

Teaching Astronomy in Kindergarten: Children's Perceptions and Projects

By Ayala Raviv & Miri Dadon†*

Young children are familiar with astronomical phenomena from everyday life, such as the movement of the celestial bodies or the shift from day to night. The present study examines the extent to which kindergarten students understand abstract concepts related to celestial bodies and processes (such as gravity and time), and whether they change their perceptions of these concepts following an educational intervention. The study also examines what children report about this learning experience. The study, conducted in a kindergarten in Israel with 32 students, combined quantitative and qualitative research methods. The children's knowledge of astronomy was examined before and after the intervention. The teacher conducted observations, collected the children's creative projects, and interviewed them. She also asked them if they enjoyed the learning process and why. The findings show that few of the children had knowledge about concepts related to astronomy prior to the learning process, and some expressed misconceptions. Following the intervention, there was a significant increase in the children's knowledge and ability to explain astronomical concepts and many of their previously expressed misconceptions had been corrected. Most of the children said they were interested in learning, although some said they felt fear during the lessons. The results indicate that kindergarten students are able to study topics related to astronomy, although they are abstract and difficult to demonstrate. The conclusion of the study is that teachers should be encouraged to integrate studies of astronomy and space into the science curricula for kindergartens. This should be done using appropriate pedagogy that will increase the children's interest and involvement in learning and avoid causing them fears.

Keywords: Science education, Astronomy learning in Preschool

Introduction

The people of Earth are conquering the outer space. They explore by observations through elaborate telescopes, and by space vessels and astronauts that exit beyond the boundaries of the atmosphere. Mankind has reached space from the first launch of a Russian satellite in 1957, through the first human launch into space in 1961, a Russian as well, through the first human landing - American - on the moon in 1969, to the establishment of manned space stations for space satellites in increasing numbers. The winners of the Nobel Prize in Physics for this year (2019) are three scientists in the fields of astronomy and cosmology, for "contributions to the understanding of the evolution of the universe and Earth's place in the cosmos".

*Lecturer and Researcher, Hemdat Hadarom College of Education, Israel.

†Preschool teacher, Hemdat Hadarom College of Education, Israel.

James Peebles from Princeton University, USA, born in Canada, won the prize for "theoretical discoveries in physical cosmology". Michel Mayor from University of Geneva, Switzerland and Didier Queloz from University of Geneva, Switzerland, and University of Cambridge, UK, both born in Switzerland, won the prize for "the discovery of an exoplanet orbiting a solar-type star."

In February 2019, Israel was the fourth state to launch a spacecraft to the moon named "Genesis", and its developers emphasized that the purpose of the launch was educational - to develop in the younger generation a desire to know and study astronomy and space science. Socially and educationally, there is a worldwide need to raise graduates with space science literacy.

Although reserachers recommended to start teaching about space at early childhood (Spektor-Levy, Kesner-Baruch, & Mevarech, 2011; Eshach, 2006) some teachers are concerned and even avoid teaching of scientific topics in general and astronomy and space issues in particular (Kallery, 2011) because the subject is abstract and difficult to understand (Chastenay, 2018). These difficulties led us to conduct the present study to explore how astronomy can be taught in early age in an effective and enjoyable way that will promote children's ability to recognize and understand abstract concepts in astronomy. The study was also designed to examine whether preschool children may change previous misconceptions about astronomical phenomena and to learn about the children's attitudes and experiences from their learning process.

Literature Review

Teaching Science and Technology in Kindergartens

Educational systems around the world are formulating developmental and social trends and processes in order to fulfill the need to educate students towards science and technological literacy. Studies (e.g. Eshach, 2006; Gelman & Brenneman, 2004; Anderson & Gulberg, 2014) show that science education is appropriate for young children, and that knowledge and understanding of scientific ideas can be achieved at an early age. The prevailing view today in educational systems around the world is that science is an important field in the education of young children (Spektor-Levy, Kesner-Baruch, & Mevarech, 2011). Researchers today no longer ask how early science and technology education should begin, but rather seek the most effective ways to teach it. Exposure of young children to science and math activities is seen by those researchers as important, given their contribution to the development of intelligence and abstract thinking (Eshach & Fried, 2005). However, in practice, it has been found that kindergarten teachers are concerned about the teaching of scientific subjects in general (Spektor-Levy, Kesner-Baruch, & Mevarech, 2011) and topics related to astronomy and space in particular (Kallery, 2011) because these subjects are abstract and difficult to understand. These and other difficulties cause many elementary school and kindergarten teachers to avoid teaching topics related to astronomy and space (Chastenay, 2018).

Although many researchers believe that young children are able to understand scientific concepts, even complex ones, and have the ability to engage in scientific thinking (Eshach, 2006; Gelman & Brenneman, 2004), some previous studies indicate that it is beyond the ability of young children to learn science, and that children aged 4-6 have difficulties in understanding scientific ideas (Kampeza & Ravanis, 2006; Mali & Howe, 1979). Some researchers claim that before age 11-12, children cannot understand that experimental evidence may support or contradict scientific hypotheses and cannot differentiate between variables in a scientific experiment (Kuhn & Pearsall, 2000; Schauble, 1996). According to those studies, young children have difficulty in research-based learning, even when it is done using simple and authentic tasks. Young children find it difficult to formulate a research question, design an experiment to test it, predict the results of an experiment, evaluate its results, identify which variable determines the results, compare variables with each other, and link between cause and effect in a scientific experiment (Kuhn & Pearsall, 2000). It has been argued that young children have difficulty in analyzing the findings of an experiment because they are easily impressed by unusual results and do not pay enough attention to more common outcomes.

