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Research Article

# Identifying Middle School Students' Alternative Conceptions of Basic Astronomy Concepts Through Score Analysis

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*Abstract* – This study aims to identify fifth-grade students' alternative conceptions regarding basic astronomy concepts such as the Sun, Earth, and Moon. The research employed a survey model, and a multiple-choice achievement test developed by Sontay and Karamustafaoğlu (2020) was used as the data collection tool. The study group consisted of 173 students studying in public middle schools in the Western Black Sea Region of Türkiye. Student responses were analyzed based on score values (S) and concentration factor (C), and the response patterns were categorized using Bao's (1999) model analysis method. The findings revealed that students were more successful in topics related to the properties and motions of the Moon. However, they exhibited learning deficiencies in areas such as comparing the sizes of celestial bodies, understanding the structure of the Sun, and the formation of day and night. It was observed that the most common response pattern among students was "MM", indicating that their answers were concentrated on two options, one of which was correct. Particularly, students gave random answers when comparing the relative sizes of the Sun and Earth within the size-matching task. These results underscore the importance of developing instructional strategies targeting the change of alternative conceptions and supporting astronomy topics with real-life contexts. The study contributes by identifying specific areas of conceptual difficulty, thereby informing the design of targeted instructional interventions in science education.

*Keywords*: Alternative conceptions, basic astronomy concepts, Bao model analysis, concentration factor, score analysis.

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## Introduction

Researchers have long held a strong interest in astronomy (Ülker & Kocakülah, 2020), given its central role in understanding the universe and advancing scientific knowledge. Scholars have been intrigued by how students comprehend basic astronomy concepts such as the Sun, Earth, and Moon, and have investigated these understandings in numerous studies (Kurnaz & Değirmenci, 2012; Trumper, 2001; Vosniadou & Brewer, 1994). Building on these investigations, the studies demonstrate that students face significant difficulties mentally constructing basic astronomy concepts (Kara & Kefeli, 2019). Students' misconceptions regarding the structure, properties, and relative sizes of the Sun, Earth, and Moon, as well as the misperception of their apparent sizes from Earth, are among the most prevalent.

As with other fundamental science concepts, students' difficulties in meaningfully constructing astronomy concepts may hinder their conceptual understanding and learning outcomes. Various learning theories have been proposed to explain how learning occurs during instructional processes (Özmen, 2004). Although these theories differ in perspective, students often enter learning environments with non-scientific knowledge. They tend to assign personal meanings to scientific concepts, leading to alternative conceptions (Pastırmacı, 2011). Students not only hold non-scientific understandings but may also persist and defend these misconceptions during instruction. This situation can cause disruptions in teaching and negatively impact new learning. The existence of alternative conceptions has adversely affected students' ability to acquire new knowledge (Berber & Sarı, 2009; Özkan et al., 2004).

In the literature, alternative conceptions are referred to by different terms that essentially convey the same meaning, such as naïve beliefs, intuitive understandings, and misconceptions (Yüzbaşıoğlu & Kurnaz, 2022). Despite terminological differences, the term "alternative conception" is used in this study to refer to students' deviation from scientifically accepted knowledge. In some studies, lacking any conception is considered preferable to having an alternative one (Baki, 1999), as holding an alternative conception indicates a weak foundational understanding that may hinder the integration of new learning, akin to building new floors on a structurally unsound foundation (Hırça, 2004). The foundation must be solid since new learning is constructed upon prior knowledge. Students often face difficulties interpreting scientific concepts daily and may construct inaccurate or incomplete mental representations, which obstruct scientific learning (Ayas, 2005). Thus, identifying and addressing students' alternative conceptions is essential for enabling them to construct scientifically accurate knowledge structures (Ayas, 2005).

Designing effective instructional processes requires understanding how students think, construct scientific knowledge, and their ideas regarding scientific concepts (Horton, 2007). Connecting concepts to everyday experiences is crucial for meaningful learning (Hançer et al., 2003). Through such associations, students are more likely to construct concepts meaningfully. Since the astronomical concepts related to the Sun, Earth, and Moon hold significant relevance in everyday life, it is vital for students to meaningfully internalize these in science classes (Karaaslan & Ayas, 2016). This enables students to see how the scientific knowledge gained in the classroom applies to real-life situations such as daily observations of the sky, understanding seasonal changes, and interpreting the movements of celestial bodies.

In Türkiye, science education starts early childhood and continues through higher education. Students often carry their ideas about concepts from lower grade levels into subsequent educational stages (Besson et al., 2007). These ideas, derived from everyday experiences, may later manifest as alternative conceptions (Kızılcık et al., 2015). The literature indicates that students across all educational levels hold misconceptions regarding fundamental astronomy concepts. Some studies have addressed misunderstandings related to the shapes of the Sun, Earth, and Moon (Bolat et al., 2014; Vosniadou & Brewer, 1990), their motions and outcomes (Bozdemir et al., 2018; Trumper, 2003), difficulties in explaining and constructing these concepts (Kikas, 2005), and the persistence of these misconceptions into later life stages (Ünsal et al., 2001). Therefore, identifying alternative conceptions in lower grades is crucial for preventing future learning difficulties, and this also provides a foundation for more coherent progression in the following instructional stages.

Students may acquire alternative conceptions through everyday experiences, instructional processes, or educational materials (Banawi et al., 2019; Kartal et al., 2011). The presence of non-scientific knowledge about a concept is the primary cause of alternative conceptions (Özkan, 2017). The literature highlights various methods for identifying these conceptions, including drawings (Bolat et al., 2014; Meşeci, et al., 2013), concept maps (Çıldır & Şen, 2006), conceptual cartoons (Ören et al., 2012), word association (Ercan et al., 2010), and tiered tests (Kaltakçı, 2012).

