Journal of Studies in Social Sciences and Humanities
http://www.jssshonline.com/
Volume 7, No. 3, 2021, 328-342
ISSN: 2413-9270

Secondary School Children's Understanding of Basic Astronomy Concepts

Felicita Gali
E-mail: galifelcy@gmail.com
Research Scholar
Department of Education
The English and Foreign Languages University, Hyderabad, India

Abstract
Understanding students' prior beliefs about the nature of the universe is a first step in improving astronomy instruction. Pre-instructional beliefs of the students can strongly influence the development of new knowledge. These pre-instructional beliefs which are inconsistent with current scientific understanding are referred to as alternative conceptions. Alternative conceptions in astronomy are an obstacle to new scientific learning. If the alternative conceptions are not dealt with at the elementary level, the likelihood of keeping the alternative conceptions may also persist in higher education. Therefore, teachers need to have a clear understanding of the alternative conceptions that students bring to science classes. This research seeks to identify alternative conceptions of secondary school students in certain astronomical events and phenomena. The sample consists of 38 class IX students from a school in Hyderabad. To uncover students' ideas on basic astronomical topics, 12 probes related to the nature of the planet Earth and the Earth-Moon-Sun system were administered. Students' responses were analyzed to provide information about their knowledge and understanding of astronomical phenomena and to identify their alternative conceptions. The results showed that the students had many alternative views on these astronomical phenomena. Implications and recommendations were made for teachers and textbook authors to incorporate a well-constructed pedagogical design into the teaching-learning process so that alternative conceptions in elementary astronomy can be redirected to conceptual changes among the learners.

Key words: ***science education, basic astronomy, astronomy concepts, alternative conceptions.***

Introduction

Children have a wealth of experiences before beginning school, and these have helped them to develop a common-sense understanding of their social and natural environment. They acquire the knowledge of the celestial world based on their experiences, observations, environment, and interaction with the parents, media, culture, religion, and other socialization factors. Studies have indicated that children construct their own knowledge and interpretations, with which they explain a wide range of natural phenomena. During this process of acquisition of knowledge, learners may view the world in the form of weird concepts which are deviant from the currently accepted scientific knowledge or theories. They bring these ideas that have been formed from their daily experience to their learning environment. The ideas of children often contradict the currently accepted scientific theories. These concepts or inappropriate interpretations have been defined by various terms, for example, "misconceptions", "alternative conceptions", "children's science", "alternative frameworks", "pre-conceptions", "naïve beliefs", "mini-theories", "intuitive notions" and "informal knowledge".

The preferred term used by many researchers is alternative conception because "it refers to experience-based explanations constructed by a learner to make a range of natural phenomena and objects intelligible, but it also confers intellectual respect on the learner who holds those ideas"

(Wandersee, Mintzes, & Novak, 1994, p. 178). Children come to formal science classrooms with various alternative conceptions of celestial bodies and astronomical phenomena. Elementary school astronomy faces complex realities in learning. Several studies in the past reported that even after learning about the basic astronomical concepts and phenomena in the formal classroom, students continue with faulty explanations for the occurrence of day and night, seasons, moon phases, eclipses, etc. Alternative conceptions, which learners carry to formal science education, cut through age, gender, and cultural boundaries. Alternative conceptions are tenacious and resistant to change. Learners' prior knowledge interacts with the knowledge presented in formal classroom instruction, resulting in a diverse set of unintended learning outcomes.

Review of Literature

Many researchers claim that alternative conceptions play a significant role in education and are resistant to reform and pose difficult challenges to science teachers and researchers of science education. Alternative conceptions concerning basic astronomical phenomena could originate from the following sources: Observing the rising and setting sun, interpreting 2-D diagrams that depict 3-D space, misleading diagrams in the textbook, societal mythological beliefs, inability to shift mentally from the earth's frame of reference, strong socio-cultural and intercultural influence, lack of observational skills, science fiction, cartoons, and media. The prior knowledge of the learner combines with the information provided in the classroom and results in many inadvertent learning outcomes. This, in turn, influences their conceptual understanding, their ability to remember, recall, reason, understand, solve problems, and learn new knowledge. Alternative conceptions in astronomy are a roadblock to new scientific learning. If these alternative conceptions are not taken into serious deliberation while teaching or before teaching, the understanding that children develop will be a divergence from what is taught in the formal classroom. Effective teaching/learning cannot occur if alternative conceptions are disregarded. Children's interpretations of natural phenomena are of great importance because they offer powerful insights into their understanding of causality. While important astronomical topics are included in the school curriculum, children who are exposed to information from non-scientific sources may have a distorted conceptual understanding of such topics. According to the curriculum, children should have a good understanding of simple astronomical concepts before they finish Grade 8 (13 to 14 years). However, various studies have found that most children are far from such a comprehensive understanding (Nussbaum, 1979; Vosniadou & Brewer, 1992, 1994; Samarapungavan et al., 1996; Barnett & Morran, 2002; Dove, 2002; Sharp & Kuerbis, 2006; Trumper, 2001; Taylor, Barker & Jones, 2003).

Hannus and Kikas (2007) researched six- and seven-years old children to evaluate their understanding of astronomy and knowledge change during the learning process. This study supported the previous research findings and interpretations of children's views on the earth as a celestial body. Cin (2007) in his study evaluated the middle-school children's alternative conceptions of celestial bodies (earth, sun, and moon). It was evident that children were attempting to combine scientific knowledge with their own beliefs. Chiras and Valanides (2008) studied the conceptual models of fourth and sixth-grade elementary school children concerning day and night. The researchers noticed that majority of the participants had adopted models that could be categorized as "geocentric". When analyzing the children's incomplete interpretations, it was found that many answers were based on wrongly held assumptions that the moon is always visible in the night sky. Plummer et al. (2011) investigated the interpretations of elementary school children on the apparent motion of the celestial objects. The findings were consistent with the previous study explaining how early to middle school children mostly work on synthetic mental models for observational astronomy-related topics. Özsoy (2012) in his study discussed the early experience of elementary school children and their knowledge of the spherical earth concept. The findings of this study have shown that drawings are a powerful tool for exploring children's conceptions of the earth. Findings have also shown that cartoons, storybooks, and daily life experiences were the causes of children's alternative conceptions. Radhakrishnan (2013) examined astronomical misconceptions prevalent among high school children in Kerala, India, using the survey method. Results showed that most of the participants had misconceptions of astronomy.

