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Mental Models Regarding the Concepts of "Space," "Universe" and "Galaxy" Among Secondary School Students

Ortaokul Öğrencilerinin "Uzay", "Evren" ve "Galaksi" Kavramlarına İlişkin Zihinsel Modelleri

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Abstract: The aim of this study was to identify the mental models of fifth and eighth grade students regarding the concepts of space, the universe, and galaxy. The study was performed using a cross-sectional approach, which is a screening-based study model. This study involved two different groups, which were fifth grade and eighth grade students. We investigated the mental models regarding the concepts of space, the universe, and galaxy among these two groups, and evaluated how these concepts differed between fifth grade and eighth grade students. The study was performed with 116 fifth and eighth grade students from a secondary school in a provincial center in northern Turkey. During the study, students were asked three open-ended questions requiring them to explain the concepts of space, the universe, and galaxy. The study data were analyzed using descriptive analysis. The study results indicated that the level of scientific understanding regarding the concepts of space, the universe, and galaxy was low among both fifth and eighth grade students, although eighth grade students exhibited a slightly higher level of knowledge about these concepts.

Keywords: Mental model, secondary school student, space, universe, galaxy.

Öz: Bu araştırmanın amacı, beşinci ve sekizinci sınıf öğrencilerinin uzay, evren ve galaksi kavramlarına ilişkin zihinsel modellerini tespit etmektir. Araştırmada tarama modelinin kesit alma yaklaşımı uygulanmıştır. Araştırmada, sınıf düzeyi açısından beşinci ve sekizinci sınıf olmak üzere iki farklı grup bulunmakta olup bu iki gruptaki öğrencilerin uzay, evren ve galaksi kavramlarına ilişkin zihinsel modelleri incelenmiş, beşinci ve sekizinci sınıf düzeyleri arasında nasıl bir farklılaşmanın gerçekleştiği araştırılmıştır. Araştırma, Türkiye'nin kuzeyinde bir il merkezindeki bir ortaokulun beşinci ve sekizinci sınıfında öğrenim gören 116 öğrenci ile yapılmıştır. Araştırmada, üç açık uçlu soru sorularak ortaokul öğrencilerinden uzay, evren ve galaksi kavramlarını açıklamaları istenmiştir. Araştırmada veriler, betimsel analiz yöntemi ile analiz edilmiştir. Araştırma sonuçları, beşinci ve sekizinci sınıf öğrencilerinde uzay, evren ve galaksi kavramlarına ilişkin bilimsel anlayışın her iki kademede de düşük olduğunu bununla birlikte sekizinci sınıfa doğru bir miktar arttığını göstermiştir.

Anahtar Sözcükler: Zihinsel model, ortaokul öğrencisi, uzay, evren, galaksi.

INTRODUCTION

Astronomy, which is the most ancient field of science, is closely associated with many other scientific fields, and has acquired an increasingly central role in the teaching of the natural sciences over recent years (Trumper, 2006). Astronomy is a field where data is collected and explained through individual experiences (Hannust & Kikas, 2007). Children initially acquire their astronomy-related knowledge through two main sources, which are their personal observations in daily life, and the communication they establish with other people (Vosniadou & Brewer, 1990; Hannust & Kikas, 2007). Knowledge acquired in these ways is generally disconnected from scientific information and facts, and consist of many misconceptions (Sewell, 2002). To ensure the proper learning of astronomy-related concepts, it is necessary to begin

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educational activities about these concepts starting from elementary school, and to continue these activities in later years and stages of education (EAAE, 1994).