Despite the strengths and weaknesses of each method, identifying students' alternative conceptions is essential for establishing effective instructional foundations. In this context, multiple-choice tests are frequently used in the literature to detect such conceptions (Bozdemir et al., 2018; Ezberci Çevik & Altan Kurnaz, 2019). These tests provide significant insights into students' diverse viewpoints. Learning deficiencies can be more clearly revealed

when student responses are analyzed with appropriate techniques (Bao, 1999; Ezberci Çevik & Altan Kurnaz, 2019; Dega & Govender, 2016). Although multiple-choice tests may seem less preferable for identifying alternative conceptions, they remain widely used by teachers nationally and internationally (Anderson, 2003). Focusing solely on the number of correct responses may be insufficient; analyzing students' selection of incorrect options can highlight conceptual gaps (Bao & Redish, 2006). In this regard, incorrect answers offer valuable insights for instructional planning.

The alternative conceptions students develop early in their educational journey often resist change. As foundational topics in science, the concepts related to the Sun, Earth, and Moon play a critical role in students' understanding of space sciences. Misconceptions about these concepts may hinder students' grasp of more complex topics such as the solar system, galaxies, and the formation of seasons. Students' long-term academic success may be compromised if they retain scientifically inaccurate understandings. Thus, before implementing strategies to eliminate alternative conceptions, it is essential to identify them first. Identifying fifth-grade students' alternative conceptions about the Sun, Earth, and Moon is crucial for revealing current learning deficiencies and developing appropriate teaching strategies. The fifth grade was selected because identifying students' alternative conceptions at the early middle school level can help reduce learning difficulties in subsequent educational stages. The research problem of this study is as follows:

"To what extent do fifth-grade students hold alternative conceptions about basic astronomy concepts such as the Sun, Earth, and Moon?".

## Method

This study aimed to identify fifth-grade students' alternative conceptions regarding the Sun, Earth, and Moon. Accordingly, the research was conducted using a survey design, a practical method within the quantitative research paradigm. Survey models are employed to examine and describe situations or phenomena (Creswell, 2014). A multiple-choice academic achievement test related to the Sun, Earth, and Moon was administered to fifth-grade students, whose curriculum includes these topics. Based on the student responses, descriptive analyses were conducted by calculating the concentration factor and score analysis to identify alternative conceptions.

**Study Group**

The study group comprised 173 fifth-grade students attending public middle schools in the Western Black Sea Region of Türkiye. This selection was made considering factors such as prior coverage of the relevant topics, teacher consent, and accessibility of the students. The purposive sampling method was employed to align with the nature of the research, targeting fifth-grade students who had covered the relevant topics. This sampling approach enabled effective use of time and resources, contributing to the sustainability of the research (Büyüköztürk et al., 2018). Depending on the sampling design, the study may include one or multiple schools (Yıldırım & Şimşek, 2005). The study was conducted during the 2024–2025 academic year to investigate fifth-grade students' alternative conceptions of the Sun, Earth, and Moon.

**Data Collection and Analysis**

The data were collected using a multiple-choice academic achievement test developed by Sontay and Karamustafaoğlu (2020) focusing on the Sun, Earth, and Moon unit in the fifth-grade science curriculum. The test consists of 25 items covering these celestial bodies' structure, properties, and motions. The test has a moderate difficulty index and a KR-20 reliability coefficient 0.83. The reliability coefficient of the test was calculated as 0.86 using Cronbach's alpha, as the test consists of multiple-choice items. Both correct and incorrect responses were included in the analysis, which was conducted using the model developed by Bao (1999). Frequencies and percentages of student responses were calculated, followed by the computation of the score (S) and concentration factor (C) for each item. This allowed for assessing both students' alternative conceptions and their overall performance.

In the achievement test, the S value is calculated by dividing the number of correct responses to an item by the total number of students, thus providing insight into the accuracy of responses. The concentration factor incorporates incorrect responses into the analysis alongside correct ones. The formula used to calculate the C value is presented below. Both S and C values range between 0 and 1. Higher S and C values indicate higher scores and greater concentration. Bao (1999) classified these values into three equal intervals, establishing interpretive levels for S and C (see Table 1).

The symbols used in the given formula are as follows: "ni" represents the number of students who selected a particular option, while "C" denotes the concentration coefficient. The symbol "m" refers to the total number of options in the relevant test, and "N" indicates

the number of students who responded. This study's concentration coefficient values were interpreted based on the classifications suggested in Table 1.

**Table 1** Three-Level Coding for Score and Concentration Factor

| Scor (S) | Level* | Concentration factor (C) | Level * |
|---|---|---|---|
| 0~0.4 | L | 0~0.2 | L |
| 0.4~0.7 | M | 0.2~0.5 | M |
| 0.7~1.0 | H | 0.5~1.0 | H |

*L: Low, M: Medium, H: High

In classifying student responses, the scores obtained from the students' answers and the concentration coefficient were evaluated to determine the response patterns. This approach allows for identifying both students' achievement levels and whether they hold alternative conceptions regarding the topic. For this analysis, response patterns were created based on the students' S and C codes. Descriptions of the patterns derived from these coding levels are presented in Table 2.

**Table 2** Patterning of Student Responses Using Two-Level Coding (Bao, 1999)

| | Pattern | Meaning |
|---|---|---|
| 1 | LL | Students demonstrate no significant performance, and their answers appear to be largely random guesses. |
| 2 | LH | Students have low scores, but most selected the same distractor. |
| | HH | Students exhibited good performance regarding the related concept. |
| 3 | LM | Student responses concentrated on two incorrect options. |
| | MH | While a dominant trend may be observed, uncommon selections are also in the responses. |
| | MM | Student responses concentrated on two options, one of which is correct. |
| | ML | Two uncommon response trends are present in the students' answers. |

The pattern analysis based on S and C scores provides comprehensive insights into high- and low-performing students as described in Table 2. For instance, comparing the HH and LL patterns reveals that the HH pattern is characterized by high S and C values, indicating that most students answered the question correctly. In interpreting the LH pattern, it is observed that although the concentration coefficient is high, the score is low. This suggests that a significant portion of the participants selected the same incorrect option, indicating the presence of strong alternative conceptions regarding the topic.