On the other hand, many studies published in the last 30 years have shown the opposite (Eshach, 2006; Eshach & Fried, 2005; Gerde, Schachter, & Wasik, 2013). According to these studies, young children do have cognitive abilities that allow them to understand scientific concepts and they are able to acquire and apply the skills relevant to scientific research processes such as selecting a research strategy, formulating research questions and hypotheses, making observations, performing experiments, predicting results of experiments, summarizing the findings, and sharing the results and conclusions. There is evidence that appropriate teaching methods can help young children acquire and learn basic scientific ideas pertaining to common phenomena in the natural world (Eberbach & Crowley, 2009; Kampeza & Ravanis, 2006). According to Gerde et al. (2013), quality science education in early childhood can definitely lay an essential foundation for children's scientific knowledge and interest in science. This foundation further contributes to children's readiness for school and strengthens language literacy and math skills. Researchers also argue that children involved in science research in kindergarten develop a better understanding of scientific ideas when they are older (Eshach & Fried, 2005; Roychoudhury, 2014; Plummer, 2014; Gerde et al., 2013). Early learning experiences can influence children's opinions about and level of interest in various areas of study, how they perceive their own abilities in these areas, and their enjoyment of engaging with them (Eberbach & Crowley, 2009). In addition, encouraging young children to have positive attitudes towards and developing their interest in science and their motivation for achievement in this field improves the likelihood of their short-term and long-term interest in and success in the sciences (Eberbach & Crowley, 2009). The availability of resources in the media and on the internet for children also helps them assimilate difficult and abstract issues. Therefore, the clear conclusion

is that it is desirable and even essential to start teaching science as early as kindergarten or even preschool (Eshach, 2006).

Some researchers have found that kindergarten is the most effective window of time for learning; a process during which neural structures undergo change and new synapses are created (Rushton, Juola-Rushton, & Larkin, 2010). It seems that children's ability to think about abstract ideas, their capacity to select the information they need to draw conclusions, their knowledge bases, and their reasoning skills are all often greater than others perceive them to be (Michaels, Shouse, & Schweingruber, 2008). Therefore, it is worthwhile to maximize learning at young ages, especially in science studies.

Astronomy and Space Studies in Kindergarten

Young children have a natural interest in and curiosity about the wonders and beauty of the universe. This inspires them to learn about it, even the aspects that are abstract and not easily observable (Ödman-Govender & Kelleghan, 2011). Although many researchers are convinced that young children can be taught astronomy, pedagogically it is important to transmit accurate scientific knowledge and data to them in an age-appropriate way (Agan & Sneider, 2003). Even more important is training the educational staff so they feel confident teaching about astronomy and space (Chastenay, 2018).

A study by Kampeza and Ravanis (2006) indicates that young children can grasp basic astronomical concepts. Although the surveyed students had little knowledge prior to learning the subject, the astronomy lessons led to considerable progress and most of them developed an understanding of the concepts. According to Plummer (2014), a core concept in science studies is that of the motion of objects in space. Understanding this involves observations of astronomical phenomena that are explained by the relative position of objects in the solar system and beyond.

Plummer developed an instructional program for teaching this issue that incorporates tests to assess how the young students are learning. In this educational framework, children learned about daily movement of the Sun, Moon, and stars, the phases of the Moon, and the shift between day and night. Plummer found that advances in the children's level of knowledge and understanding were made possible by their ability to visualize objects and their movement through different frames of reference, that is, in reference to themselves or in space.

Kallery (2011) similarly demonstrated that young children can be taught astronomical concepts. Her research was among the first to develop and test the effectiveness of a program for teaching astronomy and space that is suitable for six-year-olds. The teaching program included preliminary preparation of six teachers, who taught 104 children. The teachers' training included relevant videos and animations with explanations, a globe of the Earth, and observations of the Sun (during the day) and the Moon (at night). Through all these means of transmitting information, the kindergarten teachers were careful to present scientifically accurate information. The program was taught in three sessions over two weeks. Its effectiveness was assessed through talks with the children, and by

looking at the paintings and models they created. Kallery found that the children gained knowledge effectively, leading her to conclude that young children could be taught about astronomical phenomena and concepts with great success.

