-structured interviews, the children were presented with 3 different pictures and were asked to point out whether air exist in the illustrated images. Specifically, the images depicted an indoor room with either a closed or open window as well as an outdoor environment and the discussions with the children focused on the different characteristics of the portrayed pictures. The results showed that the presence of air is identified in a more consistent and stable manner either in outdoor environments or in indoor rooms which however come in contact with outdoor environment through an open window.

KEYWORDS
Early Childhood Science Education, air, mental representations

RÉSUMÉ
Un nombre important de recherches dans le domaine de l'éducation scientifique pour la petite enfance est orienté vers l'étude des représentations mentales des jeunes enfants concernant les entités, les phénomènes et les concepts des sciences physiques. Ces représentations peuvent s'avérer être des outils puissants pour le développement d'activités visant à surmonter les difficultés des enfants et à construire dans leur esprit de nouvelles représentations compatibles avec les modèles des sciences physiques. Malgré le fait que l'air constitue une entité physique fondamentale de la vie quotidienne des enfants, il a été très peu étudié dans la littérature

internationale. Dans le présent article, nous intéressons aux représentations mentales des enfants âgés de 4 à 6 ans concernant l'air. En particulier, nous avons étudié les représentations des enfants sur l'existence de l'air dans les environnements intérieurs et extérieurs. Quarante et un enfants fréquentant une école maternelle de Patras (Grèce) ont participé à l'étude. Au cours d'entretiens individuels semi-structurés, on a présenté aux enfants 3 images différentes et on leur a demandé d'indiquer si l'air existe dans les images illustrées. Plus précisément, les images représentaient une pièce intérieure avec une fenêtre fermée ou ouverte, ainsi qu'un environnement extérieur, et les discussions avec les enfants ont porté sur les différentes caractéristiques des images représentées. Les résultats ont montré que la présence de l'air est identifiée de manière cohérente et stable que ça soit dans les environnements extérieurs ou dans les pièces intérieures qui entrent toutefois en contact avec l'environnement extérieur par une fenêtre ouverte.

MOTS-CLÉS
Enseignement scientifique pour la petite enfance, air, représentations mentales

INTRODUCTION

An important research area within the field of Science Education, the last 50 years, deals with the study of children's and teacher's mental representations of Physical Sciences concepts and natural phenomena (Jelinek, 2021; Métioui & Trudel, 2012; Rassaa, 2011). These representations enable the researchers to have a deep insight into the difficulties that students of all ages face and therefore their exploitation supports the design and implementation of teaching interventions (Corni et al., 2022; Evangelou & Kotsis, 2023; Kaliampos et al., 2023; Li et al., 2022). This research stream has clearly influenced research in the field of Early Childhood Education as both Science Education and the various streams of Psychology that focus on learning issues began to turn their attention to the development of children's thinking aged 3-8 years. Thus, the field of research and development of Early Childhood Science Education was gradually formed and nowadays covers many aspects of the issue of initiating young children into the Physical Sciences (Akerson, 2019; Ravanis, 2022; Siry et al., 2023). One part of this field is the study of naïve mental representations and their transformation into forms of reasoning compatible with those that formulate as school science knowledge (Al Jadidi et al., 2022; Boilevin et al., 2022; Ioannou et al., 2023). The present study fits within this framework and covers issues of conceptualizing air in space.

A limited number of studies have been carried out on the way preschool children conceptualize air. In particular, a study of Borghi et al. (1998) investigated the possibility of transforming the pre-verbal explanations of 6–8-year-old children regarding air. The results showed that engaging children in a sequence of appropriate experiments that conducted in small groups of students and brought them into contact with the physical properties of air and everyday experience could lead to the formation of mental representations that deal with air as a discrete physical entity. In addition, a study of Van Hook et al. (2005) investigated the possibility of developing mental models of air by kindergarten students after completing a series of empirical-exploratory science activities. The teaching activities focused on two specific air properties: that is air occupies space and is made up of particles ('air balls').

During the activities it emerged that several children were able to make more sophisticated arguments about air phenomena, often using the 'air ball' model in their attempt to explain these phenomena. In another study, Predict-Observe-Explain activities were conducted to explore the way 6-year-old children conceptualize distinct air properties such as the existence, motion and the weight of it (Liang, 2011). Within these activities, inconsistent

data were generated between young learners' predictions and outcomes. As a consequence, these activities led some of the children, who used to confine the existence of air in specific locations, to recognize that air actually exists everywhere in the environment, although it should be noted that acquiring consistent and holistic concepts in science is a long-term process. Similar results were recorded in another similar study conducted with 5–6-year-old children (Rochovská, 2015).