The schemas in the minds of students are extremely important in learning concepts. These schemas are representations created by the individual and they are the mental models that emerge as a result of the assimilation of scientific knowledge (Greca & Moreira, 2000). In other words, mental models are specific mental representations of the beliefs, thoughts and perception of events that individuals acquire through their own cognitive processes (Harrison & Treagust, 2000). Mental models are internal/cognitive mental presentations (Bower & Morrow, 1990; Harrison & Treagust, 1996; Rapp, 2005) which students use to describe and explain events, to solve problems, and to share their thoughts with others (Buckley & Boulter, 2000; Harrison & Treagust, 2000). Interesting mental models influence individual functions and guide researchers and teachers with valid knowledge regarding conceptual frameworks of learners (Vosniadou, 1994). The mental models are extremely important in terms of reflecting the conceptual frameworks of students. Individuals build their mental models on the basis of their own expressions and behaviors (Harrison & Treagust, 2000) using the preliminary information they have and the scientific knowledge they acquire during their learning process (Kurnaz & Değermenci, 2012). Studies that attempt to evaluate and explain mental models regarding astronomy concepts (Vosniadou & Brewer, 1992; Sezen, 2002; Panagiotaki, Nobes & Potton, 2008) generally describe three different models, which are the primitive, synthesis, and scientific models. Primitive models refer to the non-scientific opinions of individuals (Sezen, 2002), while scientific models refer to models based on scientific knowledge (Vosniadou & Brewer, 1992). Synthesis models, on the other hand, refer to the models formed through the synthesis of the primitive models that children initially have with the scientific models they encounter during their education (Franco & Colinvaux, 2000; Harrison & Treagust, 2000; Sezen, 2002).

In the studies conducted, it has been seen that students cannot express most of the astronomy concepts scientifically, and the concepts they can express have deficiencies (Ünsal, Güneş & Ergin, 2001; Arıkurt, Durukan & Şahin, 2015). In addition, it has been revealed that students cannot understand the concepts of astronomy taught in school (Keçeci, 2012), they cannot explain them scientifically and that daily life experiences are the factors building perceptions of concepts (Bülbül, İyibil & Şahin, 2013). It is crucial that students' mental models overlap with scientific knowledge because the mental models they have are influential on the future learning progress. The fact that the individuals' mental models which do not overlap with the scientific knowledge affects perceptions on the subject adversely, and prevents formation of scientific model and meaningful learning. As a matter of fact, Kurnaz and Değermenci (2012) state that students who have synthesis models which are not sufficiently compatible with scientific knowledge, do not fully accept scientific models or do not understand them, instead they interprete them in their own way by integrating them with primitive models. Kikas (2005) states that students describe the concepts of astronomy with the information they synthesize from everyday life, and that their daily life information is based on the book, memory, their own inferences and experiences. As a matter of fact, Babaoğlu and Keleş (2018) state that it is important to focus on how individuals interpret the universe and the world they create within their minds, and that the number of studies on mental models and perceptions which is very limited should be increased. The aim of this study was to identify the mental models of secondary school students in fifth and eighth grades regarding the concepts of space, the universe, and galaxy, and to determine the changes that occur in these mental models between fifth and eighth grades. In addition, we believe that this study will provide useful information for the effective teaching of astronomy concepts and the development of educational programs,

while also contributing to the literature regarding the development/improvement of science and astronomy education.

METHOD

Research design

The study was performed using a cross-sectional approach, which is a screening-based study model. Based on this approach, assessments performed on different groups considered as representing different levels/stages of development were interpreted as belonging to the same group; it was thus assumed that results for different groups were continuous with one another (Karasar, 2011).

Participants

This study involved two different groups, which were fifth grade and eighth grade students. We investigated the mental models regarding the concepts of space, the universe, and galaxy among these two groups, and evaluated how these concepts differed between fifth grade and eighth grade students. The study was performed with a total of 116 fifth grade (N=61; female=34, male=27) and eighth grade (N=55; female=26, male=29) students attending a secondary school in a provincial center in northern Turkey.

Data collection tool

During the study, secondary school students were asked to describe the concepts of space, the universe, and galaxy in written asking three open-ended questions. The application was implemented at the end of the spring semester when astronomy topics were included in the curriculum.

Data analysis

The study data were analyzed using descriptive analysis, which involves summarizing and interpreting data according to pre-defined themes by making extensive use of direct citations/quotes, and then organizing the interpreted data in order to present them to readers in an understandable format (Yıldırım & Şimşek, 2011).

Once the codes, categories, themes, and all other phases are checked, results of the qualitative data analysis can be used to determine the representation level of the data set inserted into the analysis (Poggenpoel & Myburgh, 2003). It is important to code by different coders for the same data set. As a general rule, the similarity rate of the data set encoded by different coders is important (Fidan & Öztürk, 2015). This similarity rate also determines the reliability of the qualitative research. This similarity, called internal consistency in Miles and Huberman model and conceptualized as a consensus between coders can be calculated by using the formula of [$\Delta = C \div (C + \partial) \times 100$]. In the formula, Δ is the reliability coefficient, C is the number of agreed subject / terms, and ∂ is the number of nonagreed subjects / terms. According to the coding check which gives the internal consistency, the consensus between coders is expected to be at leat 80%. (Miles & Huberman, 1994; Patton, 2002). For this reason, the data obtained from the students' written expressions was coded, grouped, categorized and edited by two researchers. The reliability coefficient of the study was found 87.012%.