Perceptions of Astronomical Concepts among Young Children

Bryce and Blown (2013) conducted an in-depth study of how young children develop their own models to understand the sizes and motion of celestial bodies. They reviewed studies in which semi-structured interviews were conducted with 248 children between the ages of 3-18 from China and New Zealand. The researchers determined that in different cultures young children perceive the shape and size of the planet Earth as part of a general idea of the concept of “the Earth”, an idea that includes concepts such as physical form, land as opposed to sky, and the place where people live. Those researchers found that science teachers have a decisive influence on children’s perceptions of these astronomical concepts, and that children change their perceptions in this area according to what their teachers tell them. Prior to learning, most of the ideas that children come up with on their own in order to explain the nature of the world around them differ from accepted scientific explanations. Children’s ideas and beliefs based on their experiences are converted to cognitive structures that reflect their understandings built on personal experiences (Türkmen, 2015). Children must address and challenge these perceptions as they study science topics at school. This implies that science education should begin as early as possible, to enable young children to acquire tools and observations that prevent them from developing misperceptions and in order to help them develop correct perceptions of scientific ideas and to enhanced their cognitive abilities (Ampartzaki & Kalogiannakis, 2016). According to these researchers, it is beneficial for young children to learn about the forms and attributes of celestial bodies, since these form a basis for their understanding of other physical properties, such as physical forms and geometry, and to understand familiar astronomical phenomena such as the shift between day and night, solar events, and the phases of the Moon. Such lessons can help children understand the Earth and space in physical and astronomical terms, and to appreciate the beauty of these natural phenomena. Astronomy studies in early childhood offer a valuable and important opportunity to develop responsible citizenship, values regarding global sustainability, improving scientific literacy, and forming a positive attitude towards science. Encouraging young children to act as astronomers helps them learn scientific tasks such as observation, sorting, predicting, experimenting, presenting the findings, and so on (Ampartzaki & Kalogiannakis, 2016). To achieve these goals, the researchers propose a structured educational intervention program for teaching the properties of celestial bodies. Their multidisciplinary approach is characterized by development of activities and teaching content that emphasize two elements: (1) learning the spatial thinking that underlies astronomy; (2) an interchange between Earth-based and space-based perspectives of the form, location, and movement of celestial bodies. These form a basic foundation for understanding abstract

concepts.

The present study focuses on astronomy studies among kindergarten children in Israel. For the purpose of the study, an educational intervention was developed, based on a model of research-based learning. The effectiveness of the program was assessed according to two main aspects: the transmission of knowledge of astronomical concepts and processes to the kindergarten children, and fostering their understanding of these concepts and processes. The study also examines the children's reports on their experiences of the learning process, in order to determine the most effective pedagogical methods of teaching astronomy and space in kindergarten.

The objectives of this study were to examine the ability of 4-to-6-year-old children to learn and understand astronomical concepts and processes, following an educational intervention program, and to assess their experiences of this intervention as expressed in their own words and through creative projects.

The Research Questions were:

- 1) To what extent was there an increase in the level of knowledge, understanding and internalization of astronomical concepts and processes among kindergarten children, following the implementation of an educational intervention program, as compared to their previous level of knowledge?
- 2) To what extent did the children change their previously held conceptions about astronomy and space?
- 3) What do the children express, through their own words and their creative works, about the nature of their experiences in studying the topics of astronomy and space?

Methodology

This empirical study used qualitative and quantitative methods to assess kindergarten children before and after an intervention program.

The study population included 32 kindergarten students from a heterogeneous class made up of students from high socioeconomic backgrounds. There were 14 boys and 18 girls. There were two age groups in the kindergarten: 12 children ages 4-5 and 20 children aged 5-6 years old.

Research Tools and Process

The kindergarten teacher taught astronomical concepts with the help of an intervention program developed for the purpose of this study. This intervention program consisted of nine sessions, each lasting 15-20 minutes. It was conducted over the course of seven months.

The three main study topics covered in the program were:

1. The Sun and the solar system: the properties of the Sun, the structure and components of the solar system, the planets, interactions between the Sun and the Earth, the rotation and revolution (orbit) of the Earth.
2. The Earth: its attributes and structure, gravity, movement.
3. The Moon: its properties and motion in space, interactions with the Earth.

During the lessons, scientific explanations were presented with the assistance of videos and animations regarding astronomical events such as the movement of shadows; the rising and setting of the Sun, Moon, and stars; gravity; and the phases of the Moon. In each session, the children did creative projects related to the learned topics, and presented them to the class.

For the purpose of collecting quantitative data, we used a questionnaire designed to examine children's knowledge and understanding of astronomical concepts and processes. The questionnaire (see Appendix 1) included 14 questions. It was based on a questionnaire used in a previous study conducted in Greece (Kampeza & Ravanis, 2006). Each child completed the questionnaire two times: once before and once after the educational intervention. To assess the differences between the mean scores, a T-test was performed.

During the lessons, the kindergarten teacher made observations and documented the children's conversations and statements. The students' creative projects (which included drawing, cutting, and pasting) were photographed. During the program, a supervisor of preschools and kindergartens from Israel's Ministry of Education came to talk with the children about the topics being learned. This conversation was recorded and transcribed.

Results

Responses to Knowledge Questionnaire

A comparison was made of the number of correct responses the children gave, before and after the educational intervention, to the first 13 questionnaire items, which pertained to their knowledge of celestial bodies and astronomical concepts and processes (see Appendix 1). Each child's score was calculated as a percentage of the number of correct answers out of the total number of questions (see Table 1).

