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Determination of Middle School Students' Alternative Concepts in the Structure and Motion of Celestial

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Abstract
This study aims to determine the alternative conceptions that middle school students may have about the structure of celestial bodies, celestial events and the motions of celestial bodies. Since qualitative and quantitative methods were used in the study, the study method is mixed. Since quantitative data were collected first and qualitative data were collected after the quantitative data analysis, the study was designed as an explanatory design. The study group of the research consists of 332 students studying in the 5th, 6th, 7th, and 8th grades of a secondary school in a province in Türkiye in the 2022-2023 academic year. The sample in the study was determined by the monographic sampling method, which is one of the non-probability-based methods. The Alternative Concept Identification Test (ACIT), the quantitative data collection tool of the study, was created to identify alternative concepts. The test development stages were followed for ACIT, and the KR-20 value was found to be 0.82 after the necessary validity and reliability studies were conducted. There are 20 items in ACIT, each consisting of three stages. The alternative concepts of the students to whom ACIT was applied were identified, and frequency tables were created; then, semi-structured interview forms were prepared for 16 students randomly selected among the students determined by the typical case sampling method, and interviews were conducted with the students. The necessary validity and reliability studies were conducted for the semi-structured interview forms, which were the qualitative data collection tools of the study. As a result of the study, it was determined that students had alternative concepts in the subjects of the structure and motions of celestial bodies.

Keywords: Alternative concepts, Astronomy education, Celestial events, Structure of celestial bodies, Three-stage tests

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Introduction

Astronomy is an important discipline that emerged due to human curiosity about the universe and supports scientific discoveries. Throughout human history, the endeavor to understand the sky has been one of the cornerstones of advances in science and technology. In today's world, astronomy is not only a means of discovering the universe but also a field that contributes to individuals' development of scientific thinking skills, observation and questioning nature. Therefore, including astronomy in the education process is of great importance in increasing scientific literacy and supporting students' interest in science.

Astronomy education is one of the basic components of science education and plays a critical role in helping students understand nature and gain scientific thinking skills (Percy, 2006). The Science Curriculum aims to encourage students' interest and curiosity in natural phenomena and to develop a scientific perspective (MNE "Ministry of National Education", 2018). When international science education programmes are examined, it is seen that astronomy education is associated with standards in developed countries, and students are trying to gain astronomy education from primary school (Kahraman, 2006). In this context, the correct transfer of astronomy topics as a part of science education contributes to developing students' scientific process skills and their growth as science-literate individuals.

Students make sense of scientific concepts by associating their knowledge with newly learnt information. However, students can misunderstand scientific concepts from time to time due to their abstract structure, which leads to the emergence of alternative concepts (Ayas, 2016). Unlike scientifically verified knowledge, alternative concepts are conceptual structures that students form based on their own experiences, observations and prior knowledge (Baxter, 1989). Since students try to make sense of natural phenomena with the information they have acquired from their environment before receiving science education, they may develop concepts based on false associations (Koyuncuer, 2014). This situation becomes more evident, especially in fields such as astronomy, which cannot be directly observed or contain abstract concepts.

Since the subjects related to astronomy include abstract and complex concepts such as the structures of celestial bodies, movements and celestial events, the possibility of alternative concepts among students is quite high (Smith, 2002). Students may understand these subjects in ways different from scientific facts due to misinformation, myths and false beliefs among the people they encounter in their daily lives (Göncü, 2013). As a result, they may develop various alternative concepts about basic astronomy concepts, such as the formation of day and night, the shape and movements of the Earth, and the positions of the Sun and the Moon. Studies have also shown that alternative conceptions held by teachers and pre-service teachers directly affect students' misconceptions (Kurnaz et al., 2016). Therefore, identifying and eliminating alternative conceptions is crucial for an effective astronomy education.

Many different methods are used to determine alternative concepts. In the literature, it is seen that in addition to methods such as prediction-observation-explanation, interview, drawing technique, and word association, progressive misconception tests give very valid and reliable results (Çetinkaya &Taş, 2016; Demirci & Efe, 2007; Elmas & Pamuk, 2021; Güneş, 2020; Hestenes & Wells, 1992; Kaltakçı, 2012; Karslı & Ayas, 2013; Meşin, 2019; Novak & Gowin, 1984; Peker & Taş, 2019; Peşman,2005; Şenyiğit & Sılay, 2019; Zengin, 2018). Studies conducted to determine the alternative concepts that students have shown that using such tests helps to better understand the learning process (Büyüköztürk et.al., 2016). In particular, in the study conducted by Bolat et al. (2014), 5th-grade primary school students' alternative concepts about the Sun, Earth and Moon were determined through drawings and open-ended questions and analysed with the special case study method. These and similar studies provide important data in understanding students' misconceptions and making teaching processes more effective (Alın & İzgi 2017; Babaoğlu, 2019; Göncü, 2013; Kurnaz & Değermenci,2012; Ülker & Kacakülah, 2020; Tarakçı & Şensoy, 2019).

Considering the role of astronomy education in developing scientific thinking skills, the formation of correct conceptual structures in students is a great necessity. Identifying and correcting alternative concepts early will enable students to progress on more solid scientific foundations. In today's world, where the importance of space sciences is increasing with the developing science and technology, astronomy education should inevitably be given the necessary importance to educate future scientists and science-literate individuals. In this direction, studies on determining and eliminating misconceptions will be an important step to make astronomy education more effective.

This study is an important step towards better understanding students' scientific thinking processes and contributing to science education by identifying alternative concepts in astronomy subjects. Secondary school students are in a critical period in making sense of abstract concepts, and early identification of misconceptions in this age group is important for correctly constructing scientific knowledge. Since astronomy contains abstract concepts frequently encountered in daily life but difficult to observe and comprehend, the possibility of alternative concepts among students is high (Türk & Kalkan, 2017). Therefore, examining students' conceptions and revealing alternative conceptions in the astronomy education process is critical for developing effective teaching strategies. This study aims to shed light on future teaching processes by evaluating the conceptual understanding of secondary school students in astronomy subjects.

Method

The aim of this study is to determine the alternative conceptions of secondary school students about the structure of celestial bodies, motions of celestial bodies and celestial events. The researcher developed the alternative Concept Identification Test (ACIT) to identify the alternative concepts in secondary school students, and a survey model, one of the quantitative research methods, was used. In cross-sectional survey research, which is one of the types of survey research, the skills of large samples are measured at one time (Büyüköztürk et al., 2016). After the determination of alternative concepts with the cross-sectional survey research method, the case studies model, one of the qualitative research methods, was used with a group randomly selected from among the students with misconceptions. Situation analysis, one of the case studies types, was used to examine the different perspectives of the students. In this study, quantitative data were collected first, and qualitative data were collected to complete the analysis of these quantitative data. Since qualitative and quantitative methods were used together in this way, the method of the study is Explanatory Design. In the explanatory design, which is one of the mixed research types, quantitative data are collected first, and then qualitative data are collected in line with the information obtained from the analysis of quantitative data (Karagöz, 2017). For these reasons, an explanatory design of mixed research types was used in the study. In the study, the determination of alternative concepts in secondary school students was found with quantitative data and supported with qualitative data.

