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Investigation of Middle School Students' Model of Astronomy Events and Information Sources of Incorrect Model

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Abstract
The purpose of this study is to reveal middle school students' model understanding and information sources of incorrect model related to basic astronomy topics included in the Turkish middle school science curriculum. The study is a descriptive study focusing on qualitative data. The sample of the study includes 197 students (aged 12-13) attending eighth grade in seven schools in a city in northeastern Türkiye. Data for the study was collected using the "Astronomy Models and Source Information Form." In this study, descriptive analysis was used as one of the qualitative data analysis methods. Findings indicate that the majority of students possess the incorrect model understanding concerning subjects such as "Solar Eclipse," "Lunar Eclipse," "The Phases of the Moon," "Formation of Seasons," and "Formation of Night and Day," which are part of the middle school science curriculum. The findings also show that teachers and textbooks came to the fore as sources of information in the incorrect model.

Keywords: Astronomy education, Model, Source of information, Science education

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Introduction

Astronomical events have been among the most significant phenomena that have piqued human curiosity throughout history. Evoking a sense of wonder and awe through its accepted concepts and questions (De Leo-Winkler et al., 2016). The shapes and sizes of the Earth, Sun, and Moon have captivated the imagination of humanity throughout recorded history (Bryce & Blown, 2013). Astronomy, due to its capacity to spark curiosity in anyone regardless of age, culture, or general inclination toward science, is often regarded as a gateway science. It possesses a grandeur and mystique, intertwined with mythology, philosophy, and religion, while being connected to all disciplines (Salimpour & Fitzgerald, 2022). Astronomy education is prominent not only for its inherent value in terms of scientific knowledge but also as a catalyst that promotes 'the encouragement of scientific instruction through approaches focused on experimentation and observation of natural phenomena (Bryce & Blown, 2012).

Astronomy education can be considered a challenging field of instruction due to its incorporation of numerous intricate and abstract concepts (Önal & Önal, 2021; Yair et al., 2003). Cole et al. (2018) state that "astronomical phenomena involve the ability to imagine objects from different perspectives and to track the movement of objects in multidimensional space." Therefore, students require in-depth insights to articulate their thoughts about these apparent motions (Bekaert et al., 2022). Individuals must employ models related to the positions and movements of celestial bodies to comprehend various aspects of astronomy, explain and make predictions based on observations (Plummer et al., 2011). Starting from elementary school, visuals in textbooks particularly stand out in shaping students' knowledge of astronomy. In addition to this, other scientific publications, web pages, planetariums, and science centers, as well as parents, friends, teachers, and their own daily experiences can serve as sources that influence students' model understanding of astronomical events. As a result of advancements in science, books, the internet, television, and newspapers have become increasingly prominent as sources of information for learners of all ages studying fundamental topics in astronomy (Venville et al., 2012).

In recent years, the international literature contains a large number of studies examining students' understanding of astronomical phenomena. A review of the relevant literature reveals a strong focus on studies designed to enhance students' academic performance in astronomy. Researchers have explored the effectiveness of various methods and techniques, including augmented reality, computer-assisted astronomy instruction, argumentation-based teaching methods, interactive technology, activity-based learning, and computer-aided teaching. These studies examine their impact on students' academic achievement, attitudes toward astronomy, and overall interest in the subject (Mykoliuk et al., 2020; Önal & Önal, 2021; Shaikh et al., 2020; Sahin & Akbaba, 2018; Timur et al., 2020). It is seen that a significant number of these studies are aimed at revealing students' non-scientific understandings of astronomical phenomena (Azizah et al., 2022; Cardinot & Fairfield, 2021; Gali, 2021). In addition, it is understood that there are many studies examining students' model conceptions of astronomy events at various grade levels (Blown & Bryce, 2017; Blown & Bryce, 2020; Cole et al., 2015). However, in recent years, it has been observed that studies focusing on secondary school students' ideas about basic astronomical phenomena and the sources of their incorrect models, which are the representations of these ideas, have been quite limited in Türkiye. These limited number of studies only aimed to reveal middle school students' understanding of certain astronomical phenomena (such as the phases of the Moon, the solar system) (Babaoğlu & Babaoğlu, 2020; Babaoğlu & Keleş, 2017; Baybars & Çil, 2019). In the related literature, the insufficiency of studies examining the sources of knowledge on which students' understanding of models in astronomy is based is evident. It can be said that revealing students' understanding of models and their sources of knowledge with the same research will make important contributions to the development of astronomy teaching efforts in understanding the supporting phenomena that shape students' scientific and non-scientific understandings. In this context, this study focuses on determining students' modelling conceptions of basic astronomy topics in the Türkiye middle school (5th-8th grade) science curriculum from their perspectives and the knowledge sources of their incorrect modelling. The first reason for adopting this approach is the interconnected nature of basic astronomical phenomena. Another reason is the need to investigate in more depth whether the weaknesses in students' understanding of astronomical models are concentrated in a particular area. In this way, a significant contribution can be made to the general literature on the improvement of astronomy teaching in basic education. This may also provide critical information for the correction of inhibitors to students' effective learning of astronomy topics.

Examining students' model conceptions of astronomy at the primary and secondary school levels and identifying the phenomena that lead to the formation of incorrect model conceptions can be valuable in terms of helping to plan effective astronomy teaching, especially in the early stages of education. Existing studies in Türkiye largely focus on a single astronomical event (the phases of the Moon). In contrast, this study adopts a more general perspective and aims to reveal students' model conceptions and the sources of information of their incorrect modelling conceptions for all basic astronomical phenomena in the secondary school curriculum. In this context, the following research questions guide the study:

(1) What are the model understandings of students concerning the astronomy topics found in the middle school science curriculum?
(2) What are the sources of students' incorrect model knowledge related to astronomical events?