Table 1. Comparison of Students' Responses to Astronomy-Knowledge Questionnaire, Before and After the Educational Intervention (N = 32)

	Mean Score	SD	T-test
Before Study Program	19.73	12.23	-23.657
After Study Program	85.06	17.00	

$p < 0.01$

Table 1 clearly shows that before the children were exposed to and studied the subject of astronomy, their mean score of correct answers on the astronomy-

knowledge questionnaire was low, and that their scores improved significantly after the learning program. Thus, effective learning about astronomical concepts occurred in preschool children.

Table 2 gives a summary of the children's answers to each of the questions. Additional details about the questions and their responses are given after the table.

Table 2. Children's Answers to Astronomy-Knowledge Questionnaire, Before and After the Educational Intervention

	Before Intervention				After Intervention			
	Correct answer	Partially correct answer	Incorrect answer	No answer	Correct answer	Partially correct answer	Incorrect answer	No answer
1. What is the name of the planet we live on?	8		6	18	31	0	1	
2. What shape is the Earth? (cube / disk / sphere / ellipse)	26		6		31		1	
3. What are the three parts of the Earth's structure?	1	1		30	18	14		
4. What is gravity?	5			27	22	7	3	
5. How does the Earth move?	6		6	20	31		1	
6. What is the Sun? (a star / a moon)	15		17		32			
7. Where is the Sun at night? (behind the Moon / covered in clouds / the Sun has gone to be with the other stars/ on the other side of the Earth)			32		30		2	
8. What is the reason for the shift from day to night on Earth?		2	3	27	29	2	1	
9. What is the Moon?	3		6	23	29		3	
10. What is the orbit of the Moon? The Moon orbits the earth / The Moon orbits	8		24		31		1	

around the sun / The Moon does not orbit)								
11. Does the Moon appear only at night Where is it during the day?	7		23	2	29		3	
12. Which is bigger, the Earth or the Sun?	7		25		30		2	
13. What are the names of the planets in the solar system?	Number of planets named		Number of children who knew the names of this number of planets		Number of planets named		Number of children who knew the names of this number of planets	
	1		2		2 3 4 5 6		2 6 15 2 7	

Question 1: In response to the question “What is the name of the planet we live on?”, only eight children knew the name of the Earth, six children gave incorrect answers, and 18 children did not answer the question. Examples of incorrect answers were: Israel, Be’er Sheva (their city of residence); the name of their school, and “the lesser light” (a biblical phrase for the Moon). These answers indicate that the children were unfamiliar with the concept of a planet, and gave answers describing the geographical place where they live.

Question 2: Before the intervention, 26 children correctly answered “What is the shape of the Earth?”, six children did not answer. After learning, all but one of the children knew that the shape of the Earth is a sphere. It should be noted that in Hebrew (unlike in other languages), the answer is given in the question. In Hebrew the name (כדור הארץ) pronounced *kadur ha-aretz* literally means “ball of land”. In contrast, the words in English (Earth) or in Greek (ηΓ pronounced *Gai*) do not specify its spatial form.

Question 3: Before learning, 30 children could not answer the question “What are the three parts of the Earth’s structure?” They did not know the concepts of the core, mantle, and crust of the Earth. Only one child answered the question at all, responding “There is a volcano in the heart of the Earth”. After learning, 18 children gave correct and complete answers using all three terms core, mantle, and crust. Another 14 children remembered one or two of these terms. From this it can be seen that the kindergarten children learned the concept that the Earth is not uniform throughout, but made of three parts, each with its own specific name.

Question 4: The question “What is gravity?” deals with an abstract concept that children are aware of from daily life experiences. However, only five children demonstrated any knowledge of gravity before the intervention, compared to 22 afterwards. For this question, the children were asked to explain this concept in their own words. Some examples of their answers after learning were:

“Gravity causes us not to fly in the air like in the Moon, and we can stand on the ground.”

“Thanks to this, we can stand.”

“It holds us so we don’t fly.”

“Gravity pulls us down.”

These examples show that after the learning process most children explained gravity through the relationship between gravity (cause) and the phenomena they experience in their daily life (effect). They learned that there is some power that causes all these phenomena they described, and that what they have in common is the fact that objects remain on the surface of the Earth and do not rise up from it.

Question 5: In answering the question “How does the Earth move?” only six children were able to describe the Earth’s rotation around its axis prior to the learning. The rest did not answer or gave incorrect answers. Examples of the misconceptions expressed by the children in the preliminary questionnaire were:

“It jumps.”

“It claps its hands.”

“The Earth does not move at all.”

“It rolls.”

These are all types of movement known to children in everyday life, such as their bodily movements, or the movement characterized by a ball. After learning, all but one of the children were able to describe the Earth’s rotation around itself and its revolution around the Sun, demonstrating an understanding of Earth’s movement in space.

Question 6: In their answer to the question “What is the Sun?”, children had to choose between these options: a star / a moon. Before learning, 15 children knew that the correct answer to the question “What is the Sun?” is that the Sun is a star. The other 17 children chose the incorrect answer that the Sun is a moon. During the educational intervention, the children were taught the properties and composition of the Sun. Examples of their answers after the learning are:

“The Sun is a star made up of mostly hydrogen gas.”

“You can’t get near the Sun because it’s very hot.”

