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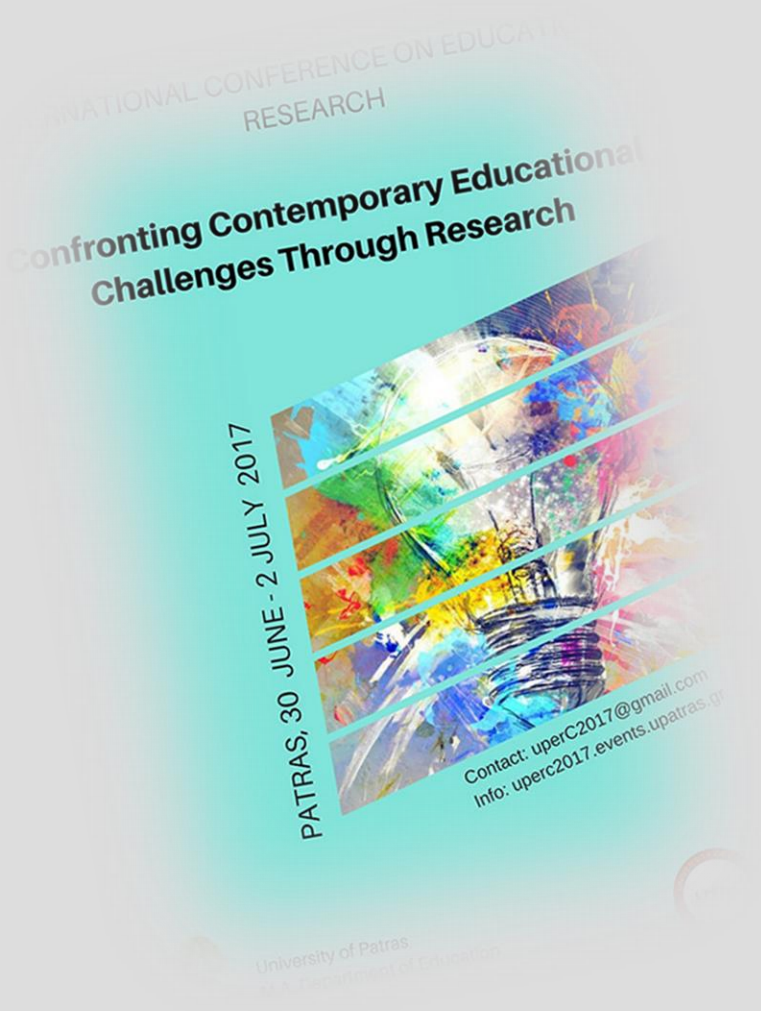
Proceedings



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Preschool Students' Understanding of Astronomical Objects and Solar System and their Categorizations of the Earth

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ABSTRACT
The purpose of the present study was to examine the relation between preschool students categorization of the Earth and their understanding of the concept of planets and the solar system. We used an open-ended questionnaire on the Earth, the planets and the solar system. The results showed that the majority of preschool students understood the concept of planets and could distinguish between astronomical and non-astronomical (physical) objects. High correlations were obtained between students' understanding of planets and their categorization of the Earth, showing that the understanding of planets precedes the categorization of the Earth as an astronomical object. Additionally, high correlations were found between student's categorizations of the Earth and their constructions of the solar system. The categorization of the Earth as an astronomical object is a prerequisite for the construction of the heliocentric solar system, since only students who categorized the Earth with the astronomical objects, constructed a heliocentric model.

Keywords: Earth's Categorization, Concept of Planets, Solar System, Preschool Students

INTRODUCTION

Categorization is one of the most powerful learning mechanisms, considering the fact that if an object is assigned to a category, then it simultaneously gets all the characteristics of the specific category (Chi, 2013; Keil, 1994; Markman, 1989; Medin & Rips, 2005). Additionally, categorization is considered to be a dynamic process, since during development many concepts may change category. This re-categorization is an important process for the learning of science. For example initially plants are considered to belong to the category of non-living things but later they change category and are considered to belong to the category of living things (Carey, 1985). This re-categorization is accompanied by important changes in the characteristics, which are applied to plants.