Two-dimensional graphs can be constructed based on the S and C scores to broadly assess students' learning levels (Bao, 1999). In these graphs, the nature of student responses and the options on which they concentrated can be more clearly observed. Responses in the

graph can be grouped into three main categories: the region of qualified responses—answers represented by the HH pattern with high concentration and high scores; the region of mixed-quality responses—including LM (low-medium) and MM (medium-medium) patterns; and the region of random responses—answers falling under the LL pattern, indicating low concentration and low achievement. This analysis does not aim to process the data using a different method but to provide a graphical representation that enhances the comprehensibility of the data presented in tables (see Graph 1).

## Findings

This section presents findings related to the frequency and percentage values of students' responses to the Sun, Earth, and Moon Achievement Test and the associated S and C values and response patterns. The frequency and percentage distributions derived from student responses are presented in Table 3.

**Table 3** Frequency and Percentage Values of Students' Responses to the Sun, Earth, and Moon Achievement Test

| Q. No | A (f) | A (%) | B (f) | B (%) | C (f) | C (%) | D (f) | D (%) | Blank (f) | Blank (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 6.94 | **133** | 76.88 | 22 | 12.72 | 5 | 2.89 | 1 | 0.57 |
| 2 | 18 | 10.4 | 47 | 27.17 | 26 | 15.03 | **78** | 45.09 | 4 | 2.31 |
| 3 | 19 | 10.98 | 28 | 16.18 | 37 | 21.39 | **86** | 49.71 | 3 | 1.74 |
| 4 | 11 | 6.36 | 5 | 2.89 | **151** | 87.28 | 3 | 1.73 | 3 | 1.74 |
| 5 | 17 | 9.83 | 52 | 30.06 | **66** | 38.15 | 36 | 20.81 | 2 | 1.15 |
| 6 | 15 | 8.67 | **118** | 68.21 | 19 | 10.98 | 18 | 10.4 | 3 | 1.74 |
| 7 | **102** | 58.96 | 4 | 2.31 | 61 | 35.26 | 5 | 2.89 | 1 | 0.58 |
| 8 | 18 | 10.4 | 13 | 7.51 | 34 | 19.65 | **105** | 60.69 | 3 | 1.75 |
| 9 | 19 | 10.98 | 27 | 15.61 | **117** | 67.63 | 8 | 4.62 | 2 | 1.16 |
| 10 | 5 | 2.89 | **148** | 85.55 | 8 | 4.62 | 6 | 3.47 | 6 | 3.47 |
| 11 | 8 | 4.62 | 9 | 5.2 | 52 | 30.06 | **102** | 58.96 | 2 | 1.16 |
| 12 | 5 | 2.89 | 10 | 5.78 | 4 | 2.31 | **152** | 87.86 | 2 | 1.16 |
| 13 | 9 | 5.2 | 26 | 15.03 | **124** | 71.68 | 11 | 6.36 | 3 | 1.73 |
| 14 | **132** | 76.3 | 10 | 5.78 | 12 | 6.94 | 15 | 8.67 | 4 | 2.31 |
| 15 | 20 | 11.56 | **101** | 58.38 | 20 | 11.56 | 25 | 14.45 | 7 | 4.05 |
| 16 | 11 | 6.36 | 8 | 4.62 | **141** | 81.5 | 7 | 4.05 | 6 | 3.47 |
| 17 | 20 | 11.56 | **117** | 67.63 | 21 | 12.14 | 8 | 4.62 | 7 | 4.05 |
| 18 | 19 | 10.98 | 26 | 15.03 | 29 | 16.76 | **87** | 50.29 | 12 | 6.94 |
| 19 | 28 | 16.18 | 24 | 13.87 | **98** | 56.65 | 17 | 9.83 | 6 | 3.47 |
| 20 | **106** | 61.27 | 28 | 16.18 | 21 | 12.14 | 12 | 6.94 | 6 | 3.47 |
| 21 | 24 | 13.87 | 27 | 15.61 | **107** | 61.85 | 6 | 3.47 | 9 | 5.2 |
| 22 | **105** | 60.69 | 20 | 11.56 | 15 | 8.67 | 23 | 13.29 | 10 | 5.79 |
| 23 | **77** | 44.51 | 25 | 14.45 | 26 | 15.03 | 36 | 20.81 | 9 | 5.2 |
| 24 | 14 | 8.09 | **92** | 53.18 | 35 | 20.23 | 22 | 12.72 | 10 | 5.78 |
| 25 | 15 | 8.67 | **91** | 52.6 | 12 | 6.94 | 49 | 28.32 | 6 | 3.47 |

(Note:Bold values represent correct answers)

In the academic achievement test on the Sun, Earth, and Moon, students answered more than half of the 25 questions correctly. The item with the highest correct response rate was Question 12. Students answered four questions with a correct response rate below 50%: Questions 2, 3, 5, and 23. Questions 2 and 3 pertain to the structure of the Sun. Question 5 involves a comparison of the sizes of the Sun and Earth. Question 23 is related to associating Earth's rotation on its axis with daily life. The item with the lowest correct response rate was Question 5 (38.15%). The most frequently selected distractor was option C in Question 7 (35.26%), which involved comparing the shapes of the Sun and Earth to everyday objects such as a basketball and a coin. Question 18, related to the phases of the Moon, was the item most frequently left unanswered (6.94%). Conversely, Question 1, about whether the Sun is the largest star, was the least likely to be left blank (0.57%).

The scores (S), concentration factors (C), and response patterns derived from the answers given to the Sun, Earth, and Moon academic achievement test are presented in Table 4.