The children were also able to describe the concept of heliocentrism and explain that the planets of the solar system orbit around the Sun.

Question 7: In order to answer the question “Where is the Sun at night?”, the children must have an understanding of an abstract idea and describe a process they cannot see with their own eyes. For this question, the children chose one of four options:

1. At night, the Sun is behind the Moon.
2. At night, the Sun goes to other stars.
3. At night, the Sun is covered in clouds.
4. At night, the Sun is on the other side of the Earth.

As shown in Table 2, before the intervention, none of the children chose the correct answer, and instead guessed one of the incorrect answers. Following the learning, 30 children out of 32 answered correctly that at night the Sun is on the other side of the Earth.

Question 8: The question, “What is the reason for the shift from day to night?” was asked as an open question. In the pre-learning questionnaire, only five children answered the question, of which two explained the phenomenon as God’s decision and three children gave explanations describing this from their own experiences of movement, such as:

- “When the Sun is tired it sinks into the water.”
- “Sometimes the Sun leaves and the Moon comes.”
- “Because this is darkness and this is morning.”

Examples of correct answers given following the learning are:

- “In Israel it is night because the Earth is spinning and we do not see the Sun from here. Then it is on the other side, where there is light.”
- “Because of the Earth’s rotation.”
- “The Earth turns and then the Sun on another country.”

Only one child answered incorrectly, saying, “The Sun is gone.” Comparison of the answers to question 8 before and after the intervention show that there was a significant improvement in the children’s understanding of the concepts of day and night. Most of the children were able to give accurate scientific explanations of the relationship between the position of the Sun in relation to us and the states of light (where the Sun is seen) and darkness (the Sun is not seen here; the Sun is seen elsewhere).

Question 9: A similar picture emerges in the responses to the open question “What is the Moon?” Before the learning program, 23 children did not answer the question at all, and six gave incorrect answers, such as: “The Moon is a star,” or “The Moon is a half a banana.”

Three children gave answers reflecting commonly held perceptions, such as: “The Moon is in the sky, in space,” or “The Moon is the lesser light.”

After learning, 29 children gave correct answers such as:

- “The Moon orbits around the Earth.”
 “The Moon is a satellite of the Earth.”
 “It’s the lesser light.”
 “There are lots of craters on it.”
 “The Moon is made of basalt stones.”
 “The Moon reflects the sunlight.”

It can be seen that the children’s answers were not uniform. They expressed varied perceptions and gave different emphases about the concept of the Moon and its characteristics and properties. The children expanded their explanations, using new concepts introduced to them in the intervention process.

Question 10: The children were given four possible answers to the question “What is the orbit of the Moon?” Before learning, eight children knew that the Moon orbited the Earth. The others chose one of the incorrect answers:

1. The Moon orbits the Sun.
2. The Moon does not move.

After learning, 31 children said the Moon orbits around the Earth.

Question 11: The open question, “Where is the Moon during the day?” required the children to give an answer and explain it. In the preliminary questionnaire, 23 children said that the Moon appears in the sky only at night, two children did not answer the question, and only seven children knew that the Moon is also in the sky during the day. After learning, 29 children answered that the Moon is in the sky during the day as well as at night, and only three answered incorrectly.

The following are examples of incorrect answers given to this open question before learning:

- “The Moon is only seen at night, and in the day, it is hiding behind the clouds.”
 “During the day the Moon is with the other stars.”
 “The Moon is in the sky during both day and night, but during the day it is transparent so you cannot see it.”
 In contrast, some of the accurate answers the children gave to this question after learning include:
 “The Moon is in the sky even during the day, but we do not always see it because the sunlight is stronger.”
 “The Moon orbits around the Earth, it does not disappear. Sometimes it is on the other side.”
 “The Moon is always in the sky and there are even days when we see it in the day, but it shines white.”
 “It is not always seen in the sky because the Sun shines stronger than it.”

These examples illustrate the change that took place in the children’s understanding of the location of the Moon. At the end of the learning process, the children were able to explain that sometimes the Moon can be seen overhead

during the day, and sometimes it is on the other side of the Earth. The children also knew how to describe moonlight as a reflection of the sunlight.

Question 12: From the answers to the question “Which is bigger, the Earth or the Sun?” it can be seen that the educational intervention led to a change in the children’s perception of the relative sizes of the Sun and the Earth. After the learning program, the children were able to answer correctly and even were able to describe in their own words that the Sun is a large star, much larger than the Earth, but that looks small due to its greater distance. This means that they learned to relate their perception of the size of a physical object and its distance; that is, they understood that further away an object is, the smaller it looks.

Question 13: In response to the question “What are the names of planets in the solar system?” before the intervention process, only two children could name any planet. After the intervention program, all children knew at least two planets, and some knew the names of up to six planets.

In summary, by comparing the children’s answers to the questionnaire before the intervention to the answers they gave afterwards, it can be clearly seen that young children are able to learn astronomical concepts, understand them, and express them in their own words. The children learned to link processes with their results (for example, the rotation of the Earth around its axis as a cause of the shift between day and night). They demonstrated knowledge of many concepts such as the structure and features of the solar system, the effect of gravity, and the structure of the Earth.