Previous literature argues that many misconceptions that children have are the result of assimilating the scientific information to their knowledge base without changing their categorizations (see, Vosniadou, Vamvakoussi, & Skopeliti, 2008; Vosniadou & Skopeliti, 2014). However, in many cases learning science requires changes in the ontological category to which an object belongs. For example, concepts like 'force' and 'heat' are initially categorized as substances or properties of objects, when they have to be categorized as interactions in order to carry the necessary explanatory power. These kind of ontological shifts are considered to be the most difficult changes; it appears to be very difficult to achieve an ontological shift when the new category does not exist (Chi, 2013). Contrary in the case of the concept of plants the ontological shift is not considered to be very difficult; it is rather easy to re-categorize a plant from a non-living to a living thing because the children already have formed the category of living things.

The case of the Earth

Studies on cognitive development have shown that elementary school students seem to have considerable difficulties in understanding the scientific concept of the Earth as a rotating sphere revolving around the Sun (Blown & Bryce, 2005; Kampeza, 2006; Nussbaum, 1958; Vosniadou & Brewer, 1992, 1994). Previous cross-cultural research supports that during the preschool years children construct an initial concept of the Earth, which is based on their everyday experience and on lay culture. As a result, the Earth initially is considered to be flat, stable, stationary, supported, physical object, and all the solar objects are located above the Earth, which is in the center of the universe. The scientific concept of the Earth violates all the presuppositions of the initial concept; the

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Earth is a planet, a spherical, unsupported astronomical object that rotates around its axis and revolves around the Sun, found in a heliocentric solar system.

It was assumed that children's' difficulties in understanding the scientific information about the Earth happen, because children initially categorize the Earth with the non-astronomical, the physical objects (those found ON the Earth's surface), and apply to it all the presuppositions of physical objects, like solidity, stability and up/down gravity. The understanding of the scientific concept of the Earth requires that children re-categorize the Earth as an astronomical object (Vosniadou & Brewer, 1992, 1994).

This hypothesis was investigated in detail in a study where elementary school students were asked categorization questions (Vosniadou & Skopeliti, 2005). The results showed that the great majority of the elementary school students could distinguish between physical and astronomical objects and that there was a developmental shift in the categorization of the Earth from a physical object to an astronomical one. Additionally, it was found that the categorization of the Earth as a physical object may constrain students' understanding of the scientific model of the Earth.

In a refutation text study elementary school students were presented with the categorical information that the Earth is an astronomical rather than a physical object, having all the characteristics of the planets; the Earth rotates around its axis and revolves around the Sun like all the other planets do (Skopeliti & Vosniadou, 2016). The results showed that there is an ontological shift in children's categorizations of the Earth from a physical to an astronomical object, and that this re-categorization is a prerequisite for students to understand that the Earth is a spherical planet that rotates around its axis and revolves around the Sun. In the case of the Earth it was hypothesized that this re-categorization is not too difficult since the researchers assumed that the students had already formed the category of astronomical objects and planets. In the present study we wanted to investigate in detail this hypothesis; whether the students that categorize the Earth with the astronomical objects have already formed the scientific concept of planets and how they conceptualize the solar system.

PURPOSE & HYPOTHESES

The purpose of the present study is to investigate how preschool students categorize the Earth and how their categorization of the Earth (as a physical or as an astronomical object) is related with their understanding of the concept of planets and their constructions of the solar system.

We expected that the majority of preschool students would categorize the Earth with the physical objects. Additionally we hypothesized that the students that would show a complete understanding of the concept of planets would categorize the Earth with the astronomical objects. Finally we expected that only the preschool students that would categorize the Earth with the astronomical objects would be more likely to create a heliocentric solar system.

METHOLOGY

Participants

The sample consisted of 21 preschool students from two middle-class kindergartens in the center of Patras in Greece. Their mean age was 5 years and 1 month. Eleven of them were girls and the other 10 were boys.

