Exploring early graders' preconceptions about air within non-formal settings

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ABSTRACT

The present paper is a meta-analysis of the implementation of the science education program "Thunderbolt hunt" at the Archaeological Museum of Ioannina. During this program students approach the concept of air through play-based actions. The goal of the paper is to explore first and second-grade primary students' preconceptions about air and to classify them according to Laurandeau and Pinard's categorization. Based on the results, students' preconceptions about air are consistent with the literature's, highlighting the importance of identifying and addressing students' preconceptions in organized context. The present paper demonstrates students' readiness to work on their preconceptions developing precursor models and moving from the everyday concepts towards more scientific.

KEYWORDS

Preconceptions, air, Archaeological Museum of Ioannina, pre-causal thinking

RÉSUMÉ

Le présent article est une méta-analyse de la mise en œuvre du programme d'enseignement scientifique "Thunderbolt hunt" au Musée archéologique de Ioannina. Au cours de ce programme, les élèves abordent le concept de l'air par le biais d'actions ludiques. L'objectif de cet article est d'explorer les idées préconçues des élèves de première et deuxième année du primaire sur l'air et de les classer selon la catégorisation de Laurandeau et Pinard. D'après les résultats, les préconceptions des élèves sur l'air sont conformes à celles de la littérature, ce qui souligne l'importance d'identifier et de traiter les préconceptions des élèves dans le contexte organisé. Le présent article démontre que les élèves sont prêts à travailler sur leurs préconceptions en développant des modèles précurseurs et en passant des concepts quotidiens à des concepts plus scientifiques.

MOTS-CLÉS

Préconceptions, air, Musée archéologique de Ioannina, pensée pré-causale

INTRODUCTION

The present paper comprises a meta-analysis of the data gathered from the implementation of the science education program "Thunderbolt hunt" at the Archaeological Museum of Ioannina. During the implementation of the program, students observe some of the museum's exhibits connected with a narrative which introduces a problem-solving situation that involves them in some science experiments. "Thunderbolt hunt" introduces students to the concept of air and some of its properties. The aim of the meta-analysis is to explore the preconceptions students bring in the learning community. More specifically, the research explores preconceptions of students in the first and second grade of primary school.

According to Vygotsky (1998), child's social development is attributed to the process of interaction between the "ideal" and present forms. Hence, in teaching process, and more specifically in science education, the ideal forms correspond to the scientific concepts and the present forms to students' everyday concepts. The scientific concepts are considered the scientifically sound concepts that are approached by the teachers in a developmentally appropriate manner, provoking interactions between the former and the everyday concepts (Kewalramani & Veresov, 2022). On the other hand, everyday concepts correspond to the way students perceive the phenomena of the world around them and the way they employ to explain them, hence everyday concepts reflect students' present development (Kewalramani & Veresov, 2022). Therefore, teachers' goal is to explore student's present development by identifying their everyday concepts and introduce scientific concepts properly by creating interactions between the everyday and scientific concepts in a play-based manner and within specially organized environments (Fragkiadaki & Ravanis, 2015).

The science education program "Thunderbolt hunt"

The educational program "Thunderbolt hunt" consists of 7 smaller actions and lasts 90 minutes (Kornelaki & Plakitsi, 2020). During these actions students are welcomed to the museum and form their groups which are as many as the museum's exhibits involved (1). Each group searches in the collection, finds and observes its exhibit and all the groups together share their observations to find the common element (2) which is the winged thunderbolt and is the key for the fourth action. Next, students listen to the narrative which incorporates mythological and non-mythological characters, as well as fictional elements and introduces them into a problem-solving situation that requires their knowledge about air (3). In the following action, students get the experiments' materials from inside the boxes on which the common element is displayed and experiment approaching the concept of air. More specifically, they study the existence of air, and some of its properties, such as that air occupies space, takes the shape of its container, can be compressed and finally, two objects cannot occupy the same space at the same time (4). After that, students compile all their wisdom using the technique, role on the wall, and advise Aeolus what to do with his problem (5). Then, Aeolus brings the winged thunderbolt to students into pieces which should be assembled (6) and finally, he asks students to gather his winds in his sack (7) (Kornelaki & Plakitsi, 2020).