Anantasook, Yuenyong and Hume (2015) researched the perception of 41 Thai children (Grade 9) about the motion of celestial bodies in their social and cultural context. These findings indicated that the social and cultural backgrounds of Thailand might have affected the knowledge construction of children. Turk, Kalkan, Iskeleli, and Kiroğlu (2015) identified the mental models of seasonal formation for elementary school children and examined how these models could change at various grade levels. The findings showed that children had developed multiple mental models on the formation of seasons. Aydin (2017) investigated children's perceptions of the earth, sun, moon, and EMS systems and how they interpret the astronomical concepts by administering the 'Astronomy Attitude Scale'. In this study, it was pointed out that children have inadequate knowledge of the interpretation of concepts, and the influence of everyday language, textbooks, and many other similar reasons might have resulted in their failure. Aydin, Keleş and Hafizoğlu (2018) attempted to evaluate the mental models of high school children on the concepts of the EMS system. This study showed that children did not understand these concepts adequately and a few could not reflect or reproduce what they have learnt.

In the Indian context, we do not find an adequate number of studies that have investigated the alternative conceptions of children in astronomy. Therefore, this study attempts to explore children's observations about celestial space, their knowledge about the basic astronomical concepts and phenomena, in particular the concepts related to the nature of planet Earth and the Earth-Moon-Sun system.

Research Questions and Hypothesis

For the purpose of the study, the following research question and hypothesis were formulated.

Research Question: How do Children explain their conceptual understanding of the nature of planet Earth and the Earth-Moon-Sun system?
Research Hypothesis: Children interpret and explain the various astronomical events and phenomena from their alternative frameworks that are derived from their daily observation, textbook knowledge, religious, cultural, and social contexts.

Participants

To achieve the objectives of this study, 36 children of Grade IX were selected. Out of 36 children, 18 were boys, and 18 were girls. The sample was drawn using a purposive sampling method, which is a non-probability sampling method. The research was conducted at a CBSE school in a semi-urban area in the Hyderabad District of Telangana. The reason for selecting this school was that the children of this school come from families of moderate socioeconomic status, of various cultural and ethnic origins. Besides, they had received formal instruction from the same teacher on basic astronomical topics under the unit 'Stars and Solar system' in their previous academic year (Grade 8).

Instrumentation

The approach of this study is qualitative descriptive research. The researcher administered 12 probes on elementary astronomical concepts related to the nature of planet Earth, Sun-Moon system, and Earth-Moon-Sun system to elicit children's ideas and promote classroom discourse and data collection. "A probe reveals significant data about children's thinking - for example, their scientifically correct ideas, their misconceptions, their partially formed ideas, and the types of reasoning and connections they use to make sense of phenomena or concepts" (Keeley, 2011, p. 12). The probe comprised of two parts, in the first part students were asked to select the correct claim from the list of statements given and in the second part to give their explanation as to why their claim is correct while supporting their claim with enough evidence, conceptual understanding and reasoning.

Procedures of Data Collection

Children's conceptual understanding of astronomical phenomena was obtained from their written descriptions to the 12 probes related to the nature of planet Earth, Sun-Moon system, and Earth-Moon-Sun system. The study participants' written answers to the probes were examined to establish the level of conceptual understanding inherent in their explanations. Children's explanations for the probes were categorized into three types viz. naïve explanations, partially scientific explanations, and accurate scientific explanations. At this stage, the data obtained from the written explanations for all the probes were analyzed using descriptive/summative content analysis, which is one of the qualitative data analysis techniques. Classroom discussions were conducted to support and validate the researchers' interpretation of written responses given by the participants.

Findings of the Study

The results indicated that the sample of this study retained certain misconceptions in astronomy even after having completed their formal classroom teaching-learning in elementary astronomical topics. Most of the participants had forgotten the scientific concepts, facts, and explanations learnt in school. Instead, they used their everyday knowledge and experience to justify their reasoning to the probes. Their responses were similar to the explanations given by children in other observational studies. There were, however, synthetic responses that combined daily knowledge with causal reasoning. The research has shown that the scientifically accurate responses given by a few children did not indicate that they understood the phenomena well but just provided the textbook information without thoroughly understanding the concepts. Children had well-developed and firmly held beliefs even before formal instruction. Using these ideas and beliefs, they tried to give explanations to the probes. These beliefs were frequently not consistent with the currently accepted views. Many teachers believed that children would acquire the currently accepted scientific understanding after formal instruction. However, research has shown that this simple assumption, especially in science education, is not valid (Taber, 2003). Often, children end up with a mixed model, combining their prior knowledge, textbook information and explanation presented by the teacher. From these findings, it is evident that many such mixed models were expressed by the children as alternative conceptions to these elementary astronomical phenomena.

The Nature of Planet Earth

In this first section on 'The Nature of Planet Earth', children's knowledge of the concept of a spherical earth, gravity, the formation of day and night, and apparent motion of the sun and earth were probed. To determine their understanding of these concepts, Keeley's probes such as "Is the earth round?", "where do people live"," What causes day and night", and "two Rs' (rotation and revolution)" were administered.

38.4% of the participants gave naïve explanations, out of which 14.3% were boys, and 24.1% were girls. Out of 30.9% of the participants who wrote partially correct scientific explanations, 17.1% were boys, and 13.8% were girls. The percentage of children who provided correct scientific explanations was 30.5% and out of which 18.5% were boys and 12% were girls. Overall, the result indicated that the level of conceptual understanding of boys was better than the girls about the nature of planet earth. While a good percentage of boys' explanations were scientifically correct, girls' explanations were mostly derived from their daily experience and perception. For children to understand different concepts in science and astronomy, such as the moon, planets, the solar system, the stars, geography, atmosphere and environment, their perception of the earth as a spherical ball in space is important.