Students' Reasoning About Astronomy Events and Student-Generated Model Representations

Astronomical concepts are often abstract and require three-dimensional thinking, making it difficult to learn and grasp fundamental astronomy concepts correctly (Yu, 2005). Astronomical representations range from diagrams, maps, and 3D models to various data-driven visualizations like computer simulations (Plummer, 2014; Salimpour et al., 2021). Creating and questioning model representations are integral parts of the epistemic practices of science, and this is of vital importance in astronomy (Salimpour & Fitzgerald, 2022; Tytler et al., 2013). Students primarily interact with scientific representations like pictures and diagrams, which are often found in textbooks and used as teaching materials (Rivet & Kastens, 2012). Based on these academic representations, students form their own interpretations and create their own representations (Gallegos-Cazares et al., 2022).

In many cases, other sources, such as science books and television programs, influence the development of these representations (Bryce & Blown, 2013). Padalker and Ramadas (2008) state that teaching astronomy requires students to develop spatial visualisation skills, including the ability to imagine spatial forms and movements such as translation and rotation. Carefully planned activities using models as an important part of pedagogy can enhance these skills (Hubber & Tytler, 2017; Lelliot & Rollnick, 2010). It is common practice to use models in lessons to explain the shape of the Earth and the formation of day and night (Gallegos-Cazares et al., 2022). While these representations may be engaging for students, they do not guarantee comprehension and can pose difficulties during interpretation by generating confusion and misunderstandings (Galano et al., 2018; Gallegos-Cazares et al., 2022). Bielik et al. (2021) state that models provide explanations and predictions of phenomena and are used by scientists as evidence to support or refute alternative models. Given its complex and non-intuitive sequence of spatial and temporal concepts, astronomy relies heavily on model representations to make these concepts concrete (Salimpour & Fitzgerald, 2022). It is known that learning astronomy with model-supported applications contributes greatly to student success (Hubber & Tytler, 2017). Astronomy models can take various forms, such as drawings, mechanical systems, simulations, software applications, or a system of rules for mathematical manipulations (Pundak et al., 2017). Studies theorize the significance of drawings as a means to reveal visual maps of concepts in an individual's mind, either explicitly or implicitly (Buck Bracey, 2018). Many studies in astronomy education have utilized student drawings to reveal incorrect learning (Bryce & Blown, 2013; Bryce & Blown, 2021; Hubber & Tytler, 2017; Vosniadou & Brewer, 1992). Because it can be said that the most important way in which students represent their understanding of models related to astronomy is drawings.

Research on Children's Astronomical Phenomena

Research on elementary and middle school students' understanding of basic astronomy topics typically focuses on students' knowledge regarding the structure of the Earth, Sun, and Moon (Ahmed & Kurnaz, 2021; Bryce & Blown, 2013; Jelinek, 2021), their rotational movements, (Bekaert et al., 2022; Galano et al., 2018; Vosniadou & Skopeliti, 2017; Vosniadou et al., 2004), and their understanding of solar and lunar eclipses (Brown & Brown, 2017; Chewoh & Sarwanto, 2021; Karslı & Patan, 2016; Wilhelm et al., 2022), and moon phases (Åberg-Bengtsson et al., 2017; Cabe Trundle et al., 2010; Chastenay & Riopel, 2020; Cole et al., 2015; Wilhelm, 2014; Wilhelm et al., 2015). Only a limited number of studies have focused on the topics of the formation of day and night (Fleer, 1997; Frède, 2019; Gallegos-Cázares et al., 2022; Tao et al., 2012; Vosniadou & Brewer, 1994; Vosniadou & Skopeliti, 2017) and the occurrence of seasons (Roald & Mikalson, 2001; Sung & Oh, 2018; Tsai & Chang, 2005). Additionally, other studies have examined the alternative conceptions that students hold about fundamental topics in astronomy (Gali, 2021; Slater et al., 2018; Trundle et al., 2007; Turkmen, 2017; Vosnidou et al., 2004). Recent research focuses on comparing the astronomical understanding of primary and middle school students across different geographies (Blown & Bryce, 2020; Blown & Bryce, 2017; Bryce & Blown, 2012; Bryce & Blown, 2021; Tao et al., 2013; Venville et al., 2012). Similarly, the findings of numerous studies conducted with primary and middle school students indicate weaknesses in their foundational understanding of the structure and movements of the Earth, Sun, and Moon (Akkas Baysal et al., 2022; Bekaert et al., 2022; Calderón-Canales et al., 2013; Dankenbring & Capobianco, 2016; Kurnaz & Değermenci, 2012; Vosniadou & Brewer, 1994).

In a recent key study on astronomy topics, Blown and Bryce (2020) sought to understand how students in China and New Zealand interpret the sources of their astronomical knowledge, using drawings as a method. This study

revealed that students held diverse knowledge structures, merging scientific notions with everyday beliefs about astronomy. Additionally, everyday experiences and ideas acquired early in life, often supported by family, have a significant impact on students' understanding of astronomy. Blown and Bryce (2017), involving 539 students from New Zealand and China, the researchers examined students' comprehension of dynamic astronomical concepts like day and night. In this study, the focus was on students' illustrative models and explanations related to the Earth, the Sun, and the Moon. The research also investigated the prevalence and character of animistic thought and metaphorical language in students' conceptualizations. The findings reveal how children transition between everyday and scientific language in both directions and how they employ imagery in their conceptualizations. The study indicates that the scientific understanding of students in this area cannot be accurately predicted solely by looking at formal scientific expressions and vocabulary.