Literature review

The concept explored in the present paper is air from the perspective of early-grade students, in the 1st and 2nd grade of primary school. Most of the published research about the concept of air and students' preconceptions refers to secondary education and focus mostly on air pressure (Akbaş & Gençtürk, 2011; Rollnick & Rutherford, 1993; She, 2002), photosynthesis (Ekici et al., 2007; Haslam & Treagust, 1987; Jayanti, 2020; Marmaroti & Galanopoulou, 2006; Svandova, 2014; Treagust & Haslam, 1986), and states of matter (Christidou, 2005; Georgantopoulou et al., 2016; Kapici & Akcay, 2016; Kind, 2004; Kirbulut & Geban, 2014; Niroj & Srisawasdi, 2014; Stojanovska et al., 2012). There is also research concerning primary school students but mostly in relation to students in the last grades, 5th and 6th grade of primary school. The latter research concerns students' perceptions about the particle theory of matter and the different states of matter (Kind, 2004; Ozdemir, 2021), air pollution and climate change (Choi et al., 2010; Thornber et al., 1999) and photosynthesis (Keleş & Kefeli, 2010). Finally, there is published research about the concept of air and phenomena related to the former in pre-school (Letsi et al., 2014; Mazas et al., 2018; Sesto Varela et al., 2022; Redfors et al., 2022). It focuses on students' preconceptions that constitute the baseline for the precursor models and the teaching interventions focus on the existence of air and some of its properties using easy science experiments and digital tools.

Interestingly, it seems that there are common preconceptions among the students of primary and secondary education around air-related phenomena, which is evident in the repeated topics that appear in literature. The latter probably means that students reaching high school haven't properly dealt with their preconceptions earlier in their school life. Therefore, they stick to their intuitions which hinder their scientific concept development. This should not be considered a discouraging sigh but could work as an indication to further elaborate on students' preconceptions and not only identify them, but also address them within the teaching process. The focus is placed on teacher preparation in higher education as well as in teachers' training and lifelong learning.

The concept of air in the Greek curricula of the first grades of school

Air is everywhere around us; it is an invisible mixture of gases surrounding Earth and is essential for our survival. The most important process of the living things that involves air is respiration that includes breathing. The motion of the air is the wind, which gave impetus to the evolution of civilization and thanks to wind many inventions and mechanisms made human life easier (Kornelaki & Plakitsi, 2022). In science education courses the comprehension of air-related concepts is considered fundamental for the scientific concept development (Lai, 2016). The appearance of the concept in the Greek science education curricula is systematically introduced in the fourth grade of primary school.

More specifically, in pre-school science education curriculum, the subject of air is approached through the weather phenomena and meteorological observations. This is achieved in relation to students' everyday experiences and habits as well as to the impact and consequences of weather phenomena in their everyday activities. Another chance pre-schoolers have, to familiarize themselves with the concept, is through environmental projects that teachers undertake throughout the school year.

In the first four grades of primary school, there is not a distinct science course. Instead, students are introduced to environmental study with its interdisciplinary character, which focuses on three main axes, 1) the human-made environment 2) the natural environment 3) the human-environment interaction. It aims to create a global perception of life that mainly consists of the development of cognitive connections and interactions between different objects. The emphasis is placed on treating the student as researcher. In relation to the concept of air, in the first grade, the concept is approached only through the senses and the different smells. In the second-grade students are introduced to air through the animals' and plants' needs to survive as well as the weather. In the third grade there is only a mention on animals' and plants' needs and in the fourth-grade students learn the existence of air in their daily life and some of its properties through easy science experiments.

Preconceptions about air from the early graders

Students' everyday concepts or preconceptions derive from intuitions and that sort of reasoning stays with the students for many years until there will be an organized context to contradict with the intuition. Therefore, the probability of a student sticking to his/her intuition which is rooted for years is greater than rejecting it due to a fact that contradicts it. Consequently, identifying and more importantly addressing students' preconceptions is far more important than introducing them to correct facts. As a matter of fact, the intuition which manifests with diverse explanations, reveals the emergence of students' embryonic causal thinking which in turn is a gradual process towards the scientific explanations. In cultural-historical approach, everyday concepts are not considered as boundaries for the student's development; on the contrary, they are considered the base on which scientific concepts will gradually be developed (Fragkiadaki, 2020; Ravanis, 2017).

It is noteworthy that the research shows that students' preconceptions follow certain patterns that allow us to classify them. Some common characteristics in students' perceptions summarized by Skoumios (2012) are: (a) Dominance of thought by perceptual data, (b) Limited focus, (c) Dependence of concepts on their context of use, (d) Inseparable Concepts, (e) Linear causal reasoning, (f) Perceptions are resistant to change.