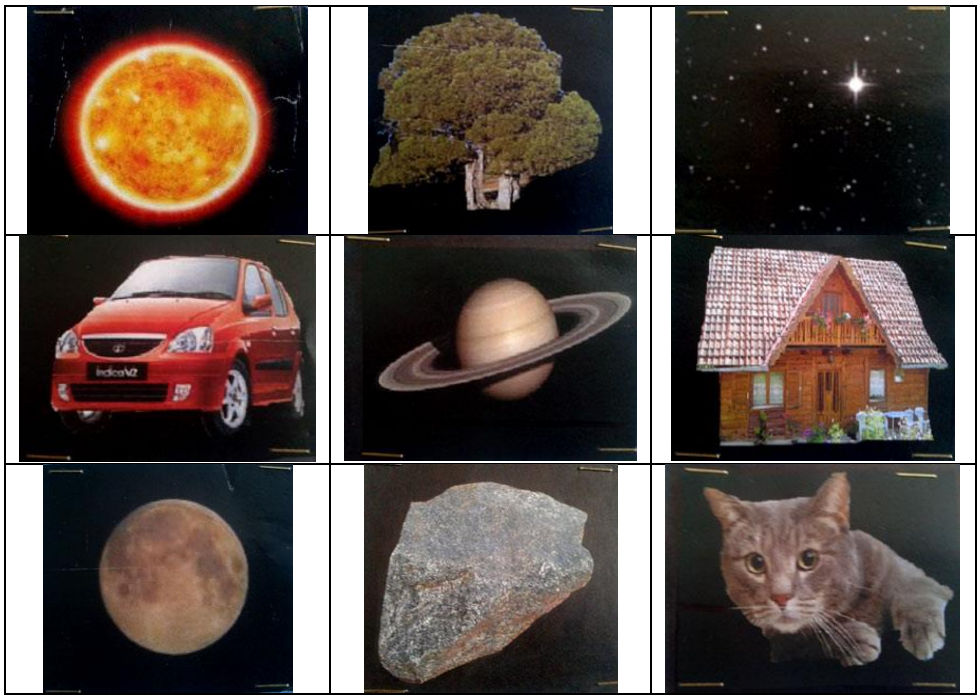
Materials

For the purposes of our study we used an open-ended questionnaire consisting of 11 questions on Observational Astronomy and more specifically on the categorization of the Earth, the concept of planets and the structure of the solar system (see Table 1). The questionnaire was based on the Vosniadou and Brewer studies (1992, 1994) and on the Vosniadou and Skopeliti study (2005).

Table 1. The Questionnaire Used for the Purposes of the Study

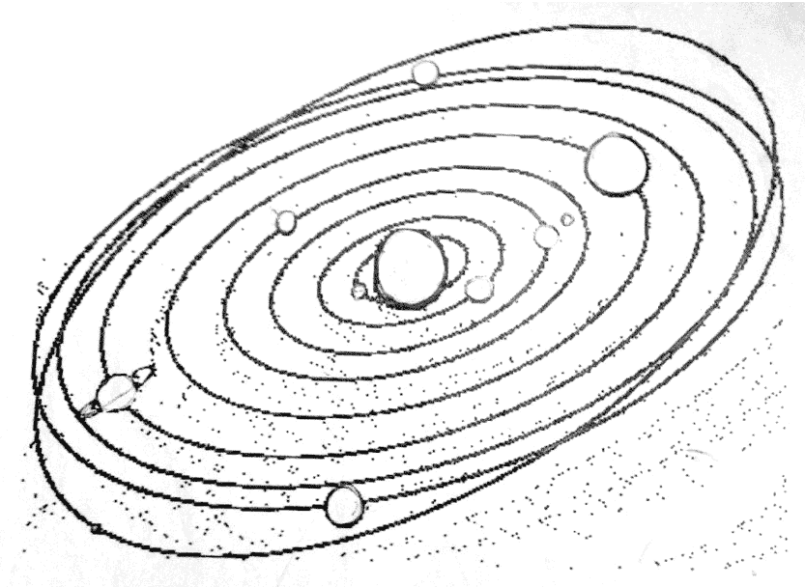
Categorization Questions
Look at these pictures.
3. I want you to put together the pictures that you think should go together, those that belong to the same category.
4. (In reference to Q. 1) Why did you put these pictures together?
5. Does the Earth match with one of these groups?
6. Could you make two groups and put in one of them the pictures that go with the Earth and in the other those that do not go with the Earth?
7. (In reference to Q. 4) Why did you put these pictures together?
Questions on Planets
8. Do you know what a planet is? What is it?
9. Name all of the planets that you know.
A. 8. What is the Earth?
Questions on Solar System
10. Can you draw the Earth, the Sun, and the Moon?
11. Do you know what this is? (showing a picture of the solar system)
12. Can you show me the Earth, the Sun and the Moon? (if he/she doesn't show the Sun) what is this in the center?

For the categorization questions we used 9 pictures; each one of them showed a different physical or astronomical object like the Sun, the Moon, the Saturn, a star, a cat, a tree, a car, a rock and a house (see picture 1).



Picture 1. Pictures Used for the Categorization Questions

For the last part of the questionnaire and more specifically for the questions 10 and 11 we used a picture of the solar system (see picture 2).