Methodology

Research Design

This study is a descriptive study focusing on qualitative data. In this study, we evaluated the knowledge about model and information sources of incorrect model related to astronomical events of 8th-grade middle school students in Türkiye based on a descriptive review. Descriptive research "sets out to depict and interpret what is" (Cohen & Manion, 1989, p. 70). Therefore, this study provides an extensive evaluation of students' perceptions of astronomical events, their knowledge sources, and the efficiency of the methods used to convey this information.

Participants

The participants consisted of 197 students (112 females and 85 males) aged 13-14, attending the eighth grade in seven different middle schools in a city in the northeastern part of Türkiye. In Türkiye, students begin to learn about basic astronomy topics academically from the third grade of middle school and continue to cover all the essential topics under the subject area of "Earth and Universe" by the time they reach the 8th grade. Hence, 8th graders were considered the most suitable group to determine what knowledge they have acquired about basic astronomy topics.

Data sources and collection

The data for this study was collected in the first week of June 2022. The "Astronomy Models and Source Information Form" was administered to the students. The form consists of sections that ask students to draw models and identify their sources of information for five fundamental astronomical events: "Solar eclipse," "Lunar eclipse," "The phases of the moon," "Formation of the seasons," and "Formation of night and day." This tool was prepared after reviewing studies in the relevant literature on student understanding of astronomy topics (Blown & Bryce, 2020; Blown & Bryce, 2022; Bryce & Blown, 2013) and consulting with experts in the field. While preparing this information form, for content validity, it was submitted to the review of educators, one of whom was a science teacher at the university where the researchers worked and the other was a science teacher at a school affiliated with the Ministry of Education and had been teaching astronomy education courses for many years. These experts provided feedback on the suitability of the prepared information form for the students and the language used. In these evaluations, some parts of the first version of the prepared information form were asked to be revised again. In this context, the necessary arrangements were made and the information form to be applied was made ready. In research conducted at the middle school level, drawing is the most intensive and important data collection technique for revealing students' model understanding of astronomy topics in this age group. Therefore, a drawing task was included in the initial section of the data collection tool. Arthurs et al. (2020) state that "drawing is a universal process skill that is widely used by scientists to develop concepts on a variety of topics, communicate ideas, and advance scientific thinking within their disciplines." In addition, students were added as a second section under each drawing task a question asking to identify the source of their models of astronomical events (Q. Describe who or where you learned the model you drew from?). The primary motivation for obtaining this second data source is to identify the information sources leading to inaccuracies in students' astronomical model and to make improvements in this area in the future.

Data collection tool was administered to participating students in a single session. Two researchers participated in the process of data collection. These researchers had several meetings with the science teachers at the schools where the data was collected in order to determine suitable timings for the data collection process. In Türkiye, the 8th grade is particularly stressful for both students and parents, as students are required to take a challenging high school transition exam at the end of the year. Hence, the academic workload and stress levels of students are particularly high at this grade level, especially during the spring term (Bayar & Gürlek, 2022; Bozkurt, 2019). A

timeframe that would not interfere with the students' regular school lessons and exam preparation was established. The final week of the school term, which is generally quieter in terms of educational activities, was specifically chosen for data collection. During this week, both researchers collected data on the same days at different schools, in collaboration with science teachers.

Ethical Approval

Ethical permission (19.10.2020-43) was obtained from Kafkas University Social Sciences Ethics Committee for this research.

Data analyses

In this study, descriptive analysis was used as one of the qualitative data analysis methods. Descriptive analysis is to summarise the content of a qualitative data with words or a short expression. In descriptive analysis, the researcher is provided with an organised idea of the study by categorising the data at a simple level (Saldaña, 2021). In order to conduct both visual and textual content analyses concerning five different astronomical events, we prepared a categorical system for drawing was employed. In preparing this categorical system, researchers reviewed textbooks and web pages about the scientific representation of five different astronomical events ("Solar Eclipse," "Lunar Eclipse," "the phases of the moon," "formation of the seasons," and "formation of night and day"). As a result of these evaluations, the primary codes for correct model and incorrect model based on the drawings related to the examined astronomical events were determined. In addition, while preparing the categorical system for the analysis, scientifically incomplete drawings were included in the definition of incorrect model. Taking into account the possibility that some students may not possess any model knowledge for certain astronomical events, a “No Model Representation” category has also been incorporated into the categorical system. In this context, the prepared categorical system comprises three categories based on the scientific appropriateness of the model: "Correct Model," "Incorrect Model," and "No Model Representation". The categorical system is shown in Table 1. In addition, a descriptive coding technique was used to analyze the students' responses concerning the sources of their incorrect model information. Researchers, in order to analyze the students' explanations regarding the sources of their incorrect models, initially extracted preliminary codes from some students' responses and subsequently established a provisional coding table based on these findings. This table was subsequently expanded through the examination of other students' responses, culminating in the final descriptive code table. This descriptive coding table comprises eight sub-codes (teachers, textbooks, science books/journals, websites, television, parents, friends, and planetarium/science museums). All of the students' statements regarding the sources of their incorrect models of astronomical events were analyzed according to this coding table, and the frequency of the expressed codes was quantified in terms of student numbers and percentages. Some of the students' statements contained multiple codes. Therefore, the coders quantified these statements to represent multiple codes. In order to ensure inter-rater reliability, two researchers initially coded the same data from 20% of the students (40 out of 197 participants). An 88% agreement rate was achieved between the two coders (Cohen's Kappa = .87). This result can be considered as a strong coding agreement and attests to the reliability of the coders (McHugh, 2012).