A categorization system to classify pre-causal and causal thinking and reasoning for early grade students in science education is introduced by Laurandeau and Pinard (as cited in Fragkiadaki 2020, p. 119). In the pre-causal category, which is studied in the present paper, the sub-categories listed are phenomenism, artificialism, animism, teleological causality, metaphysical causality, combination of pre-causal thinking categories, and no reasoning.

Previous research has shown that young students have a wide range of ideas and representations about the concept of air. We already know that student's difficulty to grasp the notion of air lies first of all on the fact that they can't have sensorial data. They can't see the air thus it doesn't exist (Driver, 1988). The latter explains student's misunderstanding between the invisible and the non-existent.

Sometimes, students express the idea that oxygen coincides with air (Driver et al., 1994; Skoumios, 2012) or that during the process of breathing, the air we breathe in is the exact same air we breathe out making no relations to lungs or heart's function (Driver et al., 1994). The other way around, students may think that the air we breathe does change drastically and as we inhale the air, we exhale the same amount of air turned into carbon dioxide. Another students' perception is that air and other gases are not physical entities (Driver et al., 1994), or they may attribute human characteristics and will to air (Driver et al., 1993). Additionally, students usually believe that it is impossible for someone to trap and transfer air or that there is no air in a closed container or a deflated tire (Driver et al., 1993). Finally, one of the most common perceptions is the confusion of air with its motion (Chang, 2000; Demirbaş & Ertuğrul, 2014; Driver et al., 1993; Piaget, 1930; Séré, 1986; Stavy, 1990) coinciding air with the wind. The latter relates to the invisibility of air while at the same time the fact that they can feel the wind and they can observe the consequences of the wind in the world around them.

Research questions

There is scarce literature about teaching the concept of air or exploring students' preconceptions in the first grades of primary school. It is believed that the present paper will fill this gap although a systematic research approach is demanded. In the present research it was sought to explore students' representations about air during the educational program "Thunderbolt hunt" at the Archaeological Museum of Ioannina. The ultimate goal was to explore the possibility of the formation of a precursor model of thought through science education programs for the early graders.

The research questions were posed as follows:

1. Which are the representations of the early-grade students at primary school about the air?
2. What kind of reasoning do students form about air and its properties?

METHODOLOGY

Sample

The sample included 7 classes of second-grade primary students from 5 schools, 3 urban and 2 suburban schools of Ioannina in Greece. In addition, 4 classes of first-grade primary students from 4 schools, 1 urban, 2 suburban and 1 private school of Ioannina were included. In total, 174 primary students participated in the educational program, 111 second and 63 first-grade students. It was a random sample since the aforementioned classes reserved the educational program “Thunderbolt hunt” for their visit at the Archaeological Museum of Ioannina during 2017 and 2018. As it is mentioned earlier the present research is a meta-analysis of the implementation of the educational program during that period.

The research procedure

The initial goal of the study was not to explore students’ preconceptions. Hence, the data is not comprised by individual interviews from the students as usual. The data of the research was gathered from the videotaped implementations of the educational program which were then transcribed and qualitatively analyzed. During the educational program and before the implementation of the experiments about air, the instructor was asking students some investigative questions to explore what students already know about the concept. After that, she would know how she should handle the concepts in the next action. During the data analysis it was considered that the results bear significant research value, and therefore it was decided to initiate a meta-analysis concentrated on students’ preconceptions. So, all the excerpts of this part of the implementations were gathered, analyzed and classified into categories. Since the former was not part of the initial design, not all students expressed their ideas because they either agreed with a classmate’s idea or they didn’t raise their hand to express their opinion. Consequently, it was decided that quantity results wouldn’t be appropriate for this kind of data. Another decision made for this paper was that there would not be separate results for the first and second-grade students. The data analysis showed no distinction between the first and second-grade students’ ideas, so they are presented altogether.

In the following section of the paper the results from the data analysis are presented.

RESULTS

Before the experimenting phase, students were encouraged to discuss about air and make assumptions. The goal was for the instructor to collect students’ prior experiences and knowledge and take them under consideration in the next phase. Considering that the data was gathered from the implementations of the educational program, as mentioned earlier, the groups’ dynamic was different in every implementation, so the duration of each action could vary depending on the timetable, students’ interest etc. The questions raised during this phase were:

1. What is air or what the word brings to your mind?
2. Where can we find air?
3. Is it possible and if yes, how can we capture it?