Comparative Analysis of Children’s Creative Projects Before and After the Intervention

During the lessons, the children were asked to do creative projects related to the program’s study topics. A qualitative analysis of their artworks shows that during the course of the learning, they internalized scientific concepts about the structure of the solar system, the movement of the main celestial bodies, the phases of the Moon, and the nature of the Earth’s structure and surface.

In one activity, the children were asked to draw the Earth. The drawing shown in Figure 1 was made by a girl prior to the intervention program. She drew a collection of circular shapes. The girl seems to have drawn from her imagination and not from any knowledge.

Figure 1. Drawing of the Earth, before the intervention



After the intervention, the children were again asked to portray the Earth. The artwork in Figure 2 was done after the intervention process by the same girl who made the drawing shown in Figure 1. After she completed this work, the girl was able to explain that she made the Earth in its circular shape and that most of the surface area is blue because it is covered in water, and that she made the land in different colors according to their elevation.

Figure 2. Drawing of the Earth, after the intervention



In another activity, the children were asked to draw the solar system. The drawing shown in Figure 3 was made by a second child (a boy), who drew the Sun in the center and larger than the other objects - the planets. He colored the Sun yellow, signifying light and heat. Each planet is painted in a different color and at a different distance from the Sun, which indicates that he understands there are multiple bodies in the solar system, and each one is a different distance from the central body. The Earth is colored blue and it is the third in the series. In the background, he drew stars as round, gray shapes. The child demonstrated a basic understanding of the structure of the solar system, in which the star of the Sun is the central body and at different distances from it there are planets, each of which has a characteristic size. In addition, the child demonstrated his knowledge that there are other stars in space.

Figure 3. Drawing of the Solar System, after the Intervention

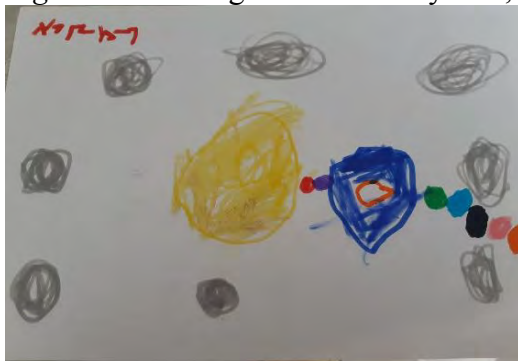


Figure 4 shows the drawing made by a third child (a girl) following the intervention. A large object, not drawn in the center of the page, extends beyond the edge of the page. Its shape is round, and is colored in red, orange and yellow, colors that symbolize light and heat. This represents the Sun. Around this body, are drawn circles in pencil, indicating a path of movement. This girl demonstrated her understanding that each of the planets has its own orbit at a more or less

constant radius around the central body, the Sun. Because the Sun extends beyond the edge of the page, the lines symbolizing the orbits are not drawn as closed circles. This implies that the girl imagined the orbits of the planets around the Sun, but drew only a part of the overall picture. In addition, bumps on the surface of the Sun indicate the release of light or heat from the Sun into space, reflecting descriptions the child heard in the learning process.

Figure 4. Drawing of the Solar System, after the Intervention

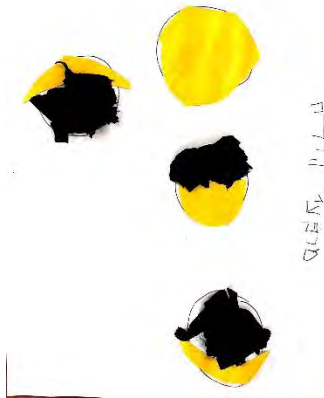


The children were asked to draw the Moon. In this drawing by a fifth child in the class (a boy) the Moon is painted as a yellow circle.

Figure 5. Drawing of the Moon, Before the Intervention



The drawing in Figure 6 was made by the same child who painted Figure 5. This time, when the children were asked to draw the Moon, the boy drew four circles in pencil. Part of each circle was painted in yellow, indicating the visible part of the Moon, and part is painted black, indicating the unseen part. In this work, the child demonstrated a change in his perception of the Moon. He expressed the idea that the way the Moon looks can change.

Figure 6. Drawing of the Moon after the Intervention

Description of Observation: Supervisor's Visit to the Kindergarten

Another aspect of the documentation of the children's explanations of astronomical phenomena is presented in the following partial transcript of an unstructured conversation between the children and a supervisor from the Ministry of Education, who they did not know. The supervisor visited the kindergarten at the end of learning process. The visit lasted about 45 minutes. All the students and the teacher sat together with the supervisor. In the conversation, the children were allowed to express themselves freely in response to open-ended questions from the teacher and the supervisor. The supervisor was not involved in the learning process and did not know what they learned and or to what concepts they had been exposed.

Supervisor: Children, I would like for you to explain to me what you learned about the Sun and the stars

Child 1 (boy): The Sun is very, very hot!

Child 2 (girl): Yeah, it's hot, it's a star you know?

Child 3 (boy): The Sun is made of hydrogen gas and we aren't allowed to go close to it. In fact, we can't because we'd be burned up, even if we are in a spaceship.

Child 4 (boy): Also, the planets orbit around it.

Supervisor: Do you know the planets?