Table 1. Categorization system for student drawing related to astronomical events

Astronomical Event	Model Category		
	Correct Model	Incorrect Model	No Model Representation
Solar eclipse	The model contains complete and accurate alignment in its visual/ symbolic, and verbal aspects. The drawn model correctly represents the scientific structure. The positioning and relative sizing of the Earth, Sun, and Moon (representing the Moon coming between Earth and the Sun and blocking the Sun's light) are correct. The moon's shadow falling on Earth and the resulting darkening of that region is represented. Both total and partial shadow, as well as total and	The model does not exhibit complete and accurate alignment in terms of visual/symbolic and verbal representations. The model contains many errors. It is a non-scientific drawing. Positions of the Earth, Sun, and Moon are incorrect. The representation of total and partial shadow and the total and partial eclipse is either incorrect or absent.	

	partial eclipses, are accurately depicted.		
Lunar eclipse	The model contains complete and accurate alignment in its visual/ symbolic, and verbal aspects. The drawn model correctly represents the scientific structure. It correctly depicts the scientifically accurate positioning and relative sizing of the Earth, Sun, and Moon (with Earth between the Sun and the Moon). The Earth's shadow falling on the Moon is depicted. The representation of the total and partial shadow, and the total and partial eclipse are accurately represented in the drawing.	The model does not exhibit complete and accurate alignment in terms of visual/symbolic and verbal representations. The model contains many errors. It is a non-scientific drawing. There are inaccuracies in the positioning of Earth, Sun, and the Moon in the drawn model. The representation of total and partial shadow, and the total and partial eclipse is either incorrect or absent.	There is a drawing, but it doesn't represent astronomical concepts or there's no drawing at all.
The phases of the moon	The model contains complete and accurate alignment in its visual/ symbolic, and verbal aspects. The drawn model correctly represents the scientific structure. It accurately represents the positions and relative sizes of the Earth, Sun, and Moon. All eight phases of the Moon (4 main and 4 intermediate phases) are accurately represented. The representation of the Moon's orbit around Earth and its resulting illumination of specific areas on the Moon's surface due to this orbital motion of the Sun has been accurately depicted in the drawing.	The model does not exhibit complete and accurate alignment in terms of visual/symbolic and verbal representations. The model contains many errors. It is a non-scientific drawing. There are inaccuracies in the positioning of Earth, Sun, and the Moon in the drawn model. The representation of the main and intermediate phases of the moon is either incorrect or incomplete.	
Formation of the seasons	The model contains complete and accurate alignment in its visual/ symbolic, and verbal aspects. The drawn model correctly represents the scientific structure. The representation of the main and intermediate phases of the moon is either incorrect or incomplete. The rotation of Earth around the Sun and its own axis has been accurately depicted in the drawing The model particularly illustrates Earth's tilt at a specific angle relative to the Sun, resulting in varying angles of radiation and the formation of different seasons throughout the year.	The model does not exhibit complete and accurate alignment in terms of visual/symbolic and verbal representations. The model contains many errors. It is a non-scientific drawing. The positioning of the Sun and Earth is incorrect. The model does not depict Earth's tilt at a certain angle relative to the Sun and the resulting variation in radiation angles, which leads to the formation of different seasons throughout the year.	
Formation of night and day	The model contains complete and accurate alignment in its visual/ symbolic, and verbal aspects. The drawn model correctly represents the scientific structure. The model accurately represents the positions and relative sizes of the Earth and Sun.	The model does not exhibit complete and accurate alignment in terms of visual/symbolic and verbal representations. The model contains many errors. It is a non-scientific drawing. The	

	Earth's rotation around the Sun and on its own axis is correctly depicted. The model correctly illustrates that the side of Earth facing the Sun experiences daylight, while the side not facing the Sun remains dark, representing nighttime.	positioning of the Sun and Earth is incorrect. It does not correctly depict that one side of Earth faces the Sun and is in daylight while the other side is in darkness.

Findings

This section includes the findings related to students' model knowledge about astronomical events and information sources of the incorrect model.

The Findings Related to Model Knowledge on Astronomical Events (Solar eclipse, lunar eclipse, phases of the moon, seasons, day and night)

Figure 1 presents the analysis findings related to students' model knowledge of astronomical events.