The first question was about what the word air brings to students’ mind. The goal was to discover students’ associations with air. The results to this question were classified into the following categories:

- Answers in which air is related to weather phenomena. For example, “a lightning”, “it is the wind”, it is the clouds”, “It is something that blows a lot”, “It is something that if there is a lot of wind, it takes the leaves”, “it can knock over a tree”.
- Answers related to morphological characteristics of air and its components, such as “it’s transparent”, “Air can escape from everywhere”, “we can’t see it”.
- Answers refer to analogies, such as “it’s like water”.

The second question urged students to share their thoughts about where the air is. There were:

- answers referring outdoors such as “in nature”, “in the sky”, “on the mountains”, “outside”,
- answers which associate air with weather phenomena. For example, “outside when it’s raining”, “there is a lightning in the clouds and when it rains, before it rains it blows”, “in bad weather”, “in the clouds”, “where there is wind there is rain, where there is rain there is thunder”.

None of the participating students answered that air exists indoors, in the room they were at. In some cases, the instructor asked the students if there is any air in the room. The first reaction was in almost all the cases negative. Students’ negative answer was followed by another instructor’s question. How do we breathe in here? At once students’ responses changed from negative to positive and they even built on this idea, adding that air has oxygen we breathe which is produced by the trees, “there is air”, “there is oxygen”, “trees produce it (oxygen)”, “there is air and oxygen”, “we breathe oxygen”.

The third question was the one that led students express their ideas about how air can be captured. Their answers are classified into categories:

- answers that refer to containers where air can be put. For example, “in a balloon”, “in a glove”, “in a vase”, “in a glass”, “in a (plastic) bag”, “in a bottle”, “in a sack (like the one Aeolus uses for his winds)”, “in a box without any holes”, “in our mouth”, “We can also trap air in a space because when there is air somewhere, if you close the doors, there will be air inside”,
- negative answers that emphasize on the impossibility of capturing air. For example, “You can’t do that. Why not? (instructor) Because it will escape. How? (instructor) It is air, it’s transparent, it can escape from anywhere”, “Air can escape from everywhere”, “You should close the lid so that it won’t leave. … And if you put some scotch tape on it... Put some glue on it too (another student adds)”, “you can’t catch him”, “No because it is air and it is like water and we cannot…”,
- answers related to other physical entities, such as “Then you should look where the wind blows, to the North and collect wind”, “You can trap air by following it and as soon as you get close to the house, take it with your hands and put it in”,
- answers related to students’ imagination, such as “tell Aeolus”, “or if you stall him (Aeolus)”, “in something made of stones”, “with windproof metal”,
- answers that refer to animistic thinking, such as “with cookies”, “we will use bait”.

Two answers were not classified to one of the previous categories. The first came from a female second-grade student who noticed that “apart from air we can also trap smells”. The second came from a male second-grade student who shared with his classmates and the instructor a related experience about capturing and transferring smoke “Shall I tell you what I did? there was smoke, I closed it in a bottle and left it and when I entered the house, I left it in the house. (student) Really? So, you could trap it huh? (instructor) Yes (student) You trapped it inside the bottle (instructor) Yes and I left it at home (student).

DISCUSSION

Based on the results, most of the students express naturalistic explanations in relation to the question “what is air/what air brings to your mind”. According to Laurandeau and Pinard (1972) categorization, as it is presented in Fragkiadaki (2020, p. 119), most of the students’ answers belong to the sub-category of phenomenism. Students relate air with some meteorological phenomena such as rain, thunder, clouds, wind and its consequences. Some of them express one of air's characteristics, transparency, and only one student compares air with water referring to its fluidity.