Lorenzo Flores et al. (2018) and Sesto Varela et al. (2022) studied the possibility of construction precursor models for air by children aged 3-5 years[1]. Using a Predict-Observe-Explain teaching strategy, they showed that initially, young children were not able to satisfactorily approximate air as an entity. However, during the development of the teaching process, their explanations gained a higher level of complexity so that they recognized that air exists and occupies space. At the same time difficulties in understanding the issue of air mass were recorded. Finally, in Kornelaki's (2023) research, the mental representations of first and second grade elementary school students (6-8 years old) about air were studied and categorized. The results findings showed that while these representations hold a pro-logical character, they seem to be amenable to processes that could lead to the construction of precursors models.

The goal of this case study consists in exploring children's mental representations of the existence of air in ‘open’ and ‘closed’ space.

METHODOLOGY

Sample

The sample of the study was 41 children (15 children 5-6 years old and 26 children 4-5 years old). They were all enrolled in a private kindergarten in the area of the University of Patras in 2022. These children had not participated in any kind of systematic activities regarding air. The sample selection was convenience, and the children were asked whether they wanted to ‘play with us’ while their parents' permission in a written form was requested.

The research procedure

FIGURES

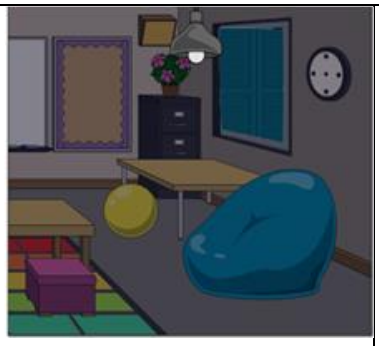

Figure 1

Figure 2

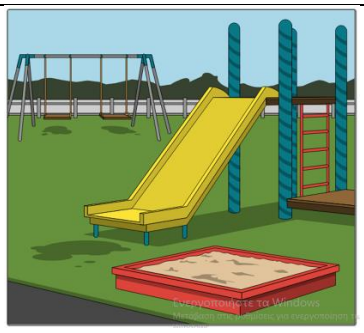

Figure 3

The figures used in the three tasks

[1] The precursor models “are cognitive constructions (concepts, models, procedures, etc.) generated by the educational context. They constitute the moulds for subsequent cognitive constructions which, without their help, would be difficult or even impossible. In precursor models, the elements and relations between them are compatible with those of the scientific models currently used in Physical Sciences teaching and learning processes” (Ravanis & Boilevin, 2022, pp. 39-40).

The research was qualitative in nature and was conducted through semi-directed individual interviews where children came across three different tasks. In advance of the interview, an introduction was made with each child about the topic of air, in which their daily experience clearly emerged. In the tasks, the children were asked to identify whether air exists in space as a distinct physical entity in three different situations (Figures).

In the first task, the children were presented with figure 1 in which a room with a closed window was drawn. In the second task they were shown figure 2 with the same room but with an open window. In the third task, the children were presented with figure 3 that depicted in a typical form the outdoor of their schoolyard. Each interview, which lasted about 15-20 minutes, was recorded and transcribed. Notes were also taken to capture the children's non-verbal behavior. Content analysis was used to interpret and classify the data.

Analysis of data

The data for each task was classified into three broad categories corresponding to three different types of mental representations.

1) In the category of sufficient responses were classified those in which the existence of air in the space is acknowledged without any restrictions.
2) In the category of intermediate responses were classified those in which the recognition of the presence of air is associated with specific characteristics of the space.
3) In the category of insufficient responses were classified those that did not acknowledge the existence of air at all.

RESULTS

In the following section the results drawn from the data analysis are presented. In particular, the categories of responses and typical examples of children's dialogues as well as tables that depicts the frequency of each category for 4-5 and 5-6 children's responses are given.

Task 1. Whether and where air exists in a room with a closed window (Figure 1).

In the first task we asked children to identify whether there is air in a room with a closed window. Two categories of mental representations were detected in children's responses.

Intermediate responses. While here children identified places in the room with air, they tended to relate them to specific features of the picture. In particular, the closed window seemed to play a key role as the distance form it considered as a criterion for the presence or absence of air. For example:

> Researcher (R): This picture depicts a classroom with two tables, a chair and a closed window. Is there air as soon as the window is closed?
> Subject 6 (S6): No
> R: Is there air on the table near the window?
> S6: Little
> R: Why is it little?
> S6: It's little because the window is closed.
> R: Is there air on the table that is on the side away from the window?
> S6: There is no air at all.
>
> R: Is there air on this classroom?