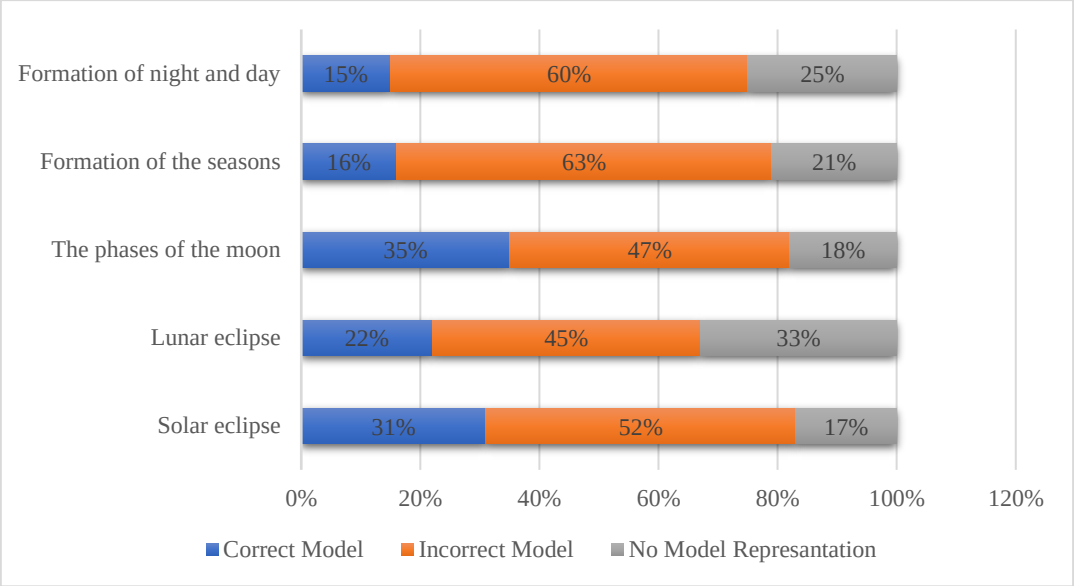


Figure 1. The distribution of students' level of model knowledge about astronomy events

The findings of the analysis of the students' drawings of astronomical phenomena showed that they mostly had "incorrect model knowledge" in the subjects of "Formation of seasons" (63%; n=124) and "Formation of day and night" (60%; n=119) (see Figure 1). In both subject areas, it is understood that nearly two-thirds of the 197 participating students have incorrect model knowledge. Additionally, students have been found to have incorrect model knowledge in almost half of the cases for "The Phases of the Moon" (47%; n=93), "Lunar Eclipse" (45%; n=89), and "Solar Eclipse" (52%; n=102). A significant number of students have “no model representation” in all the examined astronomical events. Specifically, more students do not represent the astronomical event related to the "Lunar Eclipse" (33%; n=64) in their models. However, students have the most “correct model knowledge” in the area of "The phases of the moon" (35%; n=68) among all the astronomical events. Student drawing examples related to model knowledge are shown in Figure 2.

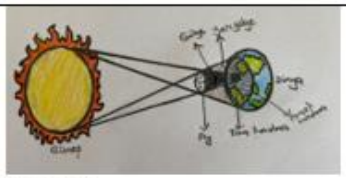
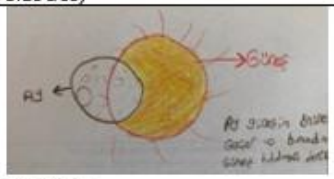
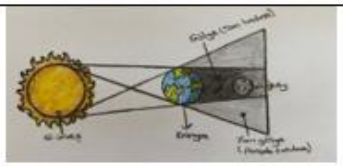
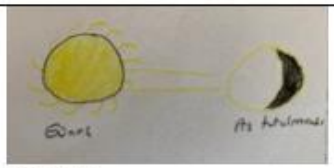
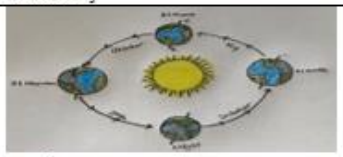
Astronomy Event	Correct Model (Scientific Model)	Incorrect Model (Alternative Model)
Solar eclipse	 Student$_{17}$	 Student$_{65}$
Lunar eclipse	 Student$_{17}$	 Student$_{41}$
The phases of the moon	 Student$_{9}$	 Student$_{71}$
Formation of the seasons	 Student$_{33}$	 Student$_{162}$
Formation of night and day	 Student$_{122}$	 Student$_{156}$

Figure 2. Examples of drawings corresponding to correct models, incorrect models, and models that do not represent astronomical events

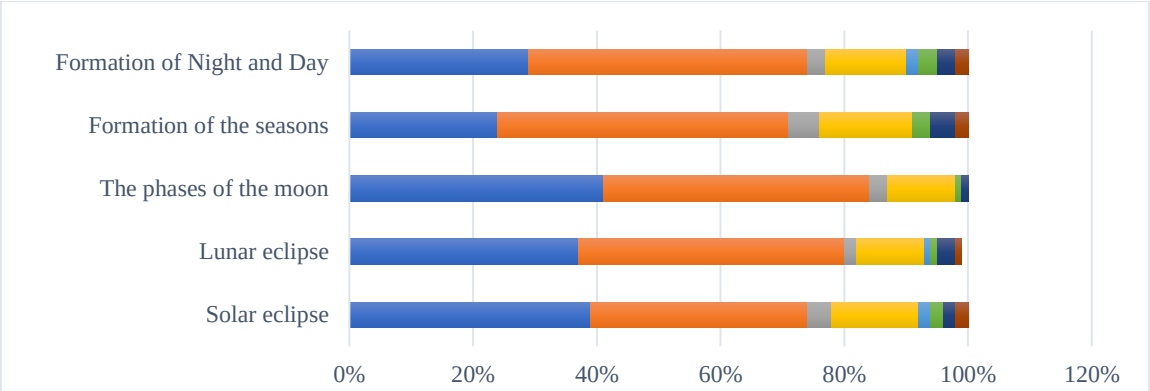
Examining the erroneous models created by students regarding astronomical events in Figure 2, it was observed that Student S65's model representation of a solar eclipse lacks the inclusion of Earth and exhibits difficulties in accurately positioning the Sun, Moon, and Earth. Notably, their model reflects a problematic understanding, as it portrays the Moon inside the Sun. Since the reference point in the model drawn by the student is the Earth, it is normal that the Earth is not included in the model. Considering that it reflects the perceived movement, the model can be accepted as correct according to the point it looks at, but the student who develops spatial thinking ability should have gained the ability to look at this phenomenon from outside the Earth. In the case of the erroneous model depicting a lunar eclipse, student S41's portrayal omitted the Earth from the model, and they struggled to accurately depict the positioning of the Sun, Earth, and the Moon. Instead of illustrating Earth's shadow falling onto the Moon, they depicted one side of the Moon as illuminated and the other as dark. Furthermore, neither of these students incorporated any representations of total and partial eclipses or the formation of total and partial shadows in their drawings. In the inaccurate model of the phases of the Moon, student S71 encountered difficulties in visually, symbolically, and verbally conveying the phases of the Moon with precision. Their drawing revealed notable deficiencies. In the student's model, the positioning of the Sun and the Moon is partially accurate, however, Earth is not included in this arrangement. Additionally, the four main and four intermediate phases of the Moon are not accurately represented in the student's drawing. Regarding the erroneous model of the astronomical event of the formation of seasons, in student S162's model, there is a lack of visual, symbolic, and verbal alignment. In this student's drawing, Earth is represented in six different positions around the Sun.