For the first probe **"Is Earth really round?" (1),** though many participants expressed their idea of spherical earth but did not give proper evidence to support the spherical concept. Children with hollow earth models (Vosniadou & Brewer, 1992) seemed to have accepted the earth as a spherical planet but thought that people live on the flat ground inside the earth, and the sky is in the upper portion of the sphere. There were a few children who had a 'dual earth model' (Vosniadou & Brewer,

1992) and they thought that the earth on which people live was flat and that the other earth in the sky was the planet. Even though these participants had learnt the scientific information about the spherical earth during formal instruction (Grade 8), they held dual and hollow models of the earth. The reason behind this is that the children with the dual earth model still considered the earth as a physical entity rather than an astronomical object. Therefore, they hold on to the presupposition that the earth is flat and that unsupported objects fall, at the same time accepting the information taught in school about the spherical earth, which is a planet. Children with a hollow sphere though accepting the earth as spherical, still, hold on to the belief that unsupported objects fall. In moving from initial ideas to the scientific ones, children acquire these intermediate ideas, which are known as synthetic models (Vosniadou & Brewer, 1992).

Some of the expressions given by the participants are given below:

"We live on the flat portion of the Earth, but there is another round Earth, globe/planet".

"Our Earth is very big, and we live on a flat, small and middle portion of the Earth that is why we can't see its spherical shape".

"Yes. Earth is spherical, but we live on the flat portion. Because Earth is excessively big, we cannot see its spherical shape. If we see from space or rocket, we can see it as a round or sphere."

"Astronauts have seen the earth from space and told us that it is spherical in shape".

In the second probe **"Where do People live?" (2),** children were asked a question about what would be seen on the other side if they see the earth through an x-ray vision. It was truly clear from their responses that they did not have a comprehensive understanding of the spherical nature of the earth and the idea that people could live anywhere on earth. They could not relate the ideas of people standing on the sphere and the concept of gravity. Children (80%) with dual earth models expressed that people are living on a flat portion of the Earth and there is nothing inside the earth except rocks, soil, and water. Around 14% of children had a partly right understanding and claimed that people could live everywhere on the sphere without falling, and when seen through the transparent earth, we see the head of the person standing on the other side of the earth. Just a few (6%) children had the right perception that people would live anywhere on earth without falling off, because of the gravity of the earth.

The expressions of some of the participants related to this concept are given below:

"We live on the upper portion of the round earth. When we look through the earth, we do not find anything under the earth except for rocks, soil, water, and dirt. When we dig the earth, we find only that".

"*We live on every part of the sphere without falling off because of gravity. If the earth is transparent and we can see the other side of the earth, we see people living on the other side of the earth. But we can see their heads, not their soles".*

"We can live all over the sphere. We do not fall off because of the earth's gravity. If we see through the earth, we can see the feet of the people standing on the other side".

To further understand the knowledge and conceptions of children about the nature of the earth, the third probe **"What causes Day and Night?" (3)** was administered. The purpose of this probe was to ascertain if the children could equate the idea of the shape of the earth and its spin with the day and night cycle. The required scientific understanding for the formation of day and night is that it takes 24 hours for the earth to rotate on its axis, while the one side of the planet which faces the sun, receives sunlight is called day, the opposite side of the planet that does not receive sunlight is in the dark and is called night. Most of the children (72%) gave the correct description for the day and night cycle. A few children (28%) gave their explanations based on their everyday experience of 'appearance and disappearance' of the things. It can be said that these children did not use the earth's rotational motion to describe the formation of night and day, which implied that they need help to connect the concept of earth's rotation, and the day and night cycle formation.

The survey results showed the following explanatory mechanisms for the formation of day-night:

"*The appearance of the Sun and the disappearance of the Moon cause day, and the appearance of the Moon and stars causes night".*

"Earth spins on its axis once a day. This motion of the Earth is called rotation. This is the reason for day and night to occur".

"Earth revolves around the Sun causing day and night cycle to occur".

"When the Sun comes on the side of the Earth, it is daytime, and when the Moon comes on the side of the Earth it is nighttime".

The fourth probe under this section, **"The two Rs" (4)** (Rotation and Revolution) surveyed children's ideas about Earth's motions and their diagrams which supported their explanations. Many children (44%) had a good understanding of the difference between rotation and revolution; about 13 children (36%) did not know the correct definitions of the terms but described the Earth movements correctly; 20% of the children were confused about the meaning of rotation and revolution. Though the problem existed with the vocabulary, children had a conceptual understanding of the earth's movement. Some of the explanations of children to this probe are given below:

"Earth rotates on its axis causing day and night. It revolves around the sun to make a year/ to cause seasons".

"Rotation means turning like a top; revolution means moving in a circle like a merry go round".

"Both are the same. The earth revolves and rotates around the sun".

"The motion of the earth around itself is rotation, and its motion around the sun is the revolution".

The Sun-Earth System

Our everyday life is regulated by the relationship between the planet earth and the sun. The ability to visualize them in space enables us to understand astronomical phenomena such as day and night and seasons. In this section, the first two probes dealt with the primary observations and ideas on the relationship between the sun and earth. The last two probes in this domain explored why we encounter various seasons throughout the year.

Children were found to have given naïve explanations out of which 13.9% were boys and 13.4 % were girls; about 52.3% (23.6% boys and 28.7% girls) of the sample had given partially correct scientific explanations while 24.4% (12.5% boys and 7.9% are girls) of the participants had given a correct scientific explanation to the probes related to the sun-earth system. It was evident that both boys and girls lack a scientifically correct understanding of the probes related to the sun-earth system, and most of their responses to the probes were partially correct and might be the result of knowledge gained from the textbooks, which they memorized, rather than from their conceptual understanding.