Child 5 (girl): Of course.

Child 2 (girl): There's Saturn and Jupiter and Uranus.

Child 6 (boy): And the Earth, don't forget it, and Mars.

Child 1 (boy): Saturn has rings around it.

Teacher: Children, please explain to our guest why the Earth has life on it and the other planets do not.

Child 7 (girl): It is possible to live here because of the distance from the Sun.

Teacher: Please explain to us what is meant by the distance from the Sun.

Child 7 (girl): Because these planets (pointing to the Mercury and Venus on a poster) are too close to the Sun and the water all dried up, and these (pointing to the planets beyond the Earth) are too far from the Sun, and the water there has frozen, it turned into ice.

Child 6 (boy): And only the Earth is right, where our water is good and we can drink it. This is thanks to God, who put us in exactly the right place.

The children expressed, in their own words, various ideas they learned as part of the intervention program, such as:

1. Characteristics of the Sun - The Sun is a star in space, it gives off light and great heat, it is a body composed of gases.
2. The solar system, the concept of heliocentrism - The planets are bodies in space that maintain a constant rotational motion around the Sun. Every planet has a name, is at a certain distance away from the Sun. The children knew some of the names of the planets.
3. Relationship between the distance from the Sun and heat in a given place - The children expressed the idea that further from the Sun, the temperature decreases. They added that the distance of the Earth from the Sun is appropriate for the existence of life.
4. Relationship between temperature and the state of water - The children described ice as a state of water when the temperature is low, and associated this condition with great distance from the Sun. They described liquid water as a result of conditions in which the temperature is not extreme, and this is dependent on being a certain distance from the Sun - the distance of the Earth from the Sun. They also described a situation where water evaporates (“dries up”) when the temperature is high, a condition that occurs close to the Sun.

From this observation, it can be seen that the children learned and internalized diverse ideas about astronomy and space.

Children’s Impressions of the Educational Experience

The third research question relates to the nature of the children’s experience of the teaching process. Table 3 summarizes the children’s answers to Question 14: Did you enjoy learning about the subject? Why?

Table 3. Distribution of Children's Responses to Question 14: Did you enjoy learning about this subject? Why?

Number of children reporting "I had fun."	Number of children reporting each impression of the astronomy lessons					
	<i>Interest</i>	<i>Desire to explore</i>	<i>Desire of adventure in space</i>	<i>Enjoyable creativity</i>	<i>Beauty and Importance of the Universe</i>	<i>Fear</i>
92	3	6	7	5	6	3

The vast majority of the children (29 out of 32) reported having a positive experience of fun and enjoyment. Of those who enjoyed the program, only two did not give a reason; the others gave various reasons.

Three children expressed interest:

"Because it is interesting."

"Space is interesting and big."

"It was very interesting to learn that the Sun does not really sink."

Six children expressed a desire to explore:

"I learned new things."

"Our kindergarten is always exploring."

"I want to be a researcher like Maimonides."

"It's important to learn and explore."

"It is very fun to explore."

"I did research and told everyone I am a scientist."

Seven children said they enjoyed the idea of having adventures in space:

"I want to invent a spacecraft that will land on the Sun even though it is very hot, but nothing will happen to it because it will be the strongest ever."

"I want to hover in space."

"I want to fly into space."

"I've always wanted to go into space and I also want to fly."

"I'll go into space, too, when I grow up and my mother will let me."

"I want to be an astronaut and fly into space and there I will fly a giant Israeli flag."

"I love spaceships."

Five children enjoyed the creative projects:

"I drew a lot of things I never drew before."

"I built a big beautiful spaceship with my Dad, it was a lot of fun."

"The most fun was when I made a model of aliens with my Mom."

"I had the most fun making a spaceship full of buttons."

"I had fun building all the space stuff together."

Six children noted the sense of beauty and importance of the subject:

“The Earth is ... very important.”

“Space is very large.”

“The Earth is beautiful and the Sun is really special.”

“Space is the most beautiful thing there is, and meteors are special.”

“It is wonderful and important.”

“It is very important that we learn about our Earth.”

Notably, three children expressed fear about issues related to astronomy and space:

“I had fun but it was also scary because it’s so big and far away.”

“I was a little bit afraid because I saw a lot of scary darkness.”

“At first I had no fun because it looked scary and big.”

In summary, according to the findings presented here, this educational intervention to teach astronomical concepts in kindergarten seems to have been successful on several levels. The children demonstrated knowledge and understanding of astronomical and scientific concepts acquired during the learning program. The children learned many new facts, such as the names of planets, the shape and composition of the Earth. They learned about a variety of processes and knew how to explain them (such as the shift between day and night, orbits of the planets around the Sun, gravity). The children also learned about various connections between general scientific phenomena, such as the relationship between the distance from a heat-emitting body and the temperature, the relationship between temperature and the state of water, and the relationship between distance and the perceived size of an object. Most of the children said that they have enjoyed the learning, yet a few of them revealed some fear when learned about astronomy and space.