The names of the students were kept confidential (F^{grade}_{n}), and examples of the answers given by students are provided below. Mental models of students; statements representing non-scientific ideas of individuals which is primitive model; statements where primitive models of individuals and the scientific models they confront during their education are synthesized which is synthesis model, and statements based on scientific knowledge were categorized in 3 groups and presented in graphics.

RESULTS

In this study, secondary school students were asked to describe the concepts of space, the universe, and galaxy; the mental models of the students were analyzed based on these responses.

In this study, secondary school students were asked to describe the concept of space. Table 1 shows the responses of fifth and eighth grade students to the question, "*What is space?*"

Table 1. *Student Definitions of the Concept of Space*

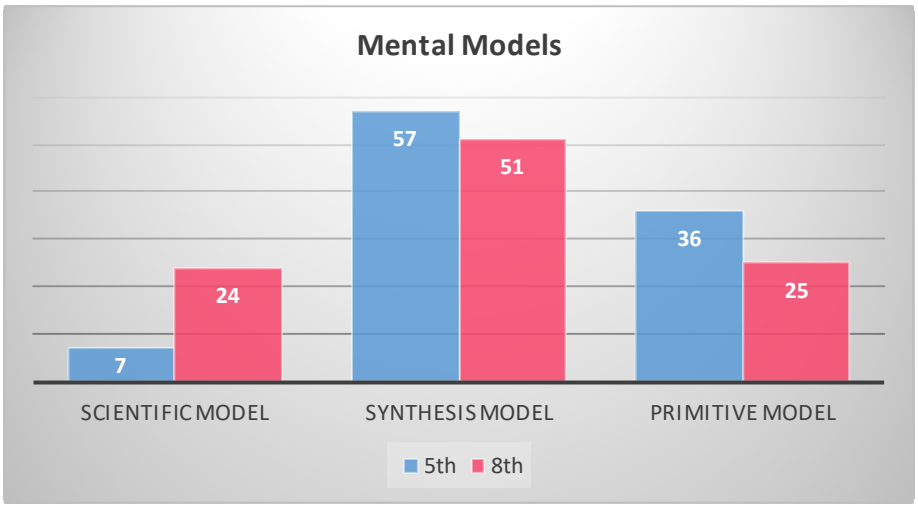
	Answers of Fifth Grade Students	f	Answers of Eighth Grade Students	f
SPACE	The place where planets are found	31	Emptiness/Void	29
	Emptiness/Void	22	Infinite	17
	The place where stars are found	11	A place where there is no oxygen	12
	Space travel	5	A place where there is no gravity	12
	The place where there is no gravity	5	The place where all the planets are found	8
	The place where the sun and moon are found	5	The place where stars are found	6
	The world	4	Dark	4
	The place that encompasses all existence	4	Everything that lies outside our world	3
	Infinite	3	A planet	3
	The place where satellites are found	3	A place where there is no sound	2
	The solar system	3		
	The galaxy	2		
	A place where there is no air	2		
	A very large place	2		
	A planet	2		
	Somewhere dark	2		
	The universe	1		
	Somewhere far away	1		
	The place where meteors are found	1		
	A round and bright place	1		
	The place where galaxies are found	1		
	A place where there is no sound	1		
	No answer	**5**	**No answer**	**4**

Table 1 indicates that fifth grade students had different opinions on what space is, and that the majority of fifth grade students described space as the place where planets are found (f=31), emptiness (f=22), and the place where stars are found (f=11). Eighth grade students provided more scientific explanations regarding the concept of space. As such, eighth grade students described the concept of space as emptiness/void (f=29), infinity (f=17), a place where there is no oxygen (f=12), a place where there is no gravity (f=12), and the place that harbors the planets (f=8) and stars (f=6). Compared to fifth grade students, eighth graders provided answers that were more scientific and common (i.e. less divergent). Examples of the answers provided by students regarding the definition of space are provided below in the form of direct citations/quotes:

Primitive Model: *"Space travel with rockets. The robots go." (F^5_{39})*
Synthesis Model: *"There are planets, Moon, Sun. It's a dark place. (F^5_7)*
Scientific Model: *"It is place with planets and no gravity." (F^5_{57})*

Primitive Model: ***"****It could be great eternity." (F^8_{22})*
Synthesis Model: *"Sound does not propagate in space. You cannot breathe in space, because there is no oxygen." (F^8_{38})*
Scientific Model: *"Space is a dark and infinite void without gravity and filled with planets. Due to the lack of oxygen, sound does not propagate through space." (F^8_{46})*

Graph 1 shows the mental models that were identified based on the comparison of the descriptive answers provided by students regarding the concept of space.



GRAPH 1. *The distribution of student mental models regarding the concept of space*

As shown in Graph 1, less than half of the fifth grade students possessed a synthesis model (27%), while very few students possessed a scientific model (7%). On the other hand, the number of students with scientific and synthesis models increased in eighth grade (reaching 24% and 51%, respectively), while the number of students with primitive models decreased (dropping to 25%).

In this study, secondary school students were asked to describe the concept of universe. Table 2 provides the answers of fifth and eighth grade students to the question, "What is the universe?"

Table 2. *Student definitions of the concept of universe*

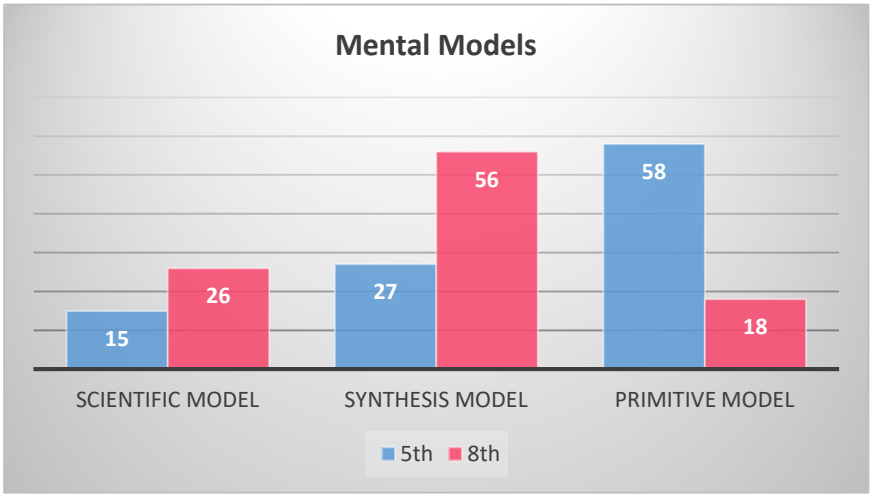
	Answers of Fifth Grade Students	**f**	**Answers of Eighth Grade Students**	**f**
UNIVERSE	The world/earth	22	A place that encompasses all of space	26
	A place that encompasses everything in space	8	The world/earth	11
	A planet	6	Emptiness/Void	10
	A galaxy	5	The place where planets are found	9
	An infinite place	5	The place where stars are found	6
	Life	5	The place where we live	1
	The place where planets are found	4		
	The place where we live	3		
	Space	3		
	Emptiness/Void	2		
	A very large place	2		
	Nebulae	2		
	A place formed by the explosion of nebulae	2		
	A place with star systems	1		
	A place without gravity	1		
	All of existence	1		
	A star	1		
	No answer	**9**	**No answer**	**8**

Table 2 indicates that compared to eight grade students, fifth grade students had a larger diversity of views concerning the concept of universe. The large majority of fifth grade students described the universe as being our world, or earth. These students also described the universe as something that encompasses everything in space (f=8), a planet (f=6), a galaxy (f=5), and life (f=5). Eighth grade students, on the other hand, described space as a place that encompasses everything in space (f=26), our world/earth (f=11), emptiness/void (f=10), and the place where planets (f=9), and stars (f=6) are found. Comparing the responses provided by students from both classes, it can be seen that eight grade students provided more common (i.e. less divergent) definitions for the concept of universe. Examples of the answers provided by students regarding the concept of universe are provided below in the form of direct citations/quotes:

Primitive Model: *"The universe is our world. It is place where people and trees are found." (F^5_{23})*
Synthesis Model: *"They are endless places in the world. Nebulae." (F^5_{28})*
Scientific Model: *"It a vast and infinite place where the earth, all the planets and stars, space, etc... are found." (F^5_{44})*

Primitive Model: *"It is the place where people live." (F^8_{14})*
Synthesis Model: *"It is the eternity that living beings and planets exist." (F^8_{35})*
Scientific Model: *"It encompasses everything that exists in space, both living and non-living." (F^8_{22})*

Graph 2 shows the mental models that were identified based on the comparison of the descriptive answers provided by students regarding the concept of universe.