The first probe under the sun-earth system, **"No shadow" (5)** was designed to study the ideas of children related to the formation of shadows and why the sun is never directly overhead. Very few children (29%) could give a correct explanation for the formation of shadows and why the sun is never directly overhead. Many children clearly expressed their misconception that the sun was directly above their heads at noon. Children have only described shadows and how they are formed instead of explaining why shadows are not formed at times in certain places. A clear alternative explanation for the location of the sun is the assumption that the sun is directly overhead at noon. Some of the children's explanations for this probe are given below:

"It depends on where you stand. Light is responsible for the shadows to fall. If we are standing in a dark room, no shadows are formed".

"The formation of shadows depends on where we live. Because some people do not get shadows for months like Greenland, Antarctica, Norway, they have no sun. So, no shadows are formed".

"It does not depend on the season because the sun is always present. Only when the clouds cover during monsoons, no shadows are formed".

"At noon, no shadows are formed because the sun will be directly overhead. For shadows to form, the light source should be either left or right".

The third probe in the Sun-Earth system**, "What is moving Sun or Earth?" (6)** elicited children's knowledge and understanding of the earth's orbit. The majority (86%) of the study participants chose the right argument that the earth orbits once a year around the sun. A very few (30%) gave the scientific explanation to support an annual cycle. Many supported their argument with the earth's spin on its axis and that this movement induces the formation of seasons. Some of the explanations of children are given below:

"The Earth goes around the sun. This we called it a revolution. It takes one year to make a complete one orbit around the sun. Because of this revolution around the sun, we get different seasons".

"*It is the earth that goes around the sun, not the other way. Sun is stationary. Earth is a planet that goes around. If the earth does not move, how can we see different constellations during the year? By this, we know that it is the earth which goes around the sun and it takes one year for one revolution".*

"*The Earth takes one day to revolve or to go around the Sun. Moon goes around the Earth. Sun does not move".*

In the probe **"Shorter days in winter" (7**), children were asked to clarify and give reasons for days to be shorter in winter. Only two children (5%) out of 36 participants surveyed could give a reasonable scientific response, i.e., the sun's winter path is shorter, causing less daylight. Many children identified the inclination of the earth's axis as the reason for shorter winter days and long summer days. A few children also expressed that the sun travels faster in winter, making the day shorter, which was an apparent misconception. Some of the responses of the children were:

"In winter we have shorter days because the sun is lower in the sky. Due to shorter days, the earth receives less heat".

"*Earth's tilt is the reason that days are longer in the summer and shorter in the winter. The hemisphere that is tilted closest to the sun has the longest and brightest days because it gets more direct light from the sun's rays. The hemisphere which is away from the sun gets less light and making the nights longer".*

"*I think the sun moves faster in the winter, saving daylight. Due to this reason, we have less light and shorter days, in summer it moves slowly heating the land, and thus we have more heat, and the days are long".*

The probe titled **"Why is it warmer in summer?" (8)** was to evaluate children's views on seasons and the explanation for warmer summer and colder winter. From the responses of the children, it was evident that only a few children (11%) could offer the correct explanation. Most children felt that the earth is tilted but could not correlate the various angles of radiation between sun and earth with the axis tilt; some participants demonstrated the theory of distance: 'The earth is closer to the sun during summer, but farther away during winter'. These participants discovered that the tilt of the planet is related to the seasons and correlated this knowledge to be 'closer' or 'far' from the sun in both hemispheres of the earth. The obvious alternative explanation for the seasons is that the gap between the planet and the sun has shifted over the year; we experience summer when the earth is near the sun, and we experience winter when the earth is further away. Some of the explanations of the children are given below:

"Seasons occur because of the distance between the sun and the earth changes. Earth is closer to the sun during summer and far away from the sun during winter".

"*It is warmer in the summer because the earth is tilted on an axis; because of this, the earth gets direct rays from the sun. It is colder in the winter because the earth is tilted away from the sun; the rays hit us at a different and less direct angle".*

"*Seasons occur due to the earth's tilt. Because of this, one hemisphere bends towards the earth and experiences more heat, in other words, summer. Furthermore, the hemisphere which is bending away from the sun receives less heat, and that is winter".*

Earth-Moon-Sun System

The probes (9-12) under this domain elicited children's conceptual understanding of the moon, its motion around the earth, its phases, lunar, and solar eclipses. The study conducted in the past also showed that describing the relationship between the earth, moon and sun, and the explanation for the lunar phase is difficult for most adolescents. It was observed that 50% (24% boys and 24.5% girls) of the participants have used naïve explanations based on their daily experience and observations, while 42.5% (18.5% boys and 23.6% girls) of the participants have written partially correct scientific explanations. In comparison, only 9% (7% boys and 2% girls) of children have given their responses based on correct scientific explanations. It is evident from these results that the participants' level of conceptual understanding of the probes related to the EMS system is deficient.

The next probe assessed children's explanations of the question **"Does Moon orbit the Earth?" (9)**. Most of the children had the factual knowledge received from formal teaching that the moon revolves around the earth and it takes a month to complete one orbit, but only three children supported their thinking with the proper scientific explanation of lunar phases. Some children did recognize the moon's orbit around the earth, but they thought it would take one day to orbit, and this resulted in a day and night cycle. Some children linked the orbit of the moon around the earth to the occurrence of religious festivals and the lunar calendar. The analysis of the responses revealed the following explanations for this probe on the moon's orbit:

"*The moon orbits the earth once a month. We know this because the full moon day or new moon day (no moon day) occurs once a month only. Full Moon day is called pournami and new moon day is Amavasya. On these days of festivals, we must follow a few rules according to our religion. These days occur once a month".*

"*The earth orbits the sun once a year. However, the moon orbits the earth once a day because of which day and night occurs".*

"*The moon does not orbit the earth. Only it spins on its axis. Because of which we see different phases of the moon".*

The purpose of the probe **"Earth or Moon Shadow" (10)** was to generate children's ideas about the lunar eclipse and phases. A scientifically correct understanding of the lunar phases suggests that the other part of the moon that we believe to be part of the earth depends on the relative positioning of the moon, earth, and sun, as half of the moon is always illuminated by the sun. For the lunar phases, only about 17% of the participants gave the appropriate scientific explanation. Most children (53%) demonstrated that moon phases occur when the moon enters the shadow of the earth, which is the eclipse of the moon. The participants of this study misrepresented the lunar phases through "eclipse" or "interference model" where the earth covers the moon by its shadow or clouds blocking some light. 30% of children gave a typical or incorrect response as the sun covered a portion of the moon, lunar phases occurred. The following are some of the explanations for moon phases:

"Moon phases occur when the moon enters the shadow of the earth".