In the second question, "where is air/where can we find air?", students again express naturalistic explanations. They refer to meteorological phenomena (rain, thunder etc.) and focus on places outside the learning community where they can feel the existence of air through its motion (outside, on the mountains, in the sky etc.). The idea that air only exists through its motion is described in previous research (Demirbaş & Ertuğrul, 2014; Letsi et al., 2014; Redfors et al., 2022; Sesto Varela et al., 2022). At this point, another instructor's question makes students reflect on whether there is air in the room. After negative responses, the instructor questions how everyone can breathe in the room. This puzzles students and lead them to build on the idea that there is air in the room (there is oxygen, trees produce it, there is air and oxygen) observing a qualitative shift in students' thinking. Some of the students' responses are compatible with the scientific concept in regards with oxygen and how it is produced (trees produce oxygen, there is air) some others refer to mixed reasoning (because there is air … from the trees) and some imply a preconception about air (there is air and oxygen, there is oxygen). In the latter case, it is implied that students do not perceive oxygen as air's component but as a distinct physical entity or that air is oxygen itself (Driver et al., 1994; Skoumios, 2012).

In the third question, students reflect on whether we can trap air and how. The vast majority of students propose containers where air can be trapped. All these responses are classified in the mixed reasoning category because, although the students express that they can trap air, they propose containers implying that they will first be filled with air meaning in most cases motion of the container and closing of its lid. The former is consistent with the literature (Driver et al., 1993) according to which students believe that there is no air in a closed container or a deflated tire. Another group of students is insistent that it is impossible to capture air confirming students' preconception from the literature (Driver et al., 1993). The latter group mostly attributes teleological causality to air, implying that it is meant not to be able to capture it. A different group of students expressing mixed reasoning, agreed that it is possible to capture air, but they focused on the way someone should do it successfully connecting air with another physical entity, wind. For the students who connected air with wind, wind is prerequisite to capture air. A small group of responses refers to students' imagination. The two explanations can be classified in the sub-category of metaphysical causality (tell Aeolus, stall him) since the students imply that Aeolus as the god of the winds (carried away from the narrative preceded) can give some air or that air can be taken by him, coinciding here air with wind. The other two responses are classified in the sub-category not reasoning since they don't show any reasoning at all (in something made of stones, with windproof metal). Finally, there are two responses grouped together, as they show animistic thinking (with cookies, we will use bait) meaning that students will use a bait to trap air as if it was a living thing. Two more responses were not classified in any category as they transfer the capture of air into different contexts. The first student noticed that in the same way we capture air we can also capture smells and the second student shared a personal experience of capturing smoke in a plastic bottle.

CONCLUSIONS

It is a fact that students find it difficult to approach abstract concepts, which is related to their general difficulty of understanding something they can't see such as air (Letsi et al., 2014; Redfors et al., 2022; Sesto Varela et al., 2022). It is noteworthy that another students' difficulty stems from the overlapping between the scientific and everyday language (Solomon, 1988). In our everyday language we use some terms which are identical but with different meaning from the ones in the scientific language, misleading students. For example, we tend to use the same word to describe "air" and its motion, "wind" or when we refer to a plastic bottle, we tend to say that it is "empty". The use of language in cases like the former is suggested to be discussed with the students in organized contexts.

The dominant in the study as we mentioned earlier was students' naturalistic explanations about air. Bearing in mind that naturalistic explanations are considered the preparatory stage of constructing mental representations (Koliopoulos et al., 2009; Sesto Varela et al., 2022), it is important to continue challenging students express their ideas, organize collective science experiments and create conflicting situations that can lead to *turning points in child's science concept formation* (Fragkiadaki, 2020, p. 126).

According to the present results, there is a gap between students' present form of air and the ideal form, i.e., the scientific concept. Students before reaching the 4th grade of primary school, they come across the concept but placed in a broader context. They learn about weather phenomena in pre-school, later on they meet the concept through animals and plants' needs for survival, but up until 4th grade, the concept is related to a broader natural process rather than being studied independently. However, in relation to the results of previous research in early childhood education (Letsi et al., 2014; Sesto Varela et al., 2022; Redfors et al., 2022), students already during pre-school have formed their own representations of air and despite their difficulties, they are capable of replacing their preconceptions with more sophisticated explanations. The above remarks raise questions on whether the concept of air from the perspective of its existence and some of its basic properties should be studied earlier in the formal context.

Science education programs such as "Thunderbolt hunt" seem to be appropriate organized contexts to challenge students' preconceptions and create conflicting situations. Of course, further research is needed to explore how the learning community can influence the teaching process and students' involvement in collective science experiments and whether the museum's context is appropriate for the creation of precursor models of a variety of scientific concepts. Nevertheless, the present paper contributes to the research related to young students' preconceptions about air and draws attention to pre- and in-service teachers and their training so they can better identify and address their students' everyday concepts.

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