Study Group of the Research

The study group of the research consists of students studying in the 5th, 6th, 7th and 8th grades of some secondary schools in a province in Türkiye in the 2022-2023 academic year. In this study, since the sample to be selected from the universe was not determined by the lottery method and since each unit in the universe did not have an equal chance of being included in the sample, the non-probability-based method was used. The target group of the researcher's study is the 5th, 6th, 7th, 8th grade secondary school students across Türkiye. The students were selected from schools, and the test was applied to 332 students, taking into account that equal numbers of students from each grade level were represented in the sample. In studies where the chances of each unit to be included in the sample are not equal to each other, when the researcher makes a selection by using initiative, this is called non-probability-based sampling. In Monographic Sampling, which is one of the non-probability-based sampling methods, the sample is determined by selecting a group or unit that is accepted to be a representative of the researched population based on the available information. The determined sample is examined in detail and interpreted by generalizing the results to the whole population (Karagöz, 2017). Due to its suitability for of the study, the researcher determined the sample using monographic sampling type and criteria. The use of non-probability-based sampling methods instead of probability-based sampling methods in qualitative research provides advantages in terms of time, cost and labour force. In typical case sampling, which is one of the non-probability-based sampling methods, the situation or event desired to be revealed is revealed and studied (Karagöz, 2017). The alternative concepts of the students to whom ACIT was applied were identified, and frequency tables were created; then, semi-structured interview forms were prepared for 16 students randomly selected among the students determined by the typical case sampling method, and interviews were conducted with the students.

Table 1. Demographic information of the students participating in the alternative concept identification test

	Participant	N	%
Gender	Female	170	51
	Male	162	49
	Total	332	100
Grade level	5th grade	61	18
	6th grade	79	24
	7th grade	91	27
	8th grade	101	31

	Total	332	100

Table 1 shows the demographic information of the students participating in the study.

Data Collection Tools of the Research

In the study, the Alternative Concept Identification Test (ACIT) developed by the researcher was used as a data collection tool to determine the alternative concepts of the students in the subjects of the structure of celestial bodies, celestial events and the motions of celestial bodies. Semi-structured interviews were conducted with students randomly selected from among the students determined by typical case sampling. These interviews were aimed at deepening the data obtained from the screening. In the semi-structured interview technique, different questions were asked to the students according to their alternative concepts.

Quantitative Data Collection Tool

This study used a three-stage test due to the limitations of classical multiple-choice tests in identifying students' alternative conceptions. While developing three-stage diagnostic tests to identify alternative conceptions, researchers were mostly inspired by the methods developed by Treagust (1988) (Güneş, 2020). While developing the ACIT, the researcher utilised the test development stages and was inspired by Güneş's (2020) studies. The researcher prepared a specification table for ACIT and prepared 29 original items after reviewing the literature. In the first stage of each item, the question is asked; in the second stage, the options that can be considered as the reason for the answer given to the first question; and in the third stage, it is asked whether they are sure of the answer given. While developing ACIT, expert opinions were obtained from 1 language expert and 5 science experts. After the expert opinions were received, the necessary corrections were made, and a pilot study was carried out with a total of 63 5th, 6th, 7th and 8th-grade students studying in a different school in the same province. Based on the item difficulty indices and discrimination indices of the data obtained from the pilot study, 9 items that were not suitable were removed from the test, and corrections were made to the items deemed necessary. According to the item difficulty index, five items determined to be easy, two items determined to be difficult, and two items whose item discrimination index was not appropriate were removed from the test. The reliability analysis of the 20 items in the final version of the test was performed, and the KR-20 value was found to be 0.82. After the pilot application, adjustments were made in 2 items that were thought to be misunderstood by the students and therefore could not be answered correctly, and after the validity and reliability studies, the test was made suitable for the actual application phase.

Expert opinion was taken to ensure the content validity of the test. In addition, the criterion and construct validity of the Alternative Concept Identification Test were examined. Since confidence scores and reasoning questions can be examined separately in tests consisting of more than one stage, it is recommended to calculate the correlation between confidence scores and reasoning questions (Kaltakçı, 2012). In his study, Güneş (2020) investigated the relationship between the students' scores at the initial, reasoning and confidence stages of the answers separately and in combinations to determine the construct validity of the scale. In this study, the construct validity of each item in the test was analyzed by looking at the correlation between the 1st and 2nd stage questions and then between the 1st and 3rd stage questions. In the 1st and 2nd stages of the test, the presence of knowledge about the subject is questioned in the 3rd stage and the state of certainty is questioned in the 3rd stage. In this study, correlations were analyzed separately for the trust questions in Stage 3 and for Stages 1 and 2. Pearson correlations (r), if r = 0.10 to r = 0.29, there is a small correlation; if r = 0.30 to r = 0.49, there is a medium correlation; and if r = 0.50 to r = 1.0, a large correlation can be mentioned (Pallant, 2011, p. 134).

Table 2. Correlations between the correct scores of the phases of the items in the test

1. Phases	Phase 2	
	Pearson Correlation	0,946
	Sig. (2-tailed)	0,000
	N	332
2. Phases	Phase 3	
	Pearson Correlation	0,384
	Sig. (2-tailed)	0,000
	N	332
3. Phases	Phase 1	

	Pearson Correlation	0,391
	Sig. (2-tailed)	0,000
	N	332

When Table 2 is analyzed, it is seen that the Pearson correlation between the correct scores of the 1st and 2nd stages is r = 0,946, which indicates a very high level of positive relationship. The values of r = 0,384 between the correct scores of the 2nd and 3rd stages and r = 0,391 between the correct scores of the 1st and 3rd stages indicate a moderate positive relationship.

Qualitative Data Collection Tool

A semi-structured interview technique was used in the qualitative part of the study. The aim was to facilitate the researcher's in-depth evaluation and analysis of the data with the questions during the semi-structured interviews conducted after the Alternative Concept Identification Test. A semi-structured interview form was used as a qualitative data collection tool in the study. The researcher created the semi-structured interview forms by using the answers containing alternative concepts that the students could give. The forms included fifteen questions, and each interview lasted approximately one hour. The interviews were conducted face-to-face and individually in the classrooms by providing students with a comfortable environment. Extra questions were added to the interview at the points deemed necessary, and questions that were not deemed necessary were removed. A total of 16 students were interviewed, selecting four students from each grade level. In addition, the validity and reliability of the scale were increased by means of the voice recordings taken during the semi-structured interviews and the care taken during the evaluation.