"*The moon orbits the earth. From earth, we see one side of the moon, which is shadowed. The side facing is always illuminated by the light of the sun. The phases of the moon are seen depending on the position on the earth and the moon".*

"We cannot see one part of the moon because the sun hides it".

The probe on **"The Moon Phase and Solar Eclipse" (11)** was administered to the children to examine if they understand how these two phenomena are related. Studies show that it is difficult for learners to grasp the eclipse phenomena and the shadow positions of the earth and the moon. The analysis of the participants' responses indicated that very few children had enough spatial visualization ability to understand the lunar phases. While children were taught about moon phases and the solar eclipse during the formal classroom instruction, there seemed to be some ambiguity about these phenomena for many children. Only two children gave an accurate interpretation that the

moon would be in the crescent phase just before an eclipse when the moon completely blocks the sun. All the other children responded that for a total solar eclipse to occur, the moon must be in full phase. They justified their answer with the fact that a total solar eclipse can only take place under a full moon since the moon would be "big enough" to cover the sun. The analysis of the responses revealed the following explanations:

"When the moon is in between the sun and earth, the moon completely covers the sun, and it is called a solar eclipse. As the moon gets closer to the sun, it cannot be seen at all. Therefore, the moon will be in the new moon phase just before and after a solar eclipse".

"*The moon will be in the new moon phase during a solar eclipse. Because we do not see the moon during a solar eclipse".*

"*During a solar eclipse, the moon will be in between the sun and earth. It covers the sun completely. Therefore, it should be in the full moon phase".*

The last probe **'Moon Spin' (12)** uncovered children understanding of the moon's spin and the time taken to complete one rotation on its axis. Out of 36 children, only three (8%) children could give the correct explanation that the moon spins on its axis like earth's motion and it takes a month (29½ days) to complete its spin. They have believed that we still see the same side of the moon as it rotates once a month on its axis. Most children (60%) replied that the moon is not rotating on its axis that is why we see the same side of the moon. About 32% of children knew that the moon spins on its axis, but they thought it would take a day to complete one rotation as in the case of the earth. There was clear evidence of confusion between spin and orbit, or revolution and rotation among the children. Some of the explanations given by children are given below:

"The Moon completes its spin around its axis and its revolution around the earth at the same time (29.5 days)".

"The Moon completes its spin around its axis and the revolution around the earth in an equal period. For this reason, we always see the same side of the moon".

"I know that the moon spins on its axis. But I think it takes one day just like the earth. That is why we have day and night".

"We are always able to see one side of the moon. Therefore, I think the moon does not spin on its axis".

Discussion

The qualitative data analysis of children's conceptual understanding of celestial bodies and their associated phenomenon was consistent with the overall constructivist view of learning. Children's perception has been profoundly influenced by primary and secondary sources of knowledge. Alternative conceptions observed in this research indicate that children lack observational skills, and their conceptual understanding of basic astronomical concepts was the result of daily experiences, traditional classroom instruction and lack of upper-level cognitive skills.

Research has shown that elementary school children often work on observational astronomy topics from naive or synthetic mental models, and this research confirms the findings of Vosniadou and Brewer (1994). Indian children are found to be with pre-held ideas about astronomical objects, events, and phenomena, along with misconceptions about specific astronomical topics - even after formal instruction. This current study establishes that Indian children have a minimum level of understanding in the area of astronomy, along with previous studies in the Indian context (Mohapatra, 1991; Padalkar & Ramadas, 2008; Radhakrishnan, 2013). Overall, the conceptual understanding of elementary astronomy of this study sample (Grade 9) is average. Regardless of children learning astronomy topics in formal classroom teaching, only a minimal percentage of them have learned and understood astronomical concepts. Most children have had little or no experience of direct celestial observations. The challenges faced by the children to understand the three domains examined in this study are presented below:

The Nature of Planet Earth

The findings of this study indicated that children did not have much difficulty in recognizing the Earth's shape as a sphere. However, they showed an incomplete understanding of the earth, indicating that they held alternative conceptions. This analysis revealed that in their conceptions of planet earth, many children were not post-Copernican, and held many alternate conceptions of various astronomical concepts. For many participants, the idea that the ground below our feet is a ball or sphere floating in space was a confrontational issue. It was found in our study that some children could not relate to the idea of people standing anywhere or everywhere on the sphere and the concept of gravity. Children believed that people live in a flat portion of the earth. The spherical earth with people living on its surface and the earth that pulls everything into its core because of gravity could be visualized by only a few. Most of the children in this study were able to describe the formation of day and night, connecting the idea of a spherical earth and its rotation. Vosniadou and Brewer (1994), Schroon (1992), Sadler (1998), and Trumper (2001) reported similar findings. Dove (2002) showed that in a UK scientific review, most of the children (91%) could describe the day and night cycle accurately because only the sun and earth are involved in this phenomenon. A few of the participants had used their daily experience of sun and moon 'appearing and disappearing' as the reason for the formation of day and night. Some children presented themselves as terrestrial observers in their presentations to explain the day and night phenomena.

Most of the participants of this study could easily define the terms revolution and rotation, explaining the motion of the earth. A few were confused about the vocabulary, though explained the earth's movements correctly. Some used the terms interchangeably due to the similarities in the sounds of these terms. One approach recommended by some teachers and textbook writers is to use the terms 'spinning and orbiting' instead of 'rotation and revolution'. Many researchers recommend the use of kinesthetic techniques to teach the meaning of rotation and revolution. Overall, it was evident that children need scientific language to understand the concepts clearly.