Consequently, this particularly fails to depict Earth's tilted position relative to the Sun, which results in the formation of different angles of radiation and, in turn, the occurrence of four distinct seasons throughout the year. Hence, the student's model indicates significant inaccuracies. Finally, concerning the erroneous model of the formation of night and day, in student S156's representation, they illustrate Earth's orbit around the Sun, yet they

omit Earth's rotation on its axis in their model, resulting in an inaccurate representation. Furthermore, their drawing does not depict the transition from day to night, where the side of Earth facing the Sun experiences daylight while the opposite side remains in darkness, signifying nighttime. Therefore, the model lacks a scientifically accurate representation. We can say that S17's Solar and Lunar eclipse models were internalised by the students and drawn as a result of complete learning or based on memorizing the visuals in the textbooks. In this sense, it is really important to determine what students think about the models they draw in order to have a deeper understanding in the interpretation of the models. However, since the main purpose of this study was to describe students' understanding of models, this was not included.

The Findings Related to Sources of Incorrect Model Knowledge on Astronomical Events

The findings of the analysis of the source of this knowledge of the students who drew incorrect models are given in Figure 3.



	Solar eclipse	Lunar eclipse	The phases of the moon	Formation of the seasons	Formation of Night and Day
Teachers	39%	37%	41%	24%	29%
Textbooks	35%	43%	43%	47%	45%
Science Books/Journals	4%	2%	3%	5%	3%
Website	14%	11%	11%	15%	13%
Television	2%	1%	0%	0%	2%
Parents	2%	1%	1%	3%	3%
Friends	2%	3%	1%	4%	3%
Planetarium/Science Museum	2%	1%	0%	2%	2%

Figure 3. The distribution of students' incorrect model knowledge sources on astronomy events

The results of the analysis showed that textbooks (47%) and teachers (24%) were the main sources of students' incorrect model knowledge on the topic of "Formation of seasons." Similarly, textbooks (45%) and teachers (29%) emerged as the main sources of students' incorrect model knowledge in the topic "The formation of day and night" (see Figure 3). Additionally, students seem to attribute their incorrect model of all astronomical events to websites as a third source of information. It has also been revealed that a small number of students attribute their incorrect model of astronomical events to sources such as science books/magazines, family members, friends, television, and planetariums/science museums. Sample excerpts from the students' answers regarding the model information sources are given in Figure 4.

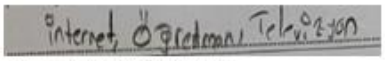
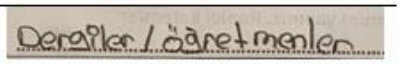
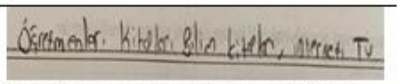
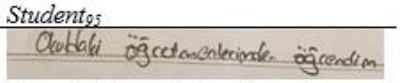
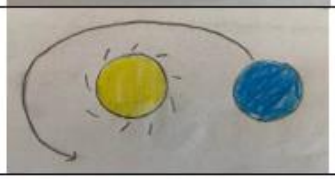
Astronomy events	Incorrect Model	Evidence from Student Responses Regarding the Source of the Model's Information
Solar eclipse		 Internet, teacher, TV *Student*$_{26}$
Lunar eclipse		 Journals, teachers *Student*$_{9}$
The phases of the moon		 Teachers, science books, internet, TV *Student*$_{95}$
Formation of the seasons		 I learnt it from the teacher at school. *Student*$_{137}$
Formation of night and day		 Teachers, books, textbooks *Student*$_{190}$

Figure 4. Examples of students' responses regarding the source of their incorrect model

Looking at Figure 4, it can be seen that students who drew the incorrect model frequently stated their teachers and textbooks as the source of this model information. However, it should be noted that all students get their basic information from these two sources. This research showed that while some of the students in the same class were drawing accurate models on astronomy subjects, some were not able to do so. The purpose of interpreting the finding here is not to judge that the source of information in incorrect models is the teacher and textbooks, but only to describe the student's expression in this direction. Therefore, it is clear that these student expressions and understandings of the model need more in-depth examination, which is not the subject of this research.