**Table 4** S and C Values from the Achievement Test

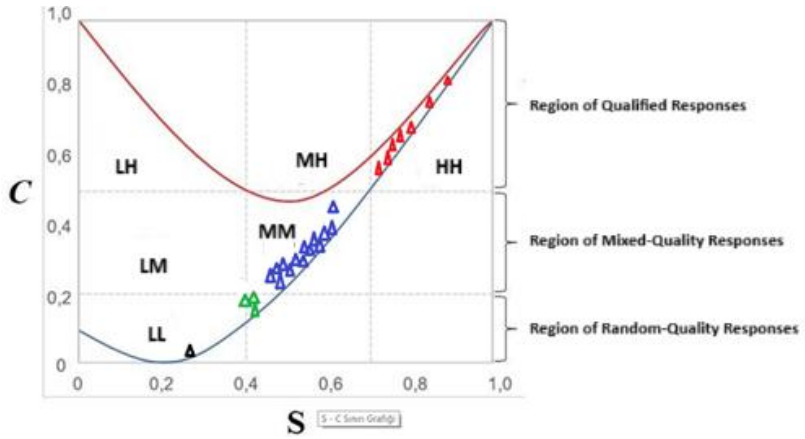
| Q. No | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S | 0.77 | 0.45 | 0.50 | 0.87 | 0.38 | 0.68 | 0.59 | 0.61 | 0.68 | 0.86 | 0.59 | 0.88 | 0.72 |
| C | 0.57 | 0.14 | 0.17 | 0.78 | 0.09 | 0.43 | 0.38 | 0.32 | 0.42 | 0.78 | 0.35 | 0.78 | 0.50 |
| Pattern | HH | ML | ML | HH | LL | MM | MM | MM | MM | HH | MM | HH | HH |
| Q. No | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | |
| S | 0.76 | 0.58 | 0.82 | 0.68 | 0.50 | 0.57 | 0.61 | 0.62 | 0.61 | 0.45 | 0.53 | 0.53 | |
| C | 0.58 | 0.30 | 0.70 | 0.46 | 0.21 | 0.27 | 0.34 | 0.38 | 0.35 | 0.13 | 0.25 | 0.26 | |
| Pattern | HH | MM | HH | MM | MM | MM | MM | MM | MM | ML | MM | MM | |

It was found that the concentration factor was at the L level for Questions 2, 3, 5, and 23; at the Y level for Questions 1, 4, 10, 12, 13, 14, and 16; and at the O level for the remaining questions. Similarly, score levels were at the L level for Question 5, the H level for Questions 1, 4, 10, 12, 13, 14, and 16, and the M level for the other items. The response patterns were identified based on the students' S and C values. It was determined that student responses followed the HH pattern in seven questions, the ML pattern in three questions, the LL pattern in one question, and the MM pattern in 14 questions. No other response patterns were observed.

The items associated with the HH pattern were found to be related to the general characteristics of the Sun and the structure, movement, and atmosphere of the Moon. Items with the ML pattern concerned the structure of the Sun and the consequences of Earth's movements. Questions with the MM pattern were related to topics such as changes in

perceived size due to distance, the comparison of sizes, movements, and shapes of the Sun, Earth, and Moon with everyday objects, the Moon not being a natural light source, the surface and movements of the Moon, the phases of the Moon, and reasons for the absence of life on the Moon.

A two-dimensional graphical representation of the S and C values for the responses to the Sun, Earth, and Moon Achievement Test is provided in Graph 1.




**Graph 1** S-C Graph for Items in the Achievement Test

In Graph 1, it is observed that student responses were predominantly concentrated in the mixed-quality response region. A lower concentration was found in the random response region. The concentration in the qualified response region was moderate. It was determined that students exhibited strong alternative conceptions in one item, which fell in the LL region.

## Discussions and Conclusions

In this study, which aimed to identify fifth-grade students' alternative conceptions of basic astronomy concepts, the performance scores and concentration factors calculated from student responses were evaluated collectively. As a result of these evaluations, students' alternative ideas and learning deficiencies were identified. Consequently, the observed patterns in students' understanding of basic astronomy concepts—such as alternative conceptions about the Sun, Earth, and Moon—can inform the design of more effective learning activities tailored to address these misconceptions (Bozdemir et al., 2018). The average S score derived from students' responses to the academic achievement test was 0.63, indicating a moderate level of understanding. This suggests that while students have grasped some basic astronomy concepts, persistent alternative conceptions may still hinder deeper learning. Such patterns align with previous studies highlighting common misconceptions

among fifth-grade students in astronomy (Bao, 1999), emphasizing the need for targeted instructional strategies to address these learning gaps.

Students demonstrated their highest performance on Question 12 (87.86%), which addressed the presence of craters on the Moon's surface, its proximity to Earth, and the absence of life on the Moon. The distractor for this item claimed that the Moon's surface is flat. These results suggest that students have a solid understanding of the general characteristics of the Moon. Moreover, based on the understanding that the Earth is not flat, most students also seem to conceptualize the Moon as a geometrically spherical object correctly. This is consistent with previous literature; for instance, Kara & Kefeli (2019) found that 78.4% of students responded in the full understanding category regarding geometric shapes.

In contrast, students performed below 50% on Questions 2, 3, 5, and 23, with the lowest performance recorded on Question 5. Question 2 (45.09%) pertained to the Sun's general features, such as its approximate distance from Earth, its composition of gases, and the occurrence of solar flares. Option B was the most frequently selected distractor (27.17%), suggesting a lack of understanding regarding solar flares. Question 3 (49.71%) addressed the Sun as a source of life, the higher temperature of its core relative to its surface, and its rotational movement. Students appeared to have misconceptions about how hydrogen is transformed into helium, releasing heat and light. Babaoğlu & Keleş (2017) similarly identified alternative conceptions about the Sun among sixth-grade students. Question 23 (44.51%) dealt with the formation of day and night. The most common distractor was option D, indicating that students have not fully grasped the outcomes of the Earth's daily (rotation) and yearly (revolution) motions. Supporting this, Yaşar Çetin (2021) found that only 3.94% of fifth-grade students could explain the formation of day and night by stating, "It is the Earth's rotation on its axis." Question 5, where students showed the lowest performance (38.15%), required matching the Sun's and Earth's relative sizes using appropriate shapes. The most selected distractor, option B, suggests that students experience difficulties associating these celestial bodies with geometric objects of different sizes in daily life. Bolat et al. (2014) reported that only 32.5% of fifth-grade students fully understood the Sun, Earth, and Moon shapes, while 55% held misconceptions. Similarly, Benli Özdemir (2019) found that 50% of sixth-grade students could not construct a meaningful mental representation of the relative sizes of the Sun, Earth, and Moon. Nas et al. (2022) also reported that students had partial understanding and alternative conceptions regarding these celestial bodies.