The Sun-Earth system

Except for a few, all the study participants had a clear perception of the apparent motion of the sun, from east to west. A few children assumed that the morning sun rose vertically above the horizon and set again in the evening. It can be concluded that the participants did not associate their everyday experiences of seeing the apparent movement of the sun (i.e., the sun rising in the morning) with the spatial view that the Sun is stationary. Very few participants in this study understood the concept of shadows and how they are formed. Though some children could describe the formation of shadows and the importance of light sources, they could not link the ideas of the apparent movement of the sun during the day and the shadow formation. Many children believed that the sun was directly overhead at noon. These results are in agreement with the findings of Plummer and Krajcik (2010) and Trumper (2001).

Most of the participants who responded to the question: what is moving - sun or earth? recognized that the Sun is stationary, and it is the Earth that revolves around the Sun. However, their supporting evidence was based on the Earth's orbit and the formation of seasons due to this motion, not the yearly cycle of constellations. This is because children learnt the earth's orbit around the Sun as a description for the seasonal cycle rather than constellations. Therefore, it should be considered to explain how the Earth's orbit around the sun makes various constellations visible at different seasons.

Most of the children could not give a correct explanation or reason, for the day to be shorter in winter and longer in summer. They could not link the apparent path of the sun to the length of daylight. A high percentage of the sample in the study had clarified the summer and winter phenomena by merely claiming that seasons were triggered by a shift of the earth's axis. The presence of a hybrid model has been revealed through alternate interpretations of seasons: a variation of the tilt of the earth and the distance from the sun. The emergence of this hybrid model is an indicator of children's persistence in interpreting their ideas with what they experience in school. Several research studies (Kikas, 1998; Tsai & Chang, 2005) indicate that having forgotten the scientific explanation, children appear to be going back to distance theory, suggesting that their scientific understanding is incomplete. The analysis showed that the children had not thoroughly explained the cause of the seasons. Several research findings have shown an alternate conception of distance theory, which describes the seasons where the earth is farther away from the sun in winter and closer in summer (Baxter, 1989; Dunlop, 2000; Trumper, 2001; Road & Mikalson, 2001; Sneider, Bar & Kavanagh, 2011). The findings of this study have shown that the interpretation and conceptualization of seasons and the day/night cycle are complex and demanding. Children face many difficulties in trying to understand these two phenomena despite being introduced to scientific knowledge through formal instruction. Rudmann (2002) found that spatial abilities constrained the tendency of children to learn valid scientific reasons for the cause of seasons.

Earth-Moon-Sun System

The findings revealed that it was difficult for learners to grasp the threefold relationship between Earth-Sun-Moon. Plummer, Wasko and Slagle (2011), and Plummer (2014) argued that children have difficulty in describing daily celestial motion because it involves comprehension through moving frames of reference. Much research has shown that it is hard for children to understand celestial motion (Vosniadou & Brewer, 1994; Adams & Slater, 2000; Plummer et al., 2011). One of those difficulties is that children have limited experience of observing changes in the position of the sun, moon, and star. Second, the apparent motion of these celestial bodies gradually happens, which we cannot experience through direct observation. Third, the presence of objects in the three-dimensional sky is hard to visualize accurately. Hence, children's lack of observational skills could have affected their understanding of celestial motions.

Children had factual knowledge of the moon's orbit around the earth and its duration as one month. There was strong evidence of misunderstandings among participants in this study between a lunar eclipse and lunar phases. Concerning lunar phases, solar and lunar eclipses, the difficulties faced by the children are linked to spatial thought and the need to gather pieces of knowledge from the motions of the earth, sun, and moon. Learning the reason for eclipses seems to be as spatially challenging to learn as any other astronomical topics and children need to comprehend the relationship between the earth, sun, and moon. They must visually move from an 'earth-based perspective' to a 'space-based perspective' to understand the connection between what is seen on earth during an eclipse to what is happening in space to cause an eclipse (Kattner, Burrows & Slater, 2018). Even after formal classroom instruction, previous studies found that it was difficult for children to gain a full theoretical understanding of the eclipse process (Barnett & Morran, 2002). Slater (2008) suggested that the use of active models, kinesthetic learning techniques, collaborative learning, lecture tutorials, and computerized tasks to teach the concept of lunar and solar eclipses.

The primary alternative conception for the moon phases seen in this analysis confirms the findings of previous studies, that children were using both the eclipse model (earth blocks sunlight and casts shadows over the moon triggering phases) (Slater, Morris & McKinnon, 2018) and the cloud model (Plummer, 2009), to describe the lunar phases. The most common explanation offered by all age groups was the earth casting shadows on the moon, and it was clear that the participants had ambiguity between the cause of the lunar eclipse and the lunar phases. From these results, it is observed that children's knowledge of spherical earth and observation of the shape of a crescent moon leads them to construct the belief that the moon is sometimes partially shaded by the earth for the phases to occur. Dunlop (2000) found that misleading diagrams in textbooks and out-of-scale models of EMS systems used in the classroom lead to difficulties for children to accept the correct explanation of the phases. Although a few children had described the lunar phases correctly, most of them were unable to understand why these phases occur or have the EMS mechanism defined consistently.

All children, except for a few, could not provide a suitable scientific explanation for a solar and lunar eclipse. Many children, however, suggested that during the solar eclipse, the moon is in the full moon phase. These children conceptualize the full moon that occurs between the earth and the sun. Similar findings were reported by Trumper (2001), Barnett and Morran (2002), and Slater et al. (2018). For those learners who memorized a basic explanation of the solar eclipse (the moon between the earth and sun), it was difficult to recognize what phase the moon must be in during the eclipse.

Another challenging concept for most of the children was to understand the moon's motion, whether the moon spins or not and if it does, how long it takes to complete one spin. While children could explain that the moon rotates, not all children could define the period of rotation. While some children were able to explain that the moon spins for a period of one-month, other children were uncertain of the period. In our study, many children were unaware that the moon spins once a month along its axis. Children require three-dimensional thinking because all moon-related activities are in 3-D space. Hence, within a 2-D diagram, it was difficult for children to explain the concepts associated with the motion of the moon. Some of the participants expressed that we see the same side of the moon and used this as a piece of evidence to validate their argument that the moon does not rotate. Similar misinterpretation was also found by Trumper (2000) in his study with high school students. Spatial abilities such as mental rotation, spatial orientation and spatial visualization are essential to understand the daily movement of celestial bodies in the sky (Wilhelm, 2009; Black, 2005). The inconsistency seen between children's explanation of the apparent motion and its description may be related to their restricted use of spatial skills, required to make a coherent argument.