Data Collection Process of the Research

The Alternative Concept Identification Test was applied to a total of 332 students attending secondary school. The duration of the test was 40 minutes. The answers given by 332 students to the 20-item test, each of which consists of three stages, were recorded as data.

In the process of collecting qualitative data, only the students who were willing to be interviewed were interviewed from the students selected among the students who were found to have alternative concepts after the analysis of ACIT. A total of 16 students, four students in each grade level, were interviewed. Of these students, six were female, and ten were male. Each student was interviewed separately and reminded of their answers, and asked to explain them.

Data Analysis of the Research

Analyzing the Quantitative Data of the Research

In this study, the answer options given by the participants for each stage were entered into the MS Excel program. The answers of the participants who chose option E, i.e. 'None', were read by the researcher, and the correct answers were coded as 'E1', while the wrong answers were coded as 'E0'. After these processes, values were entered for each option in the data transferred to the SPSS programme according to the answer key; correct answers were coded as 1 and incorrect answers as 0. For the 3rd stage of each item, the answer 'I am sure' was coded as 1 and 'I am not sure' as 0. In order to be able to talk about the existence of an alternative concept in a student in the test, he/she must choose the wrong option at the 1st stage of the item, the wrong option at the 2nd stage, and the 'I am sure' option at the 3rd stage. Alternative concepts were identified accordingly, and only the frequencies and percentages of the options for the items in which alternative concepts were identified were included. When the literature was examined, it was determined that the alternative concepts preferred by more than 10% of the sample were considered important, and these alternative concepts were included in the results (Kaltakçı, 2012; Önsal, 2016). In this study, the alternative concepts preferred by more than 10% of the sample were listed.

Analyzing the Qualitative Data of the Research

Descriptive analysis was used to analyze the qualitative data. The data obtained in the descriptive analysis are described according to appropriate themes. In descriptive analysis, quotations are often included (Karagöz, 2017). In the study, an MS Word file was created for each student by compiling the audio recordings taken during the semi-structured interviews with the students and the notes taken during the interview. The interviews were re-examined, and the answers containing alternative concepts repeated by the students were selected. The alternative concepts identified through semi-structured interviews were described under the appropriate item. A coding

indicating the number of students participating in the research was used in the samplings made from the student answers: first student S-1, second student S-2.

Findings

In this part of the study, the analyses and findings obtained from the alternative concepts identified by using ACIT prepared on the subjects of the structure of celestial bodies, celestial events and the motions of celestial bodies are given. In addition to the alternative concepts identified in the ACIT, the findings obtained from the interviews with the students using the semi-structured interview technique are also included. Each of the 20 questions in the ACIT consists of 3 stages. In the findings section of the study, as stated in the data analysis section, alternative concepts were identified, and only the frequencies and percentages of the options for the items in which more than 10% of the sample had an alternative concept and semi-structured interviews were included.

For item 3, 89 of the 332 students who participated in the ACIT at the first and second stages selected the options containing alternative concepts and chose 'I am sure' at the 3rd stage; therefore, it can be said that 89 students have the alternative concepts contained in item 3.

Table 3. Frequency table of the answers in which alternative concepts were detected in students in item 3

Item 3		A*	C	D	E0	Total
Phase 1	F	74	1	9	5	89
	%	83,1	1,1	10,1	5,6	100
Phase 2	F	76	5	7	1	89
	%	85,4	5,6	7,9	1,1	100

* Indicates the answers given by more than 10 per cent of the sample.

The most repeated alternative concept in the 1st and 2nd stages of item 3 was option 'A'. In the 1st stage of the item 'Why night and day occur', the statement 'Night and day occur when the Earth moves around the Sun.' was chosen by 74 out of 89 students (83.1%). In the 2nd stage, among the options containing alternative concepts, the statement 'One side of the Earth is illuminated, and the other side remains in darkness due to the rotation of the Earth around the Sun.' was chosen by 76(85.4%) of 89 students who chose the statements indicating alternative concepts.

After the application of the Alternative Concept Identification Test, it was seen that students S-234 and S-26, who were randomly selected among the students who were found to give answers containing alternative concepts, had the alternative concepts that Item 3 aimed to identify. The interviews with S-234 and S-26 are given below.
Interview with S-234;
Researcher: I wanted to get more detailed information from the answers you gave in the study you participated in. When I asked you, 'Why do day and night occur?', you answered as follows: 'As the Earth travels around the Sun, one side of the Earth is illuminated, and the other side remains in darkness. Why do you think that day and night are formed when the Earth travels around the Sun?
S-234: Because the Sun's rays always come in a different way when the Earth is travelling around, the side that the Sun hits is bright, and the other side is dark. That is why day and night occur.
Researcher: Are you sure about your answer?
S-234: Yes, I am sure.
Interview with S-26;
Researcher: When you were asked, 'How do day and night occur?' in the test, you answered ', One side of the Earth is illuminated, and one side is in darkness as the Earth moves around the Sun.' Why do you think day and night occur? Why do you think that day and night are formed by the rotation of the Earth around the Sun?
S-26: If we talk about day and night events, it is due to the rotation of the Earth around the Sun.
Researcher: How does the Earth's orbiting around the Sun cause day and night?
S-26: In general, when the light of the whole Earth is coming from the Sun, that is, when the Sun is rising, now, for example, the light of the Sun is received by those on one side, and it comes from the Sun as it travels around. It does not go to one side; the two sides are different, that is, one side is daytime, and the other side is dark.
Researcher: Are you sure of your answer?
S-26: Yes, yes.

For item 4, 101 of the 332 students who participated in the ACIT at the first and second stages selected the options containing alternative concepts and chose 'I am sure' at the 3rd stage; therefore, it can be said that 101 students have the alternative concepts contained in item 4.

Table 4. Frequency table of the answers in which alternative concepts were detected in students in item 4

Item 4		A*	C	D	E0	Total
Phase 1	F	86	4	10	1	101
	%	85,1	4,0	9,9	1,0	100
Phase 2	F	85	5	10	1	101
	%	84,2	5,0	9,9	1,0	100

* Indicates the answers given by more than 10 per cent of the sample.