Picture 2. Picture of the Solar System

Procedure

The children were interviewed individually in a separate classroom in their school by two experimenters. For the half children one experimenter read the questions and the other one kept detailed notes. For the other half the experimenters changed roles. Each interview lasted approximately 15 to 30 minutes and all the interviews were audio-recorded. When the children's responses were not clear, additional clarification questions were used such as "What do you mean by that" or "Can you explain this a little more?"

First the children were given the categorization task. The experimenter randomly presented the cards to the child and made sure that s/he is familiar with each one of them. Afterwards, the questions on categorization were posed. Subsequently, children were asked the questions about planets and the solar system. Finally, the picture of the solar system was presented to the children, and they were asked the last two questions; children had to show where the Sun, the Moon and the Earth are located.

RESULTS

Categorization of the Earth

Table 2 shows students responses in all the categorization questions of the questionnaire. The results from the current research replicated previous findings (Vosniadou & Skopeliti, 2005). More specifically from the first categorization question the great majority of preschool students (67%) seem to be able to distinguish between astronomical and physical objects.

This was also the case and in the last categorization question, where the children were asked explicitly to make two groups and place in one of them the things that go with the Earth and in the other those that do not go with the Earth. More specifically, the majority of the preschool students distinguished between physical and astronomical objects (77%) and about half of them categorized the Earth with the astronomical objects (48%).

Table 2. Preschool students' categorizations of the Earth in the categorization questions

	Questions	Categories of Responses	Frequency(%)
1	**I want you to put together the pictures that you think should go together, those that belong to the same category.**	**a.** Distinction between astronomical and physical objects (two groups)	4 (19%)
		b. Distinction between astronomical and physical objects (more than two groups)	10 (48%)
		c. No distinction between astronomical and physical objects	7 (33%)
2	**Does the Earth match with one of these groups?**	**a.** Earth with astronomical objects	10 (48%)
		b. Earth with physical objects	6 (28.5%)
		c. No distinction between astronomical and physical objects	4 (19%)
		d. No, the Earth does not match with any of these groups	1 (5%)
3	**Could you make two groups and put in one of them the pictures that go with the Earth and in the other those that do not go with the Earth?**	**a.** Earth with astronomical objects	10 (48%)
		b. Earth with physical objects	6 (28.5%)
		c. No distinction between astronomical and physical objects	5 (24%)

Children were also asked to justify their categorizations. Following previous research (Vosniadou & Skopeliti, 2005) we grouped students' justifications in three major categories. As 'theory-based' was considered the justification that referred to the distinction between astronomical and physical objects (e.g. All these are found on the sky. The others are found down here on the ground.). As 'similarity-based' was categorized each justification that referred to functional similarity or similarity in shape, color, and/or brightness (e.g. All these are round.). 'Arbitrary' were considered the justifications that were based on idiosyncratic grounds (e.g. The car goes with the house, because we usually park the car outside the house). The results in the justification questions replicated previous findings. The students start by giving responses belonging to one of all the described categories. In the last justification question the great majority of the preschool students (67%) gave a theory-based justification for their categorizations, saying that they used for their categorizations the astronomical-physical object distinction (see Table 3). A close look to our data showed that all the students who categorized the Earth with the astronomical or the physical objects used a theory-based justification, with the exception of 2 students.

Table 3. Preschool students' justifications of their categorizations in the justification questions

	Questions	Categories of Responses	Frequency(%)
2.	(In reference to Q. 1) Why did you put these pictures together?	**a.** Theory-based justification	8 (38%)
		b. Similarity-based justification	8 (38%)
		c. Arbitrary justification	3 (14%)
		d. No answer	2 (9.5%)
5.	(In reference to Q. 4) Why did you put these pictures together?	**e.** Theory-based justification	14 (67%)
		f. Similarity-based justification	3 (14%)
		g. Arbitrary justification	2 (9.5%)
		h. No answer	2 (9.5%)

The Concept of Planet

Table 4 shows students responses in the questions on the concept of planets. Very few students, only two out of 21 (9.5%), gave an explanation of planets in the first question. The remaining students only gave examples of planets in order to explain what a planet is (e.g. I know that Saturn is a planet). Some students (24%) referred to astronomical objects instead of planets (e.g. A planet is something like ah… like the Sun or the Moon) but most of them did not respond anything to this question (67%).

Only in the questions that followed, which asked them to give examples of planets and to specify what the Earth is, the majority of the students gave mostly correct examples of planets (73%) and

some of them recognized the Earth as an example of planets (24%), showing that they have a complete or at least a partial understanding of the concept of planets.