Implication for Teaching

Learning is enriched if teachers take a close look at the learner's prior knowledge and use this insight as an initial point of instruction. Identifying alternative conceptions of children is essential. Therefore, teachers should use appropriate teaching tools and methods to assess their knowledge base and foster understanding, and thus help reduce their alternative conceptions regarding astronomical concepts and phenomena. Children should be provided with activities including daytime and nighttime naked eye observations of the rising and setting sun, and the effect of seasonal change, and observations with instruments (telescope), where possible. Teachers must pay attention to their children's observational skills because the ability of children to proceed in meaningful and systematic observation of natural phenomena is a necessary condition for understanding many astronomical concepts. To explain three-dimensional phenomena, teachers can use different tools and techniques, apart from textbook figures and illustrations. For example, physical models, computer simulations, and graphics help learners better understand the concepts of astronomy. The use of observation exercises, animations and simulations allow children to better understand the objects, processes, and dimensions of the universe. Computer modeling and visualizations have therefore been suggested for correcting unscientific astronomy ideas. Visits to planetariums and observatories should be encouraged. Field trips to planetariums, observatories can be arranged to raise awareness among the children about the activities carried out in the field of astronomy. Teachers can use kinesthetic astronomy techniques/activities to present basic astronomical concepts easier and more understandable to the primary children.

Conclusion

In summary, this study signifies the first step to examine the conceptual understanding of Indian secondary school children for various astronomical concepts and contributes significantly to the literature. The findings show that the Indian children have many alternative conceptions in nature of planet Earth, Earth-Sun system, and EMS system. The influence of everyday experiences, socio-cultural influences, mythological beliefs, textbooks, lack of sky observation and teaching methods in schools were the reasons for the alternative conceptions. If teachers do not consider children's alternative conceptions, the children cannot grasp the subsequent concepts. If children's existing ideas were considered and addressed by incorporating effective teaching strategies, we can diminish their alternative ideas gradually as children go through secondary school astronomy scientific exposure. This research reveals that the pre-existing ideas of the pupils were not considered and that appropriate science teaching strategies were not used. Hence, the sample of the study had many alternative ideas even after learning these basic astronomy concepts. The study results suggest that a direct transfer of knowledge cannot achieve the conceptual understanding in the children unless their valid and invalid existing knowledge and experience in the fundamental astronomical concepts are taken into consideration in formal classroom teaching. In traditional science teaching, which involves direct transfer from the textbook, children just memorize basic concepts but do not facilitate them to explain and apply the knowledge to comprehend the related concepts. Direct observation of natural phenomena leads to the elimination of many of the alternative notions identified in this analysis. Ausubel (1968) suggested that teachers should "find out what the learner already knows and teach him accordingly" (p. 337). Hence, astronomy education should begin with the discovery of children's preconceived notions and simultaneously ensure that children avoid forming new misconceptions. The study findings suggest that children cannot reach conceptual understanding through direct transfer without considering the accurate and inaccurate prior knowledge and experience of the children during the instruction in the formal classroom. When it involves the direct transfer from the textbook, children merely memorize abstract concepts, without understanding their scientific meaning. They struggle to think, explain, and apply their understanding of the phenomena to real-life situations. From the results, existing methods of teaching the content from science textbooks are not adequate for children to obtain a conceptual understanding of astronomical events and phenomena. The study has indicated that probes are functional tools to detect alternative conceptions. Therefore, it follows that in science classes, particularly in teaching astronomy-related concepts, importance is given to generalizing the use of probes- teaching approach, where teaching and assessment are incorporated into one another.

References

Adams, J. P., & Slater, T. F. (2000). Astronomy in the National Science Education Standards. *Journal of Geoscience Education*, *48*(1), 39–45. https://doi.org/10.5408/1089-9995-48.1.39

Anantasook, S., Yuenyong, C., & Hume, A. (2015). Thai students' understanding about celestial motion within their social and cultural context. *International Journal of Science, Mathematics and Technology Learning*, *21*(2), 11–2. https://doi.org/10.18848/2327-7971/CGP/v21i02/58998

Ausubel, D. P. (1968). *Educational Psychology: A Cognitive View*. New York: Holt, Rinehart and Winston, Inc.

Aydin, S. (2017). 7th class students' opinions on the sun, earth and moon system, Universal *Journal of Educational Research*, *5(*12B): 34–41. https://doi.org/10.13189/ujer.2017.051404

Aydin, S., Ural Keleş, P., & Hafızoğlu, H. (2018). Secondary school students' mental models of the sun, the earth, the moon, and the Sun-Earth-Moon System. *International Journal of Eurasia Social Sciences*, *9*(34), 2425–2437.

Barnett, M., & Morran, J. (2002). Addressing Children's Alternative Frameworks of the Moon's Phases and Eclipses. *International Journal of Science Education*, *24*(8), 859–879.

Baxter, J. (1989). Children's understanding of familiar astronomical events. *International Journal of Science Education*, *11*(5), 502–513. https://doi.org/10.1080/0950069890110503

Black, A. A. (2005). Spatial ability and earth science conceptual understanding. *Journal Of Geosciences Education*, *53*(4), 402–414.

Chiras, A. & Valanides, N. (2008). Day/Night Cycle: Mental Models of Primary School Children. *Science Education International*, *19*(1), 65–83.

Cin, M. (2007). Alternative views of the solar system among Turkish students. *International Review of Education*, *53*(1), 39–53.

Dove, J. (2002). Does the man in the moon ever sleep? Analysis of student answers about simple astronomical events: A case study. *International Journal of Science Education*, 24, 823.

Dunlop, J. (2000). How children observe the universe. *Publications of the Astronomical Society of Australia*, *17*, 194–206.