The most repeated alternative concept in the 1st and 2nd stages of item 4 was option 'A'. The statement 'The Earth rotates around its axis in 365 days and 6 hours' among the options containing alternative concepts in the 1st stage of the item 'Which of the information about the rotation and circulation times of the Sun, the Earth and the Moon is true?' was chosen by 86 (85.1%) of 101 students who chose the statements indicating alternative concepts. In the 2nd stage, among the options containing alternative concepts, 'The Earth completes its rotation around its axis in 365 days and 6 hours. This period is called a year.' was chosen by 85(84,2%) of 101 students who chose the statements indicating alternative concepts.

After the application of the Alternative Concept Identification Test, it was seen that student S-5, who was randomly selected among the students who were found to give answers containing alternative concepts, had the alternative concepts that Item 4 aimed to identify. The interview with S-5 is given below.
Interview with S-5;
Researcher: In the test, you participated in before, when you were asked, 'Which of the information about the rotation and circulation times of the Sun, the Earth and the Moon is correct?' you answered, 'The Earth rotates around its axis in 365 days and 6 hours.'. Why do you think the Earth rotates around its axis in 365 days and 6 hours?
S-5: I know, so that's how we learnt it. The Earth rotates around its axis in 365 days and 6 hours. So, it takes a year.
Researcher: Are you sure about your answer?
S-5: Yes, it is 365 days.

For item 5, 81 out of 332 students who participated in the ACIT, it was seen that 81 of them selected the options containing alternative concepts in the 1st and 2nd stages and selected 'I am sure' in the 3rd stage. Therefore, it can be said that 81 students have alternative concepts contained in item 5.

Table 5. Frequency table of the answers in which alternative concepts were detected in students in item 5

Item 5		B*	C	D	E0	Total
Phase 1	F	65	3	13	0	81
	%	80,2	3,7	16,0	0	100
Phase 2	F	58	12	10	1	81
	%	71,6	14,8	12,3	1,2	100

* Indicates the answers given by more than 10 per cent of the sample.

The most repeated alternative concept in the 1st and 2nd stages of item 5 was option 'B'. 'When we observe the Sun during the day, we observe it in different positions from sunrise to sunset. What is the reason for this?' was selected by 65 (80.2%) out of 81 students who chose statements indicating alternative concepts. The statement 'The Sun is seen in different places in the sky when the Earth is travelling around the Sun' was chosen by 58(71.6%) of 81 students who selected the statements indicating alternative concepts.

After the application of the Alternative Concept Identification Test, it was seen that students S-234 and S-52, who were randomly selected among the students who were found to give answers containing alternative concepts, had the alternative concepts that Item 5 aimed to identify. The interviews with S-234 and S-52 are given below.
Interview with S-234;
Researcher: When we observe the Sun during the day, we observe it in different positions from sunrise to sunset. When I asked you what the reason for this was, 'Because the Earth revolves around the Sun, the Sun is seen in different places in the sky'. You gave an answer as follows. Do you think the reason why the Sun is observed in different positions during the day could be the Earth's rotation around the Sun?

S-234: Because as the Earth moves, for example, as it rotates, the Sun also rotates, so its position changes. As the Earth rotates around the Sun, the Sun also rotates because the Sun stays in its position.
Researcher: Why do you think the Sun staying in place will change its position in the sky?
S-234: The Sun revolves around itself. But we see it that way because the Earth revolves around it.
Researcher: I see. Are you sure of your answer?
S-234: Yes, I am sure.
Interview with S-52;
Researcher: In the test you participated in before, I asked you, 'When we observe the Sun during the day, we observe it in different positions from sunrise to sunset. What is the reason for this?' You answered as follows: 'Because the Earth revolves around the Sun, the Sun appears in different places in the sky'. Why do you think the Sun is observed in different positions during the day due to the Earth's orbit around the Sun?
S-52: Since the Earth revolves around the Sun, the position of the Sun is constantly changing. That's why I gave such an answer.
Researcher: Are you sure about your answer?
S-52: Yes, I am sure.

For item 6, 101 out of 332 students who participated in the ACIT selected the options containing alternative concepts at the 1st and 2nd stages and selected 'I am sure' at the 3rd stage; therefore, it can be said that 101 students have the alternative concepts contained in item 6.

Table 6. Frequency table of the answers in which alternative concepts were detected in students in item 6

Item 6		A	C*	D*	E0	Total
Phase 1	F	5	48	39	9	101
	%	5,0	47,5	38,6	8,9	100
Phase 2	F	6	48	39	8	101
	%	5,9	47,5	38,6	7,9	100

* Indicates the answers given by more than 10 per cent of the sample.

The most repeated alternative concept in the 1st and 2nd stages of item 6 was option 'C'. 'The statement 'When the Earth rotates on its axis, the Moon is observed in different ways.' was chosen by 48 (47.5%) out of 101 students who chose the statements indicating alternative concepts. The statement 'When the Earth rotates around its axis, the Moon is observed in different ways because it is out of the Earth's field of view.' was chosen by 48(47,5%) of 101 students who selected the statements indicating alternative concepts.

After the application of the Alternative Concept Identification Test, it was seen that students S-228, S-94, S-67 and S-52, who were randomly selected among the students who were found to give answers containing alternative concepts, had the alternative concepts that Item 6 aimed to identify. The interviews with S-228, S-94, S-67 and S-52 are given below.
Interview with S-228;
Researcher: When I asked you, 'Why is the Moon seen differently when looking at the night sky on different dates?' you answered ', The Earth's shadow falls on the Moon'. Why do you explain that the Moon appears in different ways because of the Earth's shadow?
S-228: The Moon is already travelling around in 30 days, and since it rotates in 30 days, its visible face cannot change. It looks like that because only one region remains visible, and I think it looks like that because the Earth's shadow falls.
Researcher: Does the Earth's shadow always fall on the Moon?
S-228: The Earth's shadow falls every day of the month. Let me think for a minute. It does not fall when the Moon is full.
Researcher: Are you sure about your answers?
S-228: Yes, I am sure.
When the interview researcher asked the same question to S-94,
S-94: Because it falls. When the Earth enters between the Moon and the Sun, the Earth's shadow is seen in different ways because it falls on the Moon.
Researcher: Are you sure about your answer?
S-94: Yes.
Interview with S-67;

Researcher: When I asked you in the sixth question, 'Why is the Moon seen differently when looking at the night sky on different dates?' you answered, 'When the Earth rotates around its axis, we see the Moon in different ways. Why do you think the reason why we see the Moon in different shapes is the rotation of the Earth around its axis?
S-67: We see the Moon in different shapes because the Moon is out of the Earth's field of view.
Researcher: Why do you think the Moon comes out of the Earth's field of view?
S-67: Because when the Earth rotates on its axis, the Moon should also rotate, and when the Moon rotates, both of them rotate, so we see it differently.
Researcher: Are you sure?
S-67: Yes.
Interview with S-52;
Researcher: In another question in the test, when I asked, 'Why is the Moon seen differently when looking at the night sky on different dates?' you answered, 'When the Earth rotates around its axis, we see the Moon in different ways. Why do you think the reason why we see the Moon in different shapes is the rotation of the Earth around its axis?
S-52: Because when the Earth rotates, the Moon falls in the Earth's shadow and out of sight, so it looks different.
Researcher: Why do you think the reason for the different shapes of the Moon is the shadow of the Earth?
S-52: Since we are constantly rotating, we cannot see the Moon all the time. For example, when it turns in the opposite direction, some of it can be in the shadow.
Researcher: Are you sure about your answer?
S-52: Yes, I am sure.