S39: When too much air comes into the classroom from the open window then we close the window and there is too much air.
R: When the window is closed?
S39: As soon as we open it again, the air goes out and some other air comes in… if we close it quickly so that it's completely closed then air doesn't even go out.
R: How about this window that it is closed? Does the air come through there?
R39: No ... except if there are holes… otherwise the air cannot get in.

Insufficient responses. Here the existence of air was not recognized at all and the justification for it was usually the closed window. For example:

R: Is there air in the picture where the window is closed?
S10: No.
R: Is there air on the table that is on the side away from the window?
S10: No.
R: Is there air behind the chair?
S10: No.
R: Why do you think so?
S10: Hmmm… The window is closed so air cannot get in.

R: Is there air in the room depicted in that picture where the window is closed?
S19: No.
R: Why do you think so?
S19: Because the window is closed and so air can't get in from anywhere.

Table 1 shows the frequencies of children's responses of the two age groups regarding Task 1.

TABLE 1
Frequencies of children's responses to Task 1

	Children aged 4-5 years	**Children aged 5-6 years**
Intermediate	7	6
Insufficient	19	9
Total	26	15

Task 2. Whether and where air exists in a room with an open window (Figure 2).
In the second task we asked children to identify whether there is air in a room with an open window (Figure 2). Two categories of mental representations were detected in children's responses.

Sufficient responses. Sufficient responses were classified as those that recognized the existence and maintenance of air as a physical entity everywhere in the room. Here we focused on whether children considered air to exist everywhere or in some parts of the room, as it was observed that all children recognized the existence of air due to the open window. For example:

R: Now you can see a picture of the same room but with the window open this time. Is there air in the room?
S3: Yes.
R: Why do you think so?
S3: Because you open the window.
R: So, what happens when I open the window?

S3: Air is coming in.
R: Is there any specific point in the room depicted in that picture where air is located? Can you show me where?
S3: Yes… It doesn't go somewhere specific… it goes throughout the whole classroom.

R: Is it just near the window?
S16: No.
R: And where is it?
S16: Everywhere
R: When you say everywhere, what do you mean?
S16: All over the world.

Intermediate responses. Here children did not express a fixed mental representation as they were influenced by the virtual and local elements of the environment, such as the closed shutter, the air flow and the thermal condition of the environment. For example:

R: Very nice … So, tell me now that it's morning as you said in the classroom depicted in the picture and the window in open, is there air in it?
S1: No, there is not.
R: Why there is not air?
S1: Because it's a little bit closed here (the student points to the window and more specifically to the metal bar that goes through it, considering it as a sign that while the shutter is open the window itself is closed).
R: What if I told you the window is wide open?
S1: Then, there is air everywhere.

R: Where does the air come from?
S19: It comes from the window.
R: In the room depicted in that picture where is air located?
S19: It's across the whole classroom… it's just that there is not so much air far away from the window.

R: Could you show me the points where air exists in the room depicted in the picture?
S2: Yes here … (the student points on the table near the window) … is the wind blowing hard or soft?
R: Whatever you want. Could you explain me the difference?
S2: Here it goes in and out again and again (the student points with his hand the path of air from the window to the table and back again).
R: What if the wind was blowing hard? What would happen?
S2: The air would go straight.
R: It would go straight?
S2: Yes, yes … it would go to the lamps and flowers.
R: And if the wind was blowing soft as you told before?
S2: In that case it would go to these two tables (the student shows the two tables in the picture).

Table 2 shows the frequencies of children's responses of the two age groups regarding Task 2.

TABLE 2

Frequencies of children's responses to Task 2

	Children aged 4-5 years	**Children aged 5-6 years**
Sufficient	6	4
Intermediate	20	11
Total	26	15

Task 3. Whether and where air exists in an 'open' space? (Figure 3).

In the third task we asked children to identify whether and where there is air outdoor in the schoolyard where familiar objects were presented (Figure 3). Their responses were classified into three distinct categories.

Sufficient responses. Sufficient responses were classified as those that recognized that air can be found throughout the open space of the schoolyard, regardless of the objects and different parts of it, such as the space under the slide. That is, children here seem to count air as a physical entity that exists everywhere and occupies the whole space. For example:

R: Why, how do you think about it (that there's air everywhere)?
S5: Because there's air everywhere as it is outside… there's always air outside.
R: Hmmm…
S5: The leaves may not move and there may be no air, but we can live there… everywhere we can live.
R: And why can we live everywhere?
S5: Because there is air everywhere.

R: This picture depicts the schoolyard. Is there any air over there?
S21: Yes, of course… yes, it is the environment ... air is everywhere.