GRAPH 2. *The distribution of student mental models regarding the concept of universe*

As shown in Graph 2, many (27%) fifth grade students possessed a primitive model, while a comparatively lower number of students possessed synthesis and scientific models (24% and 7%). On the other hand, the number of students with scientific and synthesis models increased in the eighth grade (reaching 39% and 47%, respectively), while the number of students with primitive models decreased (dropping to 14%)

In this study, secondary school students were asked to describe the concept of galaxy. Table 3 provides the answers of fifth and eighth grade students to the question, "What is a galaxy?"

Table 3. *Student definitions of the concept of galaxy*

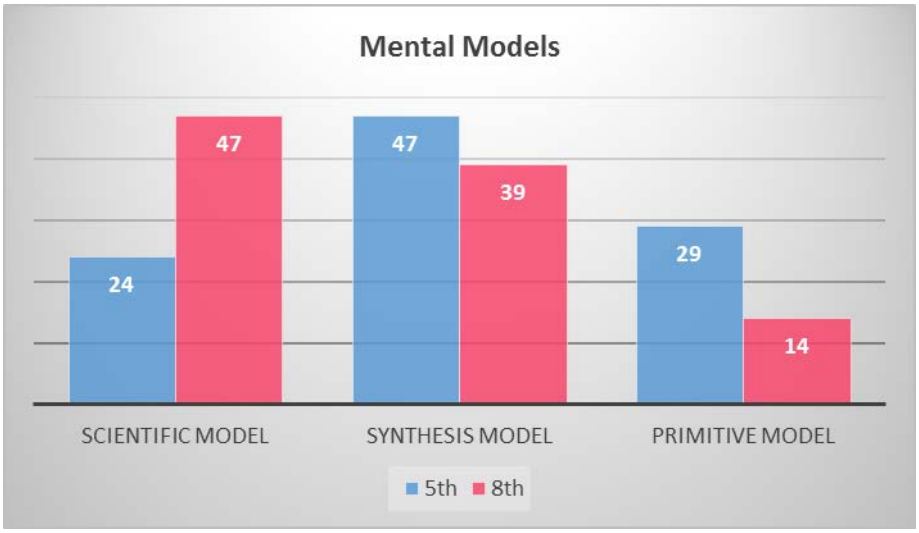
	Answers of Fifth Grade Students	f	Answers of Eighth Grade Students	f
GALAXY	A cluster of stars in space	8	The place where planets are found	9
	The universe	7	A cluster of stars	8
	Pieces of stone floating in space	5	The emptiness of the universe	5
	The place where starts are found	4	The Milky Way galaxy	4
	Space	4	Space	3
	A planet	3	A black hole	2
	The place where planets are found	2	A place found in space	2
	The Milky Way galaxy	2	The emptiness of space	2
	Clouds	2	A planet	2
	The sky	2	The universe	1
	Nebulae	2		
	Satellites	2		
	The Solar System	1		
	Stars	1		
	A group of planets	1		
	No Answer	**23**	**No Answer**	**19**

Table 3 indicates that both fifth and eighth grade students were unable to adequately define the concept of galaxy, and that many of these students left the study question unanswered. An evaluation of student answers in both grades indicated that eighth grade students tended to provide more common (i.e. less divergent) definitions than fifth grade students. The large majority of fifth grade students described the concept of galaxy as being a cluster of stars in space (f=8), the universe (f=11), pieces of stone floating in space (f=6), and the place where stars are found (f=5). On the other hand, the large majority of eighth grade students described space as the place where planets are found (f=9), a cluster of stars (f=8), the emptiness of the universe (f=5), and the Milky Way galaxy (f=4). Examples of the answers provided by students regarding the concept of galaxy are provided below in the form of direct citations/quotes:

Primitive Model: *"It refers to pieces of stone floating in space."* (F^5_{52})
Synthesis Model: *"It is the place where planets are found."* (F^5_{34})
Scientific Model: *"All stars are found in galaxies. A galaxy is a cluster of stars in space."* (F^5_{46})

Primitive Model: ***"****We live in the world. This is space.****"*** (F^8_{16})
Synthesis Model: *"The Milky Way galaxy… it might be a black hole in space."* (F^8_{35})
Scientific Model: *"Galaxies are stars clusters consisting of numerous stars"* (F^8_{21})

Graph 3 shows the mental models that were identified based on the comparison of the descriptive answers provided by students regarding the concept of galaxy.