For item 10, 93 out of 332 students who participated in the ACIT for item 10, it was seen that 93 of them selected the options containing alternative concepts at the 1st and 2nd stages and selected 'I am sure' at the 3rd stage; therefore, it can be said that 93 students have the alternative concepts contained in item 10.

Table 7. Frequency table of the answers in which alternative concepts were detected in students in item 10

Item 10		A*	B	C	E0	Total
Phase 1	F	42	21	23	7	93
	%	45,2	22,6	24,7	7,5	100
Phase 2	F	42	22	24	5	93
	%	45,2	23,7	25,8	5,4	100

* Indicates the answers given by more than 10 per cent of the sample.

The most repeated alternative concept in the 1st and 2nd stages of item 10 was option 'A'. Among the options containing alternative concepts in the 1st stage of the item 'How can the celestial phenomenon called shooting star be explained?', the expression 'It is the movement of comets.' was selected by 42 (45.2%) of 93 students who chose expressions indicating alternative concepts. In the 2nd stage, the statement 'This celestial phenomenon is observed as a result of the movement of comets.' was chosen by 42(45,2%) of 93 students who chose the statements indicating alternative concepts.

After the application of the Alternative Concept Identification Test, it was seen that students S-240, S-165, S-104, S-67 and S-52, who were randomly selected among the students who were found to give answers containing alternative concepts, had the alternative concepts that Item 10 aimed to identify. The interviews with -240, S-165, S-104, S-67 and S-52 are given below.
Interview with S-240;
Researcher: When I asked, 'How can the celestial event called shooting star be explained?' in the tenth question in the test, your answer was 'It is the movement of stars in space'. Why do you think so?
S-240: Stars move so fast from one place to another in space. This is how we observe it from Earth.
Researcher: Why do you think that shooting stars are the rapid movement of stars?
S-240: Because stars move fast and fast.
Researcher: Are you sure about your answer?
S-240: I am sure, yes.
Interview with S-165;
Researcher: In the tenth question, I asked you, 'How can you explain the celestial phenomenon called a shooting star?'. You said, 'It is a large cloud of gas and dust that comes out of the stars as they move. Can you explain why you think this way?
S-165: We had studied it in science class. That's how I remembered it as the cloud of gas and dust they emit while moving, so I expressed it that way.
Researcher: In the explanation part, you said that you thought, 'It is a celestial event observed from the Earth because they change their places quickly'. Why do you think the stars move quickly?

S-165: I mean, I think it happens quickly because it is an event that happens in a short time.
Researcher: Are you sure?
S-165: Yes
Interview with S-104;
Researcher: When I asked, 'How can the celestial event called shooting star be explained?' in the tenth question, you answered, 'It is the death of a star. It is the disappearance of the stars whose life is over in the depths of space. Why do you think that shooting stars are the death of stars and their disappearance in the depths of space?
S-104: Teacher, I think that a dying star falls at that speed because it cannot stand in space and has no energy left.
Researcher: Are you sure?
S-104: I am sure it makes sense.
Interview with S-67;
Researcher: When I asked, 'How can the celestial phenomenon called shooting star be explained?' in the tenth question, you said, 'It is the movement of comets. This celestial phenomenon is observed as a result of the movement of comets. Why do you think shooting stars are the movement of comets?
S-67: I think so because the stars are shooting. The ones with comets are shooting. There are other stars and other normal stars.
Researcher: Are you sure about your answer?
S-67: I am sure.
Interview with S-52;
Researcher: When I asked you, 'How can the celestial phenomenon called shooting star be explained?' you said, 'It is the movement of comets. This celestial phenomenon is observed as a result of the movement of comets. Why do you think shooting stars are the movement of comets?
S-52: Now, comets are formed because of shooting stars. Shooting stars turn into comets.
Researcher: Are you sure?
S-52: Yes.

For item 13, 136 out of 332 students who participated in the ACIT for item 13, it was seen that 136 students selected the options containing alternative concepts in the 1st and 2nd stages and selected ‘I am sure’ in the 3rd stage. Therefore, it can be said that 136 students have alternative concepts included in item 13.

Table 8. Frequency table of the answers in which alternative concepts were detected in students in item 13

Item 13		A*	C	D	E0	Total
Phase 1	F	108	7	2	19	136
	%	79,4	5,1	1,5	14,0	100
Phase 2	F	106	6	5	19	136
	%	77,9	4,4	3,6	14,0	100

* Indicates the answers given by more than 10 per cent of the sample.

The most repeated alternative concept in the 1st and 2nd stages of item 13 was option ‘A’. In the 1st stage of the item ‘How often does a solar eclipse occur?’, the statement ‘It occurs once every year’ was chosen by 108 (79.4%) of the 136 students who chose the statements indicating alternative concepts. In the 2nd stage, among the options containing alternative concepts, the statement ‘It occurs once every year because the Earth goes around the Sun in 1 year.’ was chosen by 106 (77.9%) out of 136 students who selected the statements indicating alternative concepts.