Table 4. Preschool students' responses in the questions about the concept of planets

	Questions	Categories of Responses	Frequency(%)
6.	Do you know what a planet is? What is it?	**a.** Gives description of planets	2 (9.5%)
		b. Gives examples of astronomical objects	5 (24%)
		c. No answer	14 (67%)
7.	Name all of the planets that you know.	**a.** Reference to planets (Earth included)	12 (57%)
		b. Reference to planets (Earth not included)	3 (14%)
		c. Reference to irrelevant objects	2 (9.5%)
		d. No answer	4 (19%)
8.	What is the Earth?	**a.** Already mentioned the Earth as planet	12 (57%)
		b. Planet	5 (24%)
		c. Other (where people live)	3 (14%)
		d. No answer	1 (5%)

Students' responses in these questions were used in order to assign the students in groups regarding their understanding of planets. Four major categories of understanding were used. Students were placed in the group of 'complete understanding' if they gave a description of planets and if they recognized the Earth as a planet. The group of 'partial understanding' was divided in two parts; in the one we placed students who gave correct examples of planets and included in them the Earth, while in the other we placed students who gave correct examples of planets but did not include the Earth in them. Finally, in the 'no understanding' category we grouped students who did not give an explanation of planets, used irrelevant examples as planets and did not recognize the Earth as a planet. Table 5 shows how the preschool students were placed into the different understanding categories. Children's responses regarding planets showed that very few preschool students had a complete understanding of the concept (9.5%). Most of the students, although they did not manage to give a description of planets, still gave correct examples of planets (64%) showing a partial understanding of the concept. Only 4 students (19%) showed that they had no understanding of the concept of planets (see Table 4).

Table 5. Preschool students' understanding of planets

Models of Planets		Frequency(%)
a.	Complete Understanding of Planets – Gives explanation	2 (9.5%)
b.	Partial Understanding of Planets – Gives correct examples – Earth included	8 (38%)
c.	Partial Understanding of Planets – Gives correct examples – Earth NOT included	7 (33.5%)
d.	No understanding of Planets – Irrelevant explanations or examples	4 (19%)

What is interesting here is that the great majority of the students, who gave the Earth as an example of planets, categorized the Earth with the astronomical objects in the previous categorization task. Table 6 shows in detail the correlation between students' categorization of the Earth and their understanding of the concept of the planet. Ten out of 21 children who categorized the Earth with astronomical object at the same time either showed a complete understanding of planets or considered the Earth as an example of planets. There were 11 students who either categorized the Earth with physical objects or did not distinguish between astronomical and physical objects and additionally did not consider the Earth to be a planet. In conclusion, it appears that only the students who showed a complete understanding of the concept of planet categorized the Earth as an astronomical object [r_s*=.537; p=.007;N=21*].

Table 6. Correlation between the categorization of the Earth and the concept of planet

Categorization of the Earth / Concept of Planet	Complete Understanding of Planets – Gives explanation	Partial Understanding of Planets – Gives correct Examples – Earth Included	Partial Understanding of Planets – Gives correct Examples – Earth NOT included	No Understanding of Planets – Irrelevant objects as example
Earth with astronomical objects	2 (9.5%)	8 (38%)	-	-
Earth with physical objects	-	-	5 (24%)	1 (5%)
No distinction between astronomical and physical objects	-	-	2 (9.5%)	3 (14%)

The Solar System

Finally, in the last part of the questionnaire preschool students were asked questions about the solar system. Their responses in these questions are shown in detail in Table 7. Most of the students drew the Earth, the Sun and the Moon as a circle (62%), said that the picture of the solar system represents 'planets' (52%), and most of them placed the Earth in the center of the solar system (62%).

Table 7. Preschool students' responses in the questions about the solar system

	Questions	Categories of Responses	Frequency(%)
9.	Can you draw the Earth, the Sun, and the Moon?	**a.** Earth, Sun, & Moon: Circle	13 (62%)
		b. Earth & Sun: Circle, Moon: Crescent	6 (28.5%)
		c. Earth: Flat, Sun & Moon: Circle	2 (9.5%)
10.	Do you know what this is? (showing a picture of the solar system)	**a.** The solar system	1 (5%)
		b. Planets	11 (52%)
		c. Irrelevant responses	2 (9.5%)
		d. No answer	7 (33%)
11.	Can you show me the Earth, the Sun and the Moon? (if he/she doesn't show the Sun) what is this in the center?	**a.** Sun in the center	6 (28.5%)
		b. Earth in the center	13 (62%)
		c. Other planet in the center	1 (5%)
		d. Irrelevant object in the center	1 (5%)

Children's responses in the last part of the questionnaire were used to place them in different models of the solar system. The results of this categorization are presented in Table 8. The great majority of preschool students, more than 60% of the children, constructed a geocentric model of the solar system with the Earth being round or flat (see Table 8). Only 6 out of the 21 students (28.5%) managed to create a heliocentric model.