In Question 7, option C was the most frequently selected distractor (35.26%), indicating a misunderstanding about the Sun's and Earth's spherical shape. The question included shapes such as a coin, a basketball, and a starfish. Students identified the basketball and the coin as resembling the Sun and Earth. This reveals learning problems related to understanding spherical shapes. In line with these findings, Ülker & Kacakülah (2020) reported that 84.1% of fifth-grade students partially understood the Sun, Earth, and Moon shapes.

Based on students' answers, performance scores, and concentration factors, response patterns were identified. Students exhibited the HH pattern in seven questions, the ML pattern in three questions, the LL pattern in one question, and the MM pattern in 14 questions. The prevalence of the HH pattern indicates that students had a meaningful mental representation of the Sun's general characteristics, the Moon's structure and movements, and the presence or absence of an atmosphere. Pedagogically, these results suggest that concepts associated with the HH pattern are well internalized and may benefit from enrichment activities rather than remedial instruction.

In questions where the ML pattern was observed (Questions 2, 3, and 23), students appeared to hold two uncommon misconceptions. For instance, while some students correctly understood that hydrogen in the Sun is converted into helium, they failed to grasp that the Sun is composed of gas. Similarly, although students could correctly differentiate between rotation and revolution, they could not fully comprehend the consequences of the Sun, Earth, and Moon's motions. These patterns highlight fragmented knowledge structures, emphasizing the need for instructional strategies that help students integrate isolated facts into coherent conceptual frameworks (Dunlop, 2000).

A significant number of students (56%) exhibited the MM pattern, indicating a tendency to focus on one correct and one incorrect option. For example, in Question 6, the distractor "The farthest star appears largest in the sky" (option C); in Question 8, "If the Sun is a football, the Earth is a volleyball" (option C); and in Question 9, "The Moon does not reflect sunlight" (option B) were all highly selected. This pattern suggests partial understanding with simultaneous misconceptions, revealing areas where instructional clarification is needed.

Similarly, in Question 11, the distractor "There is no temperature difference between day and night on the Moon" (option C); in Question 15, "The Moon must have a shiny surface to support life" (option D); in Question 17, "The Moon's rotation on its axis is revolution" (option C); in Question 18, "The duration between the Moon's main phases is about one week" (option C); and in Questions 19–25, students frequently selected distractors reflecting

alternative conceptions regarding the Moon's phases and orbital motions. Supporting studies indicate that students have limited understanding of the sizes, shapes, and movements of the Sun, Earth, and Moon, as well as the Moon's phases (Benli Özdemir, 2019; Öztürk & Uçar, 2012; Trumper, 2001, 2003). The non-scientific construction of misconceptions about the Moon's phases in students' minds highlight the importance of addressing these issues during instructional design (Brunsell & Marcks, 2005; Fatih, 2019; Öztürk, 2011).

Students' responses to Question 5 revealed an LL pattern. Their low performance and scattered choices suggest that their answers were based on guessing. The low concentration indicates that students selected different options randomly, implying learning deficiencies regarding the relative sizes of the Sun and Earth. In other words, students experience difficulties in transferring their scientific knowledge into practical representations. This might stem from insufficient opportunities to compare scientific information with familiar everyday examples. Although students may know the size order of celestial bodies, they may struggle to apply this knowledge in different contexts. Bolat et al. (2014) reported that students did not exhibit significant deficiencies in writing the Sun, Earth, and Moon size order, supporting this interpretation. Pedagogically, LL-pattern concepts highlight areas that require foundational teaching and guided practice, emphasizing the need for concrete examples and scaffolded learning to build initial understanding.

Students' poor performance on context-based questions suggests difficulties in transferring knowledge to real-life situations. Indeed, existing literature reveals that students often struggle to relate science concepts to everyday experiences (Lay et al., 2013). This is particularly critical for middle school students, as the lack of support for real-life connections may reduce scientific curiosity and negatively affect attitudes toward science (Siverton, 1993). On the other hand, effective science education provides opportunities to develop research skills, understand the societal relevance of science, and foster scientific thinking (Slavin et al., 2014). Therefore, students should engage in activities beyond mere observation and participate in experiences where they can apply their knowledge in meaningful contexts (James, 2007). This approach may help students integrate conceptual understanding with real-life experiences.

This study thoroughly analyzed fifth-grade students' alternative conceptions, learning deficiencies, and response patterns regarding basic astronomy concepts. Significant conceptual deficiencies and misconceptions were identified based on the calculated performance scores and concentration factors, especially in topics such as the Moon's

structure, Earth's movements, and the Sun's characteristics. The high frequency of MM and ML patterns suggests that students often vacillate between scientific and alternative ideas, resulting in shallow learning. Moreover, random answering patterns in certain questions indicate a failure to construct coherent mental models of these concepts. These results indicate that students struggle to transfer scientific knowledge to everyday contexts, adversely affecting their conceptual learning processes. It is therefore essential that astronomy concepts—such as the Sun, Earth, and Moon—are grounded in scientifically accurate and contextually meaningful frameworks.

## Suggestions

Instructional strategies should prioritize revealing and transforming students' alternative conceptions in astronomy. The present study indicates that students demonstrate relatively higher understanding of the Moon's observable features, yet face challenges in comparing the relative sizes of celestial bodies and understanding the consequences of rotational and orbital motions. These findings, reflected in the observed HH, MM, ML, and LL response patterns, suggest varying levels of conceptual stability. In particular, the predominance of the MM pattern indicates that many students simultaneously hold scientific and intuitive ideas, pointing to partially formed or transitional mental models. Concepts eliciting ML or LL patterns reveal areas with high cognitive demands, such as integrating gas composition and energy processes in the Sun or linking Earth's rotation and revolution to day-night formation.