After the application of the Alternative Concept Identification Test, it was seen that students S-228, S-240, S-169 and S-7, who were randomly selected among the students who were found to give answers containing alternative concepts, had the alternative concepts that Item13 aimed to identify. The interviews with S-228, S-240, S-169 and S-7 are given below.
Interview with S-228;
Researcher: In the thirteenth question, I asked you ‘How often does a solar eclipse occur?’. You stated, ‘It occurs once every month and a solar eclipse occurs when the moon is in the full moon phase. Why do you think there will be a solar eclipse every full moon phase?
S-228: Since the phases of the moon are when the moon is full, that's how I remembered the solar eclipse. I think it happens every full moon phase.
Researcher: Are you sure?
S-228: I am sure.
Interview with S-240;

Researcher: In the thirteenth question, I asked you 'How often does a solar eclipse occur?'. You answered 'It happens once every year. Since the Earth goes round the Sun in 1 year, it happens only once every year. Why do you think there will be a solar eclipse once every year?
S-240: Because the Earth goes round the Sun. Because it rotates in one year.
Researcher: What is the relation between the solar eclipse and the movement of the Earth around the Sun?
S-240: The Earth goes round in a year. The Earth also coincides with the Moon, and at that time there is a solar eclipse.
Researcher: Are you sure?
S-240: Yes.
Interview with S-169;
Researcher: In another question, when I asked you 'How often does a solar eclipse occur?' you said 'It happens once every year. Because the Sun, Moon and Earth line up once a year. You answered as follows. Why do you think a solar eclipse will occur every year?
S-169: Once every year, the order is Earth, Moon, and Sun, so there is a solar eclipse.
Researcher: Are you sure?
S-169: Yes.
Interview with S-7;
Researcher: When you were asked 'How often does a solar eclipse occur?', you said 'It happens once every year'. Why do you think the solar eclipse happens once every year?
S-7: As the earth rotates around the sun, one year passes in each rotation. It comes to the same position only once, so it happens once.
Researcher: Why do you think they come to the same position once a year?
S-7: The sequence is between the Sun and the Earth, so the Moon enters.
Researcher: Are you sure of your answer?
S-7: I am sure, yes.

For item 14, 53 of the 332 students who participated in the ACIT for item 14, it was seen that 53 of them selected the options containing alternative concepts at the 1st and 2nd stages and chose 'I am sure' at the 3rd stage; therefore, it can be said that 53 students have the alternative concepts contained in item 14.

Table 9. Frequency table of the answers in which alternative concepts were detected in students in item 14

Item 14		B*	C	D	E0	Total
Phase 1	F	38	8	6	1	53
	%	71,7	15,1	11,3	1,9	100
Phase 2	F	37	9	6	1	53
	%	69,8	17,0	11,3	1,9	100

* Indicates the answers given by more than 10 per cent of the sample.

The most repeated alternative concept in the 1st and 2nd stages of item 14 was option 'B'. In the 1st stage of the item 'How does a lunar eclipse occur?', the statement 'It occurs when the Sun enters between the Earth and the Moon' was selected by 38 (71.7%) of 53 students who chose the statements indicating alternative concepts. In the 2nd stage, the statement 'Since the Moon is behind the Sun, we cannot observe the Moon from the Earth.' was chosen by 37(69.8%) of 53 students who selected the statements indicating alternative concepts.

After the application of the Alternative Concept Identification Test, it was seen that student S-234, who was randomly selected among the students who were found to give answers containing alternative concepts, had the alternative concepts that Item 14 aimed to identify. The interview with S-234 is given below.
Interview with S-234;
Researcher: In question 14, when I asked, 'How does a lunar eclipse occur?', you said, 'It occurs when the Sun enters between the Earth and the Moon. We cannot see the Moon from the Earth because the Sun is entering between the Earth and the Moon. ' Why do you think that the Sun enters between the Earth and the Moon for a lunar eclipse to occur?
S-234: Because when the Sun comes between the Earth and the Moon, we cannot see the Moon. The Moon cannot be seen because the Sun is too big.
Researcher: Are you sure about your answers?
S-234: Yes.

For item 15, 89 out of 332 students who participated in the ACIT for item 15, it was seen that 89 of them selected the options containing alternative concepts in the 1st and 2nd stages and chose 'I am sure' in the 3rd stage. Therefore, it can be said that 89 students have alternative concepts included in item 15.

Table 10. Frequency table of the answers in which alternative concepts were detected in students in item 15

Item 15		B*	C	D	E0	Total
Phase 1	F	51	6	19	13	89
	%	57,3	6,7	21,3	14,6	100
Phase 2	F	47	11	20	11	89
	%	52,8	12,4	22,5	12,4	100

* Indicates the answers given by more than 10 per cent of the sample.

The most repeated alternative concept in the 1st and 2nd stages of item 15 was option 'B'. In the 1st stage of the item 'How often does a lunar eclipse occur?', the statement 'It occurs once every year' was selected by 51 (57.3%) of 89 students who chose the statements indicating alternative concepts. In the 2nd stage, among the options containing alternative concepts, the statement 'It occurs once a year since the Moon circles around the Sun with the Earth in 1 year.' was selected by 47(52.8%) of 89 students who chose the statements indicating alternative concepts.

After the application of the Alternative Concept Identification Test, it was seen that students S-228, S-129, S-165, S-104 and S-7, who were randomly selected among the students who were found to give answers containing alternative concepts, had the alternative concepts that Item15 aimed to identify. The interviews with S-228, S-129, S-165, S-104, S-7 are given below.
Interview with S-228;
Researcher: In question 15, when I asked, 'How often does the lunar eclipse occur?', you answered, 'The lunar eclipse occurs once every month. Why do you think the lunar eclipse occurs once every month?
S-228: Since the Moon comes between the Earth and the Sun every month, a shadow is constantly cast on the Moon. A shadow is cast on the Moon every time.
Researcher: Are you sure about your answer?
S-228: Yes.
Interview with S-129;
Researcher: In the 15th question, I asked, 'How often does a lunar eclipse occur?' and you answered, 'A lunar eclipse occurs once every month. Since the Sun, the Earth and the Moon are aligned in the same direction every month, it happens every month. Why do you think that a lunar eclipse occurs every month when the Earth and the Sun are aligned?
S-129: Because the Sun gives light and the Moon creates a shadow on the Earth by covering that light. They should not be random; they should be equal. It has to be in such a reciprocal way that it coincides once a month.
Researcher: Are you sure?
S-129: Yes.
Interview with S-165;
Researcher: When I asked, 'How often does a lunar eclipse occur?' in the question, you answered, 'It happens once every year. Since the Moon circles around the Sun with the Earth in 1 year, it happens once a year. Why do you think the lunar eclipse occurs once every year?
S-165: Because they occur once a year in the same order as in the solar eclipse.
Researcher: Are you sure?
S-165: Yes
Interview with S-104;
Researcher: In the 15th question, I asked, 'How often does a lunar eclipse occur?' and you answered, 'It occurs once every month. Since the directions of the Sun, the Earth and the Moon are aligned every month, it happens every month. Why do you think so?
S-104: Because it happens during the full moon phase of the Moon. In every full moon phase, an eclipse occurs because the same Moon, Earth and Sun are aligned. Because the Moon is behind the Earth.
Researcher: Are you sure of your answer?
S-104: Yes, I am sure.
Interview with S-7;
Researcher: In question 15, when I asked, 'How often does a lunar eclipse occur?', you answered, 'It happens once every year. You answered as follows. Why do you think a lunar eclipse occurs every year?
S-7: Now, while the Moon goes round the Earth, the Earth also goes round the Sun. Since it aligns with the Earth once, there is a lunar eclipse once every year.
Researcher: Are you sure?
S-7: Yes, I am very sure.