Hannust, T., & Kikas, E. (2007). Children's knowledge of astronomy and its change in the course of learning. *Early Childhood Research Quarterly*, *22*(1), 89–104. https://doi.org/10.1016/j.ecresq.2006.11.001

Kattner, S.A., Burrows, A.C., & Slater, T.F. (2018). Relationship between students' spatial ability and effectiveness of two different eclipse teaching pedagogies. *Revista Latino- Americana de EducaçãoemAstronomia - RELEA*, *26*, 7–33.

Kikas, E. (1998). The Impact of teaching on students' definitions and explanations of astronomical phenomena. *Learning and Instruction*, *8*(5), 439–454.

Keeley, P., & Sneider, C. (2012). *Uncovering student ideas in astronomy, 45 new formative assessment probes*. Arlington, VA: NSTA Press.

Keeley, P. (2011). Formative assessment probes: Is it living? *Science and Children*, *48*(8), 24–26.

Mohapatra, J. K. (1991). The interaction of cultural rituals and the concepts of science in student learning: a case study on solar eclipse. *International Journal of Science Education*, *13*(4), 431–437.
Nussbaum, J. (1979). Children's conceptions of the Earth as a cosmic body: A cross-age Study. *Science Education*, *63*(1), 83–93.
Özsoy, S. (2012). Is the earth flat or round? Primary school children's understandings of the planet earth: The case of Turkish children. *International Electronic Journal of Elementary Education*, *4*, 407–415.
Padalkar, S., & Ramadas, J. (2008). Modelling the round earth through diagrams. *Astronomy Education Review*, *6*(2), 54–74.
Plummer, J. D., & Krajcik, J. (2010). Building a learning progression for celestial motion: Elementary levels from an earth-based perspective. *Journal of Research in Science Teaching*, *47*(3), 768–787.
Plummer, J. D. (2009). Early elementary students' development of astronomy concepts in the planetarium. *Journal of Research in Science Teaching*, *46*(2), 192–209.
Plummer, J. D. (2014). Spatial thinking as the dimension of progress in astronomy: Learning progression. *Studies in Science Education*, *50*(1), 1–45.
Plummer, J. D., Wasko, K. D., & Slagle, C. (2011). Children learning to explain daily celestial motion: Understanding astronomy across moving frames of reference. *International Journal of Science Education*, *33*(14), 1963–1992. https://doi.org/10.1080/09500693.2010.537707
Radhakrishnan, R. (2013). Astronomical misconceptions prevalent among high school students of Kerala. *Issues and Ideas in Education*, *1*(2), 151–159.
Roald, I., & Mikalsen, O. (2001). Configuration and dynamics of the earth-sun-moon system: an investigation into conceptions of deaf and hearing pupils. *International Journal of Science Education*, *23*(4), 423–44.
Rudmann, D.S. (2002). *Solving astronomy problems can be limited by intuited knowledge, spatial ability or both.* Paper presented at the Annual Meeting of the American Educational Research Association. New Orleans, L.A.
Sadler, P. M. (1998). Psychometric models of student conceptions in science: Reconciling qualitative studies and distractor-driven assessment instruments. *Journal of Research in Science Teaching*, *35*(3), 265.
Samarapungavan, A., Vosniadou, S., & Brewer, W. F. (1996). Mental models of the earth, sun, and moon: Indian children's cosmologies. *Cognitive Development*, *11*(4), 491–521. https://doi.org/10.1016/S0885-2014(96)90015-5
Schoon, K. (1992). Students' alternative conceptions of earth and space. *Journal of Geological Education*, *40*, 209.
Sharp, J.G., & Kuerbis, P. (2006). Children's ideas about the solar system and the chaos in learning science. *Science Education*, *90*(1), 127–147.
Slater, T. F. (2008). A contemporary approach to teaching eclipses. In *African Cultural Astronomy* (pp. 95-107). Springer, Dordrecht.
Slater, E.V., Morris J.E., & McKinnon, D. (2018). Astronomy alternative conceptions in pre-adolescent students in Western Australia. *International Journal of Science Education*, *40*(17), 2158–2180.
Sneider, C., Bar, V., & Kavanagh, C. (2011). Learning about Seasons: A Guide for Teachers and Curriculum Developers. *Astronomy Education Review*, *10*(1).
Taber, K. S. (2003). Lost without trace or not brought to mind? A case study of remembering and forgetting of college science. *Chemistry Education: Research and Practice*, *4*(3), 249–277.
Taylor, I., Barker, M., & Jones, A. (2003). Promoting mental model building in astronomy education. *International Journal of Science Education*, *25*, 1205–1225.
Trumper, R. (2000). University students' conceptions of basic astronomy concepts. *Physics Education*, *35*(1), 9–15. https://doi:10.1088/0031-9120/35/1/301
Trumper, R. (2001). A cross-age study of junior high school students' conceptions of basic astronomy concepts. *International Journal of Science Education*, *23*(11), 1111–1123.

Tsai, C., & Chang, C. (2005). Lasting effects of instruction guided by the conflict map: Experimental study of learning about the causes of the seasons. *Journal of Research in Science Teaching*, *42*(10), 1089–1111.

Turk, C., Kalkan, H., İskeleli, N. O., & Kiroglu, K. (2015). Improving astronomy achievement and attitude through astronomy summer project: A design, implementation and assessment. *International Journal of Higher Education*, *5*(1), 47–61. https://doi.org/10.5430/ijhe.v5n1p47

Wilhelm, J. (2009). Gender differences in lunar-related scientific and mathematical understandings. *International Journal of Science Education*, *31*(15), 2105–2122.

Vosniadou, S., & Brewer, W. F. (1992). Mental models of the earth: A study of conceptual change in childhood. *Cognitive Psychology*, *24*, 535–585.

Vosniadou, S., & Brewer, W. F. (1994). Mental models of the day/night cycle. *Cognitive Science*, *18*, 123–183.

Wandersee, J. H., Mintzes, J. J., & Novak, J. D. (1994). Research on alternative conceptions in science. In D. L. Gabel (Ed), *Handbook of Research on Science Teaching and Learning* (pp. 177-210). New York: Macmillan.