Pedagogically, astronomy topics should be taught using observable phenomena and real-life analogies, emphasizing spatial reasoning and helping students link abstract concepts to tangible experiences. Multiple-choice assessments should not only measure correct responses but also identify prevalent misconceptions to inform targeted instructional interventions. These recommendations align with prior research on conceptual change and mental model development in astronomy education (Vosniadou & Brewer, 1990; Trumper, 2001, 2003). Limitations of the current study include reliance on multiple-choice data from a single region, suggesting caution in generalizing the findings. Future research should examine how students' response patterns evolve over time, exploring processes of conceptual transformation and the effectiveness of instructional strategies aimed at addressing partially formed mental models.

## Compliance with Ethical Standards

*Disclosure of potential conflicts of interest*

The authors declare that this study and no processes involved in conducting the study have the potential for conflicts of interest.

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*CRediT author statement*

The article was collaboratively written by two authors, with each contributing equally to its content.

*Research involving Human Participants and/or Animals*

This study was reviewed and approved by the Social and Human Sciences Ethics Committee at Kastamonu University, Türkiye. All procedures followed national ethical guidelines, and informed consent was obtained from all participants prior to their involvement in the study.

## Ortaokul Öğrencilerinin Temel Astronomi Kavramlarına Yönelik Alternatif Fikirlerinin Skor Analiziyle Belirlenmesi

**Özet:**

Bu araştırmanın amacı, beşinci sınıf öğrencilerinin Güneş, Dünya ve Ay gibi temel astronomi kavramlarına ilişkin sahip oldukları alternatif fikirleri belirlemektir. Araştırmada tarama modeli kullanılmış ve veri toplama aracı olarak Sontay ve Karamustafaoğlu (2020) tarafından geliştirilen çoktan seçmeli başarı testi uygulanmıştır. Çalışma grubu, Türkiye'nin Batı Karadeniz Bölgesi'ndeki devlet ortaokullarında öğrenim gören toplam 173 öğrenciden oluşmaktadır. Öğrenci cevapları skor puanları (S) ve yoğunlaşma faktörü (C) doğrultusunda analiz edilmiş, yanıt desenleri Bao'nun (1999) model analiz yöntemi temel alınarak sınıflandırılmıştır. Araştırma bulguları, öğrencilerin Ay'ın özellikleri ve hareketleriyle ilgili konularda daha başarılı olduklarını, ancak gök cisimlerinin büyüklüklerinin karşılaştırılması, Güneş'in yapısı ve gece-gündüz oluşumu gibi konularda öğrenme eksikliklerine sahip olduklarını ortaya koymuştur. Öğrencilerin en yaygın olarak "OO" deseninde yanıt verdikleri, bunun da öğrenci cevaplarının biri doğru olmak üzere, iki seçenek üzerinde yoğunlaşmayı işaret ettiği görülmüştür. Özellikle güneş ve dünyanın büyüklüklerini farklı büyüklükteki toplarla eşleştirmede rastgele cevaplar verdikleri belirlenmiştir. Bu sonuçlar, alternatif fikir değişimini hedefleyen öğretim stratejilerinin geliştirilmesinin ve astronomi konularının günlük yaşam bağlamlarıyla desteklenmesinin önemini ortaya koymaktadır. Araştırma, fen bilimleri öğretiminde etkili müdahaleler tasarlanmasına katkı sağlamaktadır.

*Anahtar kelimeler*: Alternatif fikirler, temel astronomi kavramları, Bao model analizi, yoğunlaşma faktörü, skor analizi.

## References

Anderson, L. W. (2003). *Classroom assessment: Enhancing the quality of teacher decision making*. Routledge.

Ayas, A. (2005). Kavram öğrenimi. In S. Çepni (Ed.), *Kuramdan uygulamaya fen ve teknoloji öğretimi* (pp. 66–91). PegemA.

Babaoğlu, G., & Keleş, Ö. (2017).. Determination of 6th grade students' perceptions regarding the concepts of 'the earth', 'the moon' and 'the sun'. *Journal of Theory and Practice in Education, 13*(4), 601–636. https://doi.org/10.17244/eku.347791

Baki, A. (1999). *Cebirle ilgili işlem yanılgılarının değerlendirilmesi*. III. Fen Bilimleri Eğitimi Sempozyumu, 23-25 Eylül 1998, Karadeniz Teknik Üniversitesi, Trabzon MEB. ÖYGM. 46–55.

Banawi, A., Sopandi, W., Kadarohman, A., & Solehuddin, M. (2019). Prospective primary school teachers' conception change on states of matter and their changes through Predict Observe Explain Strategy. *International Journal of Instruction, 12*(3), 359-374. https://doi.org/10.29333/iji.2019.12322a

Bao, L. (1999). *Dynamics of Student Modeling: A Theory, Algorithms, and Application to Quantum Mechanics.* https://www.compadre.org/Repository/document/ServeFile.cfm?ID=4760&DocID=188

Bao, L., & Redish, E. F. (2006). Model analysis: Representing and assessing the dynamics of student learning. *Physical Review Special Topics-Physics Education Research, 2*(1), Article 010103, 1–16. https://doi.org/10.1103/PhysRevSTPER.2.010103

Benli Özdemir, E. (2019). The effect of animation-supported science teaching on correcting misconceptions about the concepts of sun, earth, and moon among 6th-grade students and on their attitudes towards astronomy. *Başkent University Journal of Education*, *6*(1), 46-58. https://search.trdizin.gov.tr/tr/yayin/detay/321512