Discussion and Conclusion

This study focused on the diagrammatic description of eighth-grade students' model understandings of astronomical events ("Solar eclipse", "Lunar eclipse", "phases of the moon", "formation of seasons" and "formation of day and night") that they have learnt during the middle school period and the identification of the knowledge sources of students with incorrect model knowledge. The findings revealed that a significant portion of students held the incorrect model and no model representation about astronomical events. Notably, students exhibited the highest level of incorrect model in topics related to the "Formation of the seasons" and "Formation of night and day." Considering the importance of early education in helping students grasp fundamental astronomy topics, based on these findings, that middle school science classes may not be placing sufficient emphasis on model-based learning activities, and this aspect is overlooked. Astronomy topics, like many abstract subjects in the field of science, can be learned incorrectly during early education, such as in primary and middle school. When incorrect model about astronomy concepts is established at an early stage, they tend to persist into later periods, hindering the acquisition of more complex astronomy knowledge in the future. Therefore, it is crucial to provide students, especially at the early stages of their education, with concrete and visual representations of astronomy events. One of the most effective methods for achieving this is through hands-on model activities, where students can create visual representations of astronomy concepts using drawings, clay, and various materials (Joolingen et al., 2015). Today, in most secondary schools in Türkiye, astronomy education is largely provided through traditional teaching, that is, through oral explanation. Many of these trainings are far from model-based applications and involve only presenting visuals of astronomy concepts and events in textbooks or various software

programs. It can be said that the efforts to have students draw or prepare models are very limited because many teachers reported that they cannot spare time for such studies due to their busy schedules. This study revealed that many students lack a model-based knowledge base to support their accurate understanding of astronomical phenomena.

The findings indicate that there is a deficiency in activities that could help students grasp the fundamental factors in the "Formation of seasons," such as the positioning of the Earth and the Sun, the Earth's rotation around the Sun, and its axial tilt, all of which can be represented through model. It is also necessary to combine models with students' concrete experiences. Therefore, we need to create a way to connect the model to students' lives and real experiences in teaching. To address this issue and ensure that students fully comprehend the reasons behind the formation of seasons, it is essential for them to grasp the central role of the relationship between the Sun and the Earth in this phenomenon. To facilitate this understanding, model activities can be employed that focus on a Sun-centered perspective and incorporate the concept of Earth's axial tilt along with relative dimensions. Especially, the failure of teachers to exclude the factor of distance (the Earth's distance from the Sun) in their model and their inability to accurately convey to students the Earth's rotational and orbital periods within a Sun-centered model can be expressed as the most crucial factor contributing to the lack of comprehension regarding the topic of seasons. Furthermore, students should be informed that variations in the distance between the Earth and the Sun do not significantly influence “the formation of seasons.” It has been stated that only when these concepts have firmly established the influence of the Earth's tilt on day length and temperature values on Earth can be introduced to students (Slater et al., 2018). This study identified that many students aren't aware that the temperature in certain regions of the Earth changes depending on the angle at which sunlight strikes the Earth due to the Earth's orbital motion around the Sun. Moreover, it was determined that many students in this study did not have the knowledge that the temperature values in certain regions of the Earth will change according to the angle of the sun's rays hitting the Earth during the Earth's orbit around the Sun. It can be argued that in order to make full sense of the relationships in such phenomena, it is necessary to learn more about what the learner knows and what they rely on for such understandings. It can be said that although the students knew the effect of the Earth's axis curvature on the formation of the seasons, they did not reflect this factor correctly in their drawings. Despite students knowing that the tilt of the Earth's axis affects the angle of sunlight incidence, they often fail to depict this accurately in drawings. It can be argued that inaccurate model may stem from a student's incomplete or erroneous preconceptions about the definition of seasons. Because cognitive theorists make one of the most important generalizations that students' prior knowledge is highly effective on their learning (Kandemir & Apaydın, 2020). So much so that the newly acquired knowledge of the student is built on his/her prior knowledge, but if the prior knowledge is problematic, learning may result in failure (Ecevit & Şimşek, 2017). Defining seasons as periods with similar average weather conditions could contribute to correct model. Another reason for the gaps in understanding the process of season formation might be the teaching methods and techniques applied. A teaching process that is predominantly lecture-based, teacher-centered, and lacks adequate use of materials may not yield successful outcomes in topics that require three-dimensional and spatial thinking skills. Even if scientific explanations are provided verbally or in written form, they can be quite challenging for students to understand. Therefore, there is a need for different model approaches to explain the formation of seasons in classroom settings. The chances of achieving positive results can increase when these processes are supported with student-centered strategies. Similarly, it can be stated that the incorrect model many students have regarding the "formation of night and day" astronomical phenomenon originates from the lack of classroom exercises that visualize Earth's rotation on its axis, in conjunction with its orbit around the "Solar System".

The second finding of the study indicates that most students point to textbooks and teachers as the source of their incorrect model about the events of the “formation of the seasons” and the “formation of night and day,” which they predominantly understand incorrectly. The study by Blown and Bryce (2020) corroborates the results of this study. The researchers examined the sources of knowledge regarding astronomical phenomena among a broad sample of students in China and New Zealand. As a result of their study, they determined that in both cultures, a significant portion of the students' sources of knowledge were primarily teachers and books. This suggests that the early misconceptions students have about astronomy are significantly shaped through textbooks and by teachers. This outcome emphasizes that teachers and textbooks, considered key elements in the learning process, play a fundamental role in influencing students' misconceived model understandings. However, the fact that 30% of the students had correct models of the astronomy phenomena discussed means that they learned despite the deficiencies in the teachers and books. An issue that needs to be examined in terms of the result obtained here is how teachers and textbooks present astronomy events and why this is meaningful for some students and meaningless for others. This situation requires in-depth examination with a different research topic. Science teachers have an important role in identifying students' incorrect model of astronomical phenomena and providing