Table 8. Preschools students' models of the Solar System

Solar System Models	Frequency(%)
a. Heliocentric	6 (28.5%)
b. Geocentric – Earth round	11 (52%)
c. Geocentric – Earth Flat	2 (9.5%)
d. Mixed	2 (9.5%)

An interesting finding was that the students, who constructed a heliocentric solar system, categorized the Earth with astronomical objects in the first categorization task. Table 9 shows the correlation between students' categorization of the Earth and their construction of the solar system.

More specifically, 11 out of the 21 students, who categorized the Earth with physical objects or did not distinguish between astronomical and physical objects, did no manage to construct a heliocentric model of the solar system. Contrary, out of the 13 students who categorized the Earth with the astronomical objects, 6 created a geocentric model and 6 managed to create a heliocentric model of the solar system. To conclude, only the students who have categorized the Earth with the astronomical objects constructed a heliocentric solar system model [r_s*=.384;p=.054;N=21*].

Table 9. Correlation between the categorization of the Earth and the solar system models

Categorization of the Earth \ Solar System Model	Geocentric	Mixed	Heliocentric
a. Earth with astronomical objects	3 (14%)	1 (5%)	6 (28.5%)
b. Earth with physical objects	5 (24%)	1 (5%)	-
c. No distinction between astronomical and physical objects	5 (24%)	-	-

CONCLUSIONS

The results of the present study in the categorization task conducted with preschool students replicated previous findings from elementary school students (Vosniadou & Skopeliti, 2005). The majority of the preschool students distinguished between astronomical and physical objects and most of them categorized the Earth with the astronomical objects. Additionally, most of them used a theory-based justification for their categories.

In addition, the results of the present study show that children from a young age (kindergarten) seem to have formed the concept of planets. It appears that this understanding is not explicit, since they cannot give a specific explanation of the concept. However, the fact that most of preschool students gave correct examples for planets shows that they have at least a partial understanding of the concept. This understanding appears to be strongly related to their categorizations of the Earth. It seems that understanding the concept of planet precedes the categorization of the Earth as an astronomical object. This finding adds to the argument that the ontological shift for the concept of the Earth from a physical to an astronomical object is a rather easy change, because it appears that children have formed the scientific concept of planets from early on (Vosniadou & Skopeliti, 2014). Contrary, this change is not expected to be that easy for concepts like 'force' where the ontological shift has to be made from the category of properties to the category of interactions and the latter category does not exist (Chi, 2013). For example, concepts like 'force' and 'heat' are initially categorized as substances or properties of objects, when they have to be categorized as interactions in order to carry the necessary explanatory power. These kind of ontological shifts are considered to be the most difficult changes; it appears to be very difficult to achieve an ontological shift when the new category does not exist (Chi, 2013). Contrary in the case of the concept of plants the ontological shift is not considered to be very difficult.

Finally, the findings of the study add to the literature showing that the categorization is a prerequisite not only for understanding the concept of the shape of the Earth (Vosniadou & Skopeliti, 2005) but for the understanding of other scientific concepts, such as the structure of the solar system. It appears that the categorization of the Earth as an astronomical object precedes their understanding of the heliocentric solar system. This result adds to the argument that categorization is a powerful mechanism because it carries a great deal of implicit information, which can promote learning. In conclusion, it seems that students have to understand the concept of planets, then categorize the Earth as a planet and finally understand all the other scientific information related to the Earth concept, like the shape of the Earth, the solar system, the day/night cycle and the seasons.

The current study faces some limitations, such as the small number of participants, or the fact that only one science domain is used. It would be interesting to investigate and compare how easily the ontological shifts are accomplished and to compare the impact of categorizations in the understanding of scientific information in different domains. Nevertheless, the findings of the present research add to the literature on the importance of the categorization in the process of learning science and may have important implications for the diagnosis of students' misconceptions in science as well as for instruction.

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