Berber, N. C., & Sarı, M. (2009). Effectiveness of conceptual change texts in understanding work-power-energy subject. *Ahmet Keleşoğlu Faculty of Education Journal (AKEF)*, *27*, 159-172. https://silo.tips/download/kavramsal-dem-metnlernn-g-enerj-konusunu-anlamaya-etks

Besson, U., Borghi, L., De Ambrosis, A., & Mascheretti, P. (2007). How to teach friction: Experiments and models. *American Journal of Physics, 75*(12), 1106-1113. https://doi.org/10.1119/1.2779881

Bolat, A., Aydoğdu, R. Ü., Uluçınar Sağır, Ş. & Değirmenci, S. (2014). 5th grade students' mısconceptions related to the subjects of "the sun, the earth and the moon". *Journal of Research in Education and Teaching, 3*(1), 218-229. http://www.jret.org/FileUpload/ks281142/File/21.bolat.pdf

Bozdemir, H., Ezberci Çevik, E., Candan Helvacı, S. & Kurnaz, M. A. (2018). Determine of alternative ideas of science teacher candidates' about some astronomical concepts. *Trakya Journal of Education, 8*(4) 808-821. https://dergipark.org.tr/tr/download/article-file/565077

Brunsell, E., & Marcks, J. (2005). Identifying a baseline for teachers' astronomy content knowledge. *Astronomy Education Review*, *2*(3), 38-46. https://istardb.org/wp-content/uploads/tainacan-items/1018/19970/Brunsell_Marcks_2004_Identifying-A-Baseline-for-Teachers-Astronomy-Content-Knowledge.pdf

Büyüköztürk, Ş., Çakmak, E. K., Akgün, O. E., Karadeniz, S., & Demirel, F. (2018). *Bilimsel araştırma yöntemleri.* PegemA.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). Sage. https://www.ucg.ac.me/skladiste/blog_609332/objava_105202/fajlovi/Creswell.pdf

Ezberci Çevik, E., & Altan Kurnaz, A. (2019). Analysis the responses of science teacher candidates to force concept inventory by concentration factor. *Universal Journal of Educational Research, 7*(1), 111-117. https://doi.org/10.13189/ujer.2019.070115

Çıldır, I., & Şen, A. İ. (2006) Identification of high school students' misconception about electric current by concept maps. *H.U. Journal of Education*, *30*, 92-101. https://izlik.org/JA47RW44LH

Dega, B. G., & Govender, N. (2016). Assessment of students' scientific and alternative conceptions of energy and momentum using concentration analysis. *African Journal of Research in Mathematics, Science and Technology Education*, *20*(3), 201-213. https://doi.org/10.1080/18117295.2016.1218657

Dunlop, J. (2000). How children observe the universe. *Publications of the Astronomical Society of Australia*, *17*(2), 194-206. https://doi.org/10.1071/AS00194

Ercan, F., Taşdere, A., & Ercan, N. (2010). Observation of cognitive structure and conceptual changes through word associations tests. *Journal of Turkish Science Education*, *7*(2), 136-154. https://www.tused.org/index.php/tused/article/view/515

Fatih, D. (2019). *Investigation of the effects of inquiry-based teaching on secondary school students' conceptual change processes related to the moon's movements and phases* (Publication No. 561638) [Master's thesis, Balıkesir University]. Council of Higher Education Thesis Center.

Hançer, A. H., Şensoy, Ö., & Yıldırım, H. İ. (2003). An evaluation about the importance of contemporary science education at elementary schools and how this kind of science teaching must be. *Pamukkale University Journal of Education, 13*(13), 80-88. https://izlik.org/JA44MW38GD

Hırça, N. (2004). *The determination of misconceptions related energy concept in the eight-level students and comparing the differences between* schools (Publication No. 151936) [Master's thesis, Kafkas University]. Council of Higher Education Thesis Center.

Horton, C. (2007). Student alternative conceptions in chemistry. *California Journal of Science Education, 7*(2), 18–38. https://www.docsity.com/es/docs/student-alternative-conceptions-in-chemistry-lecture-notes-com-508/6109433/

James B. Hunt, Jr. Institute for Educational Leadership and Policy. (2007). K-8 science education: Elements that matter: A Report from the 2007 North Carolina science summit. https://files.eric.ed.gov/fulltext/ED505668.pdf

Kaltakçı, D. (2012). *Development and application of a four-tier test to assess preservice physics teachers' misconceptions about geometrical optics* schools (Publication No. 318966) [Doctoral dissertation, Middle East Technical University]. Council of Higher Education Thesis Center.

Kara, F., & Kefeli, N. (2019). Perceptions of the secondary fifth grade students towards the sun, earth, and moon. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education*, *13*(2), 1000-1014.https://doi.org/10.17522/balikesirnef.560113

Karaaslan, E. H., & Ayas. A. (2016). 'Scientific explanation' in science education and its importance. *Ahi Evran University Kırşehir Faculty of Education Journal, 17*(3), 101-120. https://izlik.org/JA46HH68KZ

Kartal, T., Öztürk, N. & Yalvaç, H. G. (2011). Misconceptions of science teacher candidates about heat and temperature. *Procedia Social and Behavioral Sciences, 15*, 2758–2763. https://doi.org/10.1016/j.sbspro.2011.04.184

Kızılcık, H. Ş., Çelikkanlı, N. Ö., & Güneş, B. (2015). Change of physics teacher candidates' misconceptions on regular circular motion by time. *Necatibey Faculty of Education Electronic Journal of Science and Mathematics Education, 9*(1), 205-223. https://doi.org/10.17522/nefefmed.41287

Kikas, E. (2005). The development of children's knowledge: The sky, the earth and the sun in children's explanations. *Folklore: Electronic Journal of Folklore, 31*, 30–56. https://doi.org/10.7592/FEJF2005.31.kikas

Kurnaz, M. A., & Değirmenci, A. (2012). Mental models of 7th grade students on sun, earth and moon. *Elementary Education Online, 11*(1), 137-150. https://izlik.org/JA72XN47NR