For item 16, 66 out of 332 students who participated in the ACIT for item 16, it was seen that 66 students selected the options containing alternative concepts at the 1st and 2nd stages and chose 'I am sure' at the 3rd stage, so it can be said that 66 students have the alternative concepts contained in item 16.

Table 11. Frequency table of the answers in which alternative concepts were detected in students in item 16

Item 16		A*	B	C	E0	Total
Phase 1	F	36	12	16	2	66
	%	54,5	18,1	24,2	3,0	100
Phase 2	F	37	14	13	2	66
	%	56,1	21,2	19,7	3,0	100

* Indicates the answers given by more than 10 per cent of the sample.

The most repeated alternative concept in the 1st and 2nd stages of item 16 was option 'A'. 'The statement 'Stars are the smallest celestial bodies.' was selected by 36 (54.5%) out of 66 students who chose the statements indicating alternative concepts. In the 2nd stage, the statement 'When looking at the sky at night, the stars appear very small.' was chosen by 37(56.1%) of 66 students who chose the statements indicating alternative concepts.

After the application of the Alternative Concept Identification Test, it was seen that students S-234 and S-94, who were randomly selected among the students who were found to give answers containing alternative concepts, had the alternative concepts that Item 16 aimed to identify. The interviews with S-234 and S-94 are given below.
Interview with S-234;
Researcher: When I asked you, 'Which of the information about the stars is correct?' in Question 16 of the test you participated in, you said, 'The moon is a star'. Why do you think the Moon is a star?
S-234: Because all planets and objects are stars. We only see them as planets, for example. But they are actually stars. So they are all different types of stars.
Researcher: Why do you think all celestial bodies are stars?
S-234: They emit light, that is, they reflect. They give the reflection coming from the sun. The sun provides light because it is the biggest.
Researcher: Are you sure?
S-234: Yes.
Interview with S-94;
Researcher: In the question, I asked, 'Which of the information given about stars is correct?'. You said, 'Stars are the smallest celestial bodies. Why do you think stars are the smallest celestial bodies?
S-94: Actually, the big ones are small compared to the planets. They are big compared to us, but they are small compared to other celestial bodies.
Researcher: Are you sure?
S-94: Yes.

For item 18, 47 out of 332 students who participated in the ACIT for item 18, it was seen that 47 students selected the options containing alternative concepts at the 1st and 2nd stages and chose 'I am sure' at the 3rd stage. Therefore, it can be said that 47 students have alternative concepts contained in item 18.

Table 12. Frequency table of the answers in which alternative concepts were detected in students in item 18

Item 18		A*	B	D	E0	Total
Phase 1	F	34	8	5	0	47
	%	72,3	17,0	10,6	0	100
Phase 2	F	32	10	5	0	47
	%	68,1	21,3	10,6	0	100

* Indicates the answers given by more than 10 per cent of the sample.

The most repeated alternative concept in the 1st and 2nd stages of item 18 was option 'A'. 'Why are constellations grouped by being likened to various animals, objects or figures?' was chosen by 34 (72.3%) out of 47 students who selected the statements indicating alternative concepts among the options containing alternative concepts in the 1st stage of the item 'Because they are clusters of stars close to each other, they have a common name'. In the 2nd stage, the statement 'These stars are the closest stars to each other in space, so they are named in common.' was chosen by 32(68.1%) out of 47 students who chose the statements indicating alternative concepts.

After the application of the Alternative Concept Identification Test, it was seen that students S-94 and S-26, who were randomly selected among the students who were found to give answers containing alternative concepts, had the alternative concepts that Item 18 aimed to identify. Interviews with S-94 and S-26 are given below.
Interview with S-94;
Researcher: In the eighteenth question, when I asked, 'Why are constellations grouped by likening them to various animals, objects or figures?', you answered, 'They are named in common because they are star clusters close to each other'. You answered. Why do you think stars are named in common because they are close?
S-94: They are close because they are close to each other, so they are common.
Researcher: Are you sure?
S-94: Yes
Interview with S-26;
Researcher: When I asked you, 'Why are constellations grouped by likening them to various animals, objects or figures?' you answered, 'Stars consisting of the same types of stars are named in common'. You answered. Why do you think the same types of stars will be named in common?
S-26: For example, when they look at the stars there, they have the same objects (talking about smartphone applications), and they name them the same. When some of them have the same shapes, they can also name them differently. Stars are generally similar in type and shape, so they are named in common.
Researcher: Are you sure?
S-26: I am sure.

For item 20, 99 out of 332 students who participated in the ACIT for item 20, it was seen that 99 of them selected the options containing alternative concepts at the 1st and 2nd stages and selected 'I am sure' at the 3rd stage. Therefore, it can be said that 99 students have alternative concepts contained in item 20.

Table 13. Frequency table of the answers in which alternative concepts were detected in students in item 20

Item 20		B*	C	D	E0	Total
Phase 1	F	61	15	20	3	99
	%	61,6	15,2	20,2	3,0	100
Phase 2	F	62	14	20	3	99
	%	62,6	14,1	20,2	3,0	100

* Indicates the answers given by more than 10 per cent of the sample.

The most repeated alternative concept in the 1st and 2nd stages of item 20 was option 'B'. The statement 'Scientists who are interested in astronomy are called astrologers' among the options containing alternative concepts in the 1st stage of the item 'Which of the given comments about astronomy is correct?' was chosen by 61 (61.6%) of 99 students who chose the statements indicating alternative concepts. 62(62,6%) out of 99 students who selected alternative concept-containing options in the 2nd stage, the statement 'Astrologers are scientists who work on subjects such as the structure of celestial bodies and celestial events.' was selected by 62(62,6%) of 99 students who selected the statements indicating alternative concepts.

After the application of the Alternative Concept Identification Test, it was seen that student S-240, who was randomly selected among the students who were found to give answers containing alternative concepts, had the alternative concepts that Item 20 aimed to identify. The interview with S-240 is given below.
Interview with S-240;
Researcher: When I asked you, 'Which of the comments about astronomy is correct?' in our last question, you answered, 'Scientists who are interested in astronomy are called astrologers. Why do you think scientists interested in astronomy are called astrologers?
S-240: These names, experienced names, astrologers, interpreters, as far as I know, take videos of space with pictures or something like that.
Researcher: Why do you think astrologers make scientific interpretations?
S-240: They do not do exact science. They only bring evidence and interpret it from space. They create them in a scientific way.
Researcher: Are you sure?
S-240: I am sure.