Intermediate answers. While here children seemed to recognize the existence of air in the wider environment, they did not recognize it in specific parts of the picture such as the slide, some wooden surfaces or the swings. The absence of air at these parts was attributed to factors such as the environment, shadows, wind direction and the possible immobility of objects. For example:

R: Is there any particular point in the place depicted in the picture where air does not exist
S23: There is… in the desert… here there is not such point as only in the summer there is little air.
R: So, if it was winter in this picture, would there have been some air?
S23: Yes

R: Is there air on the slide?
S33: Yes, there is because it goes like this (the student points vertically from the sky to the top of the slide) … there is no air underneath.
R: Why isn't there just underneath?
S33: Because there is shadow.

Insufficient responses. Here were classified responses that tended to relate the existence of air to physical processes that have nothing to do with air. For example:

R: This picture depicts the schoolyard. Is there any air over there?

S27: Yes
R: Why do you think so?
S27: Because the sky is blue and it's sunny and a little bit windy.
R: Is it only when it's sunny that it is windy?
S27: Yes… and when it is windy it rains.

R: This picture depicts the schoolyard. Is there any air over there?
S39: Yes, there is air… because there are clouds and the sky.
R: In this place where is air located?
S39: In the cloud
R: Is that where it's coming from?
S39: Yes… from all the clouds.

Table 3 shows the frequencies of children's responses of the two age groups regarding Task 3.

TABLE 3
Frequencies of children's responses to Task 3

	Children aged 4-5 years	**Children aged 5-6 years**
Sufficient	7	6
Intermediate	17	7
Insufficient	2	2
Total	26	15

DISCUSSION

In the current research an attempt was made to study the mental representations of children aged 4-6 years about the existence of air in 'closed' and 'open' spaces. From the presentation and analysis of the research data it became obvious that the direct or indirect contact with the open environment plays a key role in the recognition of the existence of air. Thus, the presence of visible open paths to the environment is extremely crucial. We could therefore conclude that in general children attach great importance to the constant physical presence of air in the open environment and conversely its absence from enclosed spaces which seem to be treated as empty and waiting to be 'connected' to the open environment in order to obtain air. A very typical indication of this mental representation is the totally absence of responses that acknowledge the existence of air in the first task in which the room appears closed, and the insufficient ones that exclude the existence of air due to the closed window. Interesting are the sufficient responses in the other two task. According to these answers, in the second task air passes through the window while in the third task air appears everywhere because of the open space.

Of particular interest are the intermediate responses which are based on representations strongly influenced by pre-logical forms of thought which are dominated by strong focus on particular points of the layout[2]. For example, a large number of responses are based on the idea that while air passes through some larger or smaller openings, it seems to be trapped next to them and attenuated at greater distances. In addition, as it can be seen in the third task, air is

[2] The pre-logical forms of thinking have been systematically studied in the context of Genetic Epistemology and lead to a particular reasoning that does not follow from a systematic correlation of cause and effect. These reasonings, arise from correlations that are not accepted by integrated logical thinking and are referred to within the literature as "egocentrism", "anthropomorphism", "artificialism" (Ravanis et al., 2022).

not identified at specific points in the layout as the representation that air 'comes from above' prevents it from being identified 'below' the objects in the layout.

Furthermore, the data of this research reflects different mental representations of air as an entity. Particularly, while in some cases its universal propagation is fully recognized, in others it is regarded as an entity that has the potential to be concentrated in points where nothing seems to restriction its propagation, such as openings, while less frequently it is associated with physical entities such as the sun or clouds.

The results of the current study did not lead to statistically significant differences between the two age groups of children. Looking at the percentages of responses by age level, we find a slight difference in favour of the older children's group, but this simply captures a weak trend which would be worthy of further study. This tendency has also been recorded in other studies with children of these ages and could perhaps be attributed to developmental reasons (Kilia et al., 2015).

These findings are consistent with those of the relevant literature (Borghi et al., 1998; Liang, 2011; Van Hook et al., 2005). The focus on particular parts of the layout, the instability of the mental representations and their modification in diverse tasks highlight the pre-logical characteristics of children's representations. At the same time, it seems worthwhile the study of children's thinking in different tasks, such as the presence of air in confined objects like open or closed bottles, as it can give a more complete picture of their thinking. It would also be interesting to study circumstances where there is not just air but wind, which could create a record of different representations of the existence of air. Thus, children's mental representations could be integrated into a developmental perspective of their thinking in a perspective of constructing precursor models. This is the path our ongoing research fulfil to follow.

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