the necessary support to eradicate alternative model ideas that deviate from established scientific understanding. To effectively perform this function, teachers must first critically examine their own understanding of the model in relation to astronomical events and adapt it to facilitate student learning. In addition, textbooks have consistently served as a foundational resource for students in science courses. However, current reviews show that many science textbooks have structural defects in their scientific content (Sideri & Skoumios, 2021) and visual representations (Inaltekin & Goksu, 2019), and these negatively affect learning. Alongside their textual content, the visual elements in textbooks—especially when dealing with complex scientific subjects like astronomy—are invaluable in promoting student understanding. Therefore, the correct and pedagogically effective presentation of illustrative drawings, images, and photographs that complement the scientific text is crucial for making textbooks an effective resource for students. Many students intuitively construct incorrect models of astronomical phenomena based on the knowledge and experiences they have gained from various sources in their daily lives. For example, Plummer (2014) found alternative ideas among students that suggest the Sun is blocked by the Moon, causing nighttime darkness. These ideas have emerged as a product of students' intuitive thinking. Moreover, students think outside the teacher or textbooks. As identified in this study, students who have not undergone an effective learning process may hold model understandings that represent the products of their own intuitive thought rather than scientific knowledge. Identifying and rectifying the misconceptions and alternative concepts caused by prior knowledge can be beneficial in this process. In particular, the model related to astronomy topics in science textbooks play a significant role in eliciting alternative model understandings. This is because many teachers rely on ready-made models from these textbooks for their explanations and often choose not to engage students in model activities. Some textbooks may also lack model representations that could support students' scientific understanding of astronomical events. Consequently, these shortcomings will significantly hinder the formation of the student's scientific understanding.

In the 2024 science curriculum, the astronomy units include "Let's Explore Our World" for Grade 4, "Our Neighbors in the Sky and Us" for Grade 5, "Solar System and Eclipses" for Grade 6, "Space Age" for Grade 7, and "Seasons and Climate" for Grade 8. In Grade 4, Unit 3 focuses on estimating the Earth's shape based on scientific observations, illustrating the Earth's layered structure (air sphere, water sphere, stone sphere, living sphere) through modeling, estimating the Earth's rotation and circulation movements by observation, and understanding the phenomena of day and year that result from the Earth’s movements (MoNE, 2024). This unit includes goals related to developing and proposing models to understand the Earth's shape, structure, and movements. Findings indicate that the topic of day and night formation has the second highest number of incorrect models, highlighting the importance of aligning our study with the new program's objectives. In Grade 5, Unit 1 aims to define the structure and rotational motion of the Sun, discuss the properties, phases, and movements of the Moon, and prepare models illustrating these phases. Additionally, students are expected to create models that take into account the volumetric sizes and motions of the Sun, Earth, and Moon (MoNE, 2024). This unit provides essential data for modeling the five events/topics examined in the study, emphasizing spatial and dimensional evaluation of the movements of the Sun, Earth, and Moon, both individually and in relation to one another. This is crucial for promoting effective modeling skills. Grade 6, Unit 1 addresses the solar system and eclipses. In this unit, students will classify the planets in the solar system, create models of the solar system, and develop models for solar and lunar eclipses based on inference (MoNE, 2024). The processes of proposing, creating, and developing models have been emphasized to achieve the targeted outcomes. Grade 7, Unit 1 focuses on space exploration technologies, preparing models for space observations, and generating ideas that will stimulate further research in space studies. This unit also highlights the hierarchical relationship between the concepts of stars, the universe, and galaxies. Modeling is an integral part of developing a space observation tool (MoNE, 2024). Grade 8, Unit 1 covers seasons and climate. It compares the Earth's movement around the Sun, the effects of axial tilt, and the resulting climate and weather events. Defining the Earth's motion around the Sun in the context of axial tilt is identified as a process skill (MoNE, 2024). This skill can be enhanced through modeling activities. Notably, study findings reveal that incorrect modeling was most prevalent in understanding the formation of seasons, underscoring the need for accurate and effective models in teaching. Based on these findings, it can be emphasized that it is appropriate to focus on modeling in the 2024 science program, as incorrect modeling is done in all subjects and modeling knowledge is lacking.

The findings obtained from this study indicate that many students have a weak understanding of basic astronomical events during middle school. These findings point to the need for questioning the quality of teachers and textbooks cited as the cause of these deficiencies in understanding about astronomy events.

Limitations and Recommendations

This research was conducted in a small-scale city in the east of Türkiye. This study can be repeated in other cities to obtain more comprehensive information about the understanding of students at the same education level. The study aimed to examine drawing models related to astronomical events as its data source. Although the researchers wanted to interview some students in order to understand the model drawings representing the students' understanding of astronomical phenomena and the sources of knowledge that the basis of these drawings, they could not do this due to the students' workload and time problems. In-depth interviews could be conducted to examine students' understanding of the models they drew, which would shed more comprehensive light on their mental models of understanding. Science textbooks should be updated to include comprehensible visuals and various activity exercises that will enhance students' modeling understanding of astronomical events. The researchers gave coloring pencils to each of the students for their model drawings. The observation of the researchers showed that this kind of practice motivated the students to participate in the research process. In addition, using only pencils in students' model drawings of astronomy phenomena may not fully reflect their understanding of models. In this study, the data showing that students benefited from textbooks were excluded from the analysis. In such astronomy model drawing studies, in order for students to reflect their own model understanding, an environment independent of the sources that they will copy one-to-one should be created, Sufficient time and appropriate working hours should be determined.

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