Ethics approval notification
Ethical permission (04.04.2023-2023-500) was obtained from Gazi University Ethics Commission this research.

Discussion and Conclusion

The frequencies and percentages of all alternative concepts determined by ACIT, which was created to determine the alternative concepts of secondary school students in the subjects of the structure of celestial bodies, celestial events and the motions of celestial bodies, are given in the findings. When the literature was examined, it was determined that the alternative concepts preferred by more than 10% of the sample were considered important, and these alternative concepts were included in the results (Kaltakçı, 2012; Önsal, 2016).

In this study, the alternative concepts preferred by more than 10% of the sample were listed. It is noteworthy that more than 30% of the students preferred the statements' A solar eclipse occurs once every year.' and 'Since the Earth revolves around the Sun in 1 year, a solar eclipse occurs only once every year.' which include the alternative concepts in item 13. Research shows that students' misunderstanding of the Sun, Earth and Moon positions leads to the spread of alternative conceptions about the occurrence of eclipses (LoPresto & Murrell, 2011). In particular, a significant number of students think that a solar eclipse occurs only once every year and that it is directly related to the motion of the Earth around the Sun. However, this misconception stems from incomplete or erroneous knowledge about the orbital motions and alignments of the Sun, Earth and Moon (Vosniadou & Skopeliti, 2017). Although studies in the literature support those alternative conceptions are frequently encountered in the subjects of solar eclipse and lunar eclipse, no alternative conceptions about the frequency of solar and lunar eclipse were found in these studies (Bostan, 2008; Harman, 2016; Küçüközer & Bostan, 2010; Trumper, 2001).

More than 25% of the students stated, 'The Earth rotates around its axis in 365 days and 6 hours.' and 'The Earth completes its rotation around its axis in 365 days and 6 hours. This period is called a year.' statements were repeated quite frequently. The alternative concepts identified in item 4 are also supported by studies in the literature (Uğurlu, 2005). Such misconceptions may result from deficiencies in the learning of basic astronomical concepts. For example, one complete rotation of the Earth around its axis takes approximately 24 hours (23 hours 56 minutes 4 seconds to be precise), while one complete revolution around the Sun takes approximately 365 days 6 hours. Confusing the durations of these two different motions may lead to misconceptions in students.

It was observed that more than 20% of the students repeated the statements 'When the Earth revolves around the Sun, there is day and night' and 'When the Earth revolves around the Sun, one side of the Earth is illuminated, and the other side remains in darkness', which contain alternative concepts. When the literature was examined, studies supporting the alternative concepts identified in item 3 were found (Frede, 2006; Trumper, 2003; Türk, 2010). For example, Bostan (2008) found that students thought that the motion of the Earth around the Sun caused the formation of day and night. Similarly, in Aygören's (2023) study, it was stated that 60% of the students thought that the Earth's rotation around the Sun effectively formed day and night.

The statements containing alternative concepts preferred by more than 10% of the students are given below:

- When we observe the Sun during the day, the reason why we observe it in different positions from sunrise to sunset is that the Earth moves around the Sun.
- As the Earth travels around the Sun, the Sun appears in different places in the sky.

When the literature was analyzed, results similar to the alternative concepts identified in item 5 were found (Göncü, 2013)

- When the Earth rotates on its axis, the Moon is observed in different ways.
- When the Earth's shadow falls on the Moon, the Moon is observed in different ways.
- When the Earth rotates around its axis, the Moon is observed in different ways because it is out of the Earth's field of view.
- When the Earth is between the Moon and the Sun, different shapes are observed when the Earth's shadow falls on the Moon.

When the literature was analyzed, it was seen that similar results were obtained to the alternative concepts identified in item 6 (Frede, 2006; Öztürk, 2011; Trumper, 2003; Ünsal et al., 2001).

- The celestial event called the shooting star is the movement of comets.
- The celestial phenomenon called the shooting star is observed as a result of the movement of comets.

When the literature was analysed, it was seen that the studies supported the alternative concepts identified in the 10th item (Bostan, 2008; Göncü, 2013; Küçüközer & Bostan).

- A lunar eclipse occurs when the Sun enters between the Earth and the Moon.

- Since the Moon is behind the Sun, we cannot observe the Moon from Earth.
- A lunar eclipse occurs once time every year.
- A lunar eclipse occurs once a year as the Moon orbits around the Sun with the Earth in 1 year.

When the literature was analyzed, it was seen that there were alternative concepts identified in the studies on topics such as the positions and order of the Moon, the Earth and the Sun during solar and lunar eclipses. Although the studies in the literature support that alternative concept involving the confusion of the positions of the Sun, Earth and Moon during the solar eclipse and lunar eclipse identified in the 14th item are frequently encountered, in these studies.

In item 15, no alternative concept was found regarding the frequency of solar and lunar eclipses (Bostan, 2008; Harman, 2016; Küçüközer et al., 2010).

- Stars are the smallest celestial bodies.
- When you look at the sky at night, the stars look very small.

When the literature was analyzed, it was found that the alternative concepts identified in the 16th item about the structure and properties of stars were supported (Emrahoğlu & Öztürk, 2009; Ercan et al., 2010; İyibil et al., 2010).

- Constellations are common names because they are clusters of stars close to each other.

When the literature was analyzed, the fact that the alternative concept related to the naming of constellations identified in item 18 was also observed in another study supports the result of the study (Kurnaz, 2012).

- Scientists interested in astronomy are called astrologers.
- Astrologers are scientists working on subjects such as the structure of celestial bodies and celestial events.

The results revealed that the developed Alternative Concept Identification Test is a valid and reliable measurement tool. This shows that the test can be used effectively to determine the alternative concepts of secondary school students in the subjects of the structure of celestial bodies, celestial events and the motions of celestial bodies. The test is a useful tool for determining students' misconceptions and revealing their learning deficiencies related to these concepts. In addition, comparing the correct scores obtained from the test with the alternative concept scores can be used to measure students' mastery of the subject and to analyze their achievement levels.

Recommendations

The literature review revealed that there has not yet been a study that analyses the alternative conceptions of secondary school students in these specific topics at all grade levels together and compares them according to grade levels. This finding points to the need for a more comprehensive and detailed analysis of the structure of celestial bodies, celestial phenomena and the motions of celestial bodies across grade levels. Increasing research in this area will help to develop teaching strategies to eliminate students' conceptual misconceptions about these topics. In addition, such studies can make science education practices and teaching methodologies more effective so that students can better understand the basic concepts of science.

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Author (s) Contribution Rate

The authors of the study contributed equally at all stages, from the planning of the research to the writing of the discussion part.

Ethical Approval (only for necessary papers)

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