GRAPH 3. *The distribution of student mental models regarding the concept of galaxy*

As shown in Graph 3, nearly half of fifth grade students (47%) had a synthesis model regarding the concept of galaxy, while nearly a third had a primitive model (29%), and an even lower number of students (24%) had a scientific model. On the other hand, nearly half of eighth grade students (47%) had a scientific model regarding the concept of galaxy. The number of eighth grade students with synthesis and primitive models (39% and 14%, respectively) was lower compared to fifth grade students.

CONCLUSION

The study results demonstrated that both fifth and eighth grade students have different mental models regarding the concepts of space, the universe, and galaxy. It was observed that eighth grade students possessed a comparatively higher ratio of mental models illustrating a scientific understanding of these concepts; however, this increase compared to fifth grade students was not sufficient, with eighth grade students still lacking an adequate level of scientific understanding/model regarding these concepts. In the study most of the fifth and eight grade-students were found to have synthesis model for the concept of 'space', and most of the fifth-grade students were found to have primitive model and eight grade-students were found to have synthesis model for the concept of 'Universe'. For the concept of "Galaxy", fifth grade-students were determined to have synthesis model and eight grade students were determined to have scientific model. In the research conducted by Kurnaz and Değermenci (2012), it has been put forward that 7th grade students have synthesis models that are not sufficiently compatible with the scientific information about the sun, the earth, moon and solar-earth-moon system, and that they do not fully accept or understand scientific models, instead they integrate this data with primitive models by intepreting them in their own way. In the study conducted by Roald and Mikalsen (2001), the earth model in the minds of 9-year-old students was determined to be synthesis model. Similarly, the research conducted by Öztürk and Doğanay (2013) shows that fifth and eighth grade students have seven different understanding and mental models on the Earth's shape and gravitational force one of which is scientific, and that scientific understanding is low at both levels, while it increases a little towards the eight grade. In the study carried out by Canales, Flores-Camacho, and Cazares (2013) where mental models of students between the age of 6-12 on Solar System ware determined it is seen that the rate of mental models reflecting scientific understanding increases as the class-grade increases. It was determined that most fifth and eighth grade students lacked a scientific understanding regarding the concepts of space, the universe, and galaxy, and that, despite a slight increase in the level of understanding towards

these concepts by eighth grade, the large majority of eighth grade students continued to have mental models reflecting alternative (i.e. a non-scientific) understanding of the concepts in question. As a matter of fact, Vosniadou and Brewer (1992, 1994) also state that students have some acquisition from the school knowledge; however this is not sufficient. Moreover, it is thought that the primitive and synthesis models of students continue in the same way as the class level increases because primitive and synthesis models are resistant to change. As a matter of fact, in the studies carried out by Trumper (2000, 2006) on university students' understanding of observed astronomical phenomena and concepts, mental models and misconceptions; and in the study by Vosniadou and Brewer (1994) on the understanding and mantal models of first-third and fifth grade stuıdents on formation of day and night, it is put forward that students studying in different class grades have so many alternative understanding and mental models of observable astronomical phenomena, and despite the increase in education level some of these altenative understanding and mental models show resistance to change. Considering that the mental models created by students lie behind the meaningful learning (Duit & Glynn, 1996), it is thought that determining mental models of students with this regard and planning the teaching this way will have an impact on students to create mental models overlapping with scientific knowledge.

Based on the results of our study, we believe that in order to remedy the students' lack of knowledge regarding astronomy, and to develop their mental models matching up with scientific knowledge, it is both necessary and important to make use of concept networks, three-dimensional models and visuals, concept maps, concept caricatures, informative texts, analogies, texts on conceptual changes, activities that encourage students to think (while also promoting their interest towards the subject), and animations and simulations that allow students to better grasp astronomy-related concepts.

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