Discussion and Conclusions

The purpose of this study was to investigate the extent to which young children have the ability to learn and understand scientific ideas related to astronomy and space. The findings clearly show that after the educational intervention, the children’s understanding of both tangible and abstract concepts improved. Their level of knowledge increased significantly after the learning program. The kindergarten students gained knowledge and understanding about the name, shape, structure, and two types of movement of the Earth. They learned about the nature of the Sun and the Moon and were able to explain the structure of the solar system and the movement of the main celestial bodies. The children were able to describe the qualities of gravity and the reasons for the shift between day and night. They also demonstrated an understanding of the relationship between distance from a heat source and the level of heat and the relationship between the

temperature and the three states of water, and the relationship between the distance of the observer from a physical object and its apparent size. In their artwork, the children further demonstrated an understanding of the circular motion of the planets around the Sun and the various lunar phases.

These findings are consistent with previous studies indicating the abilities of 4-6-year-old children to understand various scientific ideas, including those related to space and astronomy (Ampartzaki & Kalogiannakis, 2016; Bryce & Blown, 2013; Kallery, 2011; Spektor-Levy, Kesner-Baruch & Mevarech, 2011). Teaching the science of astronomy at an early age is challenging because it deals with abstract ideas that are beyond children's experiences (objects in space, the movement of celestial bodies, the idea of "forces" and relationships among these celestial bodies). However, these ideas do apply to their daily lives (the shift between day and night, seeing the Sun, Moon, and stars, the daily impact of gravity). Observations and conversations with the children revealed that studying astronomy in kindergarten enriched their conceptual world and scientific language. As a result of this learning, the children acquired new scientific concepts and ideas and were able to express in their own words the ideas they learned. They used terms such as: gravity, living conditions, planet, gas, hydrogen, and the crust, mantle, and core of the Earth. They also expressed through artwork the concept of celestial bodies at varying distances from one another.

The findings of the present study also show that young children who had not yet received formal teaching on scientific subjects had some perceptions about astronomical concepts, but that many of these were incorrect. The learning process succeeded in building their knowledge and enabling the children to express scientifically accurate ideas. An example of this can be seen in the process the children underwent in describing the properties of the Sun. They began with misconceptions, applying human attributes to the celestial body ("the Sun is tired") or describing them as they appear ("The Sun is smaller than the Earth", "the Sun sinks into the sea at night"). Afterwards, they expressed scientifically accurate ideas such as: "The Sun is a star", "The temperature in the Sun is very high.", "The Sun is bigger than the Earth.", "At night the Sun is on the other side of the Earth", "The Moon reflects the sunlight."

The results of this study are consistent with previous studies demonstrating changes in the perceptions of 4-6-year-olds about astronomical phenomena. For example, a study of the perceptions held by 76 preschoolers regarding phenomena on the Earth's surface found that after only two weeks of learning, the children gained new understandings and changed their explanations of these phenomena (Kampeza & Ravanis, 2009). Another example is a study of 33 kindergarten students who, after only two weeks of learning, abandoned their misconceptions and demonstrated new understandings of astronomical phenomena such as the Sun and the Earth as separate spherical objects existing in space (Valanides, Gritsi, Kampeza, & Ravanis, 2000). Some children were able to link the rotation of the Earth around its axis to the shift between day and night. These understandings are necessarily associated with the development of spatial vision (Plummer, 2014), which is crucial for learning engineering and mathematics.

It is not surprising that young children have misconceptions regarding astronomy, as these often originate from experiences that are unexplained or poorly processed. The process by which young children build their knowledge and conceptual world is of special interest, mainly because it can have practical implications for the way elementary school and kindergarten teachers are trained. It is essential that the teachers learn how to teach accurate concepts. Hence, they must first study and understand the subjects they choose to teach (Ampartzaki & Kalogiannakis, 2016). They must have adequate knowledge of the chosen field and the pedagogical skills necessary to teach scientific content and ideas to young children (Andersson & Gullberg, 2014; Bose & Seetso, 2016; Thulin & Redfors, 2017). Lack of knowledge about the subject may lead teachers to hold misconceptions that are similar to their students' misconceptions. Lack of pedagogic skills may make it difficult for them to teach science, since they do not speak the "scientific language" fluently and have difficulty translating it into the language of instruction. Pedagogically inappropriate teaching can lead to the development of fears in children, especially when teaching concepts that seem mysterious or inexplicable. Students should be helped to form perceptions that are as accurate and precise as possible (Eshach, 2006). Hence it is important to encourage and guide kindergarten teachers and properly prepare them to teach astronomy. Kindergarten teachers should be encouraged to become well acquainted with scientific information and pedagogical tools appropriate to teaching science to young children (Andersson & Gullberg, 2014; Thulin & Redfors, 2017) and to help them, through mentoring and training, so that more early education teachers are exposed to the scientific fields and choose to teach science, including astronomy, in to kindergarten students.

Research Limitations and Directions for Further Investigation

The main limitation of this study was its reliance on a relatively small group of children in one kindergarten from a high socioeconomic background. Further studies among different preschool-aged populations are needed. It would also be worthwhile to carry out further studies examining the questions that arise from this study, such as the impact of learning astronomy in early childhood on children's attitudes towards science later in their educational career. Different learning models need to be further explored in order to find the best ways to develop scientific knowledge, thinking, and understanding among kindergarten students.

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