Lay, Y. F., Khoo, C. H., Treagust, D. F., & Chandrasegaran, A. L. (2013). Assessing secondary school students' understanding of the relevance of energy in their daily lives. *International Journal of Environmental and Science Education, 8*(1), 199-215. https://www.researchgate.net/publication/255703966_Assessing_secondary_school_students'_understanding_of_the_relevance_of_energy_in_their_daily_lives

Meşeci, B., Tekin, S., & Karamustafaoğlu, S. (2013). Identification of conceptual misconceptions related to the particulate structure of matter. *Dicle University Social Sciences Institute Journal*, 5(9), 20-40. https://izlik.org/JA63UF89AZ

Nas, S. E., Çalık, M., Akbulut, H. İ., Çoruhlu, T. Ş., Ergül, C., Tatlı, Z., & Gülay, A. (2022). The effect of science experimental guidebook on the conceptual understanding of students with learning disabilities: a case of "Earth and Universe" unit. *Bolu Abant Izzet Baysal University Journal of Faculty of Education*, *22*(1), 100-123. https://doi.org/10.17240/aibuefd.2022..-824214

Özkan, F. (2017). *Determination of misconceptions by developing the two-stage multiple-choice test for 7th grade digestive system* (Publication No. 477322) [Master's thesis, Erciyes University]. Council of Higher Education Thesis

Özkan, Ö. Tekkaya, C., & Geban, Ö. (2004). Facilitating conceptual change in students understanding of ecological concepts. *Journal of Science Education and Technology*, *13*, 95–105. https://doi.org/10.1023/B:JOST.0000019642.15673.a3

Özmen, H. (2004). Fen öğretiminde öğrenme teorileri ve teknoloji destekli yapılandırmacı (constructivist) öğrenme. *The Turkish Online Journal of Educational Technology – TOJET, 3*(1), 100–111. https://www.tojet.net/articles/v3i1/3114.pdf

Öztürk, D., & Uçar, S. (2012). Investigation of elementary school students' conceptual change on the phases of the moon in a collaborative learning environment. *Journal of Turkish Science Education*, *9*(2), 98-112. https://www.tused.org/index.php/tused/article/view/432

Öztürk, D. (2011). *Primary 6th and 8th grade students? misconceptions of the moon phases and investigation of conceptual change in coopetarive learning environment* (Publication No. 300326) [Master's thesis, Çukurova University]. Council of Higher Education Thesis

Pastırmacı, E. (2011). *Investigation of the conceptual understanding and argumentation process of 7th grade students on work and energy* (Publication No. 501644) [Master's thesis, Balıkesir University]. Council of Higher Education Thesis

Siverton, M. L. (1993). *Transforming ideas for teaching and learning science.* Washington, DC: US Department of Education. https://scispace.com/pdf/transforming-ideas-for-teaching-and-learning-science-a-guide-3qahmml6w1.pdf

Slavin, R. E., Lake, C., Hanley, P., & Thurston, A. (2014). Experimental evaluations of elementary science programs: A best-evidence synthesis. *Journal of Research in Science Teaching, 51*(7), 870-901. http://dx.doi.org/10.1002/tea.21139

Sontay, G., & Karamustafaoğlu, O. (2020). Developing achievement test for science course's "sun, earth and moon" unit. *Journal of Gazi Faculty of Education, 40*(2), 511-551. https://izlik.org/JA82FA28ZZ

Ören, F., Karatekin, P., Erdem, Ş., & Ormancı, Ü. (2012). Determining of teacher candidates' level of knowledge on the issue of plant respiration photosynthesis through concept cartoons and its analysis depending on different variables. *Ahi Evran University Journal of Kırşehir Faculty of Education*, *13*(3), 155-174. https://izlik.org/JA25HU59EZ

Trumper, R. (2001). A cross-age study of senior high school students' conceptions of basic astronomy concepts. *Research in Science & Technological Education*. *19*(1), 97-109. https://doi.org/10.1080/02635140120046259

Trumper, R. (2003). The need for change in elementary school teacher training-a cross college age study of future teachers' conceptions of basic astronomy concepts. *Teaching and Teacher Education, 19*(3), 309-323. https://doi.org/10.1016/S0742-051X(03)00017-9

Ülker, S., & Kocakülah, A. (2020). Özel yetenekli 5. sınıf öğrencilerinin güneş, dünya, ay kavramları hakkındaki kavram yanılgılarının tespit edilmesi ve giderilmesi. *Çocuk ve Medeniyet Dergisi, 5*(10), 447-471. https://izlik.org/JA69RU34SR

Ünsal, Y., Güneş, B. & Ergin, İ. (2001). A study to investigate the fundamental astronomy knowledge levels of undergraduate students. *Journal of Gazi Faculty of Education, 21*(3), 47-60. https://izlik.org/JA35JN58NA

Vosniadou, S. & Brewer, W. F. (1990). A cross-cultural investigation of children's conception about the earth, the sun and the moon; Greek and American data. Center for the Study of Reading Technical Reports, https://scispace.com/pdf/a-cross-cultural-investigation-of-children-s-conceptions-1ktadwr3il.pdf

Vosniadou, S. & Brewer, W.F. (1994). Mental models of the day/night cycle. *Cognitive Science, 18*, 123-183. https://doi.org/10.1207/s15516709cog1801_4

Yıldırım, A. & Şimşek, H. (2005) *Sosyal bilimlerde nitel araştırma yöntemleri* (5th ed.). Seçkin.

Yaşar Çetin, B. (2021). Images of 5th grade students about the basic concepts of astronomy. *Journal of Research in Informal Environments (JRINEN)*, *6*(1), 1-23. https://izlik.org/JA28LZ25XB

Yüzbaşıoğlu, M. K, & Kurnaz, M. A. (2022). Investigation of secondary school students' alternative ideas for "measuring of force and friction" unit: score analysis. *Mehmet Akif Ersoy University Journal of Education Faculty*, *61*, 1–22. https://doi.org/10.21764/maeuefd.982221