STEM Education International, *e-ISSN: 3124-0755*
Vol. 2, No. 2, December 2026, Pages 96-118

STEM-EI
STEM Education International

Identification of Students' Cognitive Abilities in the Solar System

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Abstract: Conceptual understanding is an important aspect of science learning because it supports students' ability to relate, explain, and apply scientific concepts. The Solar System is a complex topic that can make it difficult to understand relationships among concepts and astronomical phenomena. This study aimed to identify seventh-grade students' cognitive ability regarding the solar system using an essay test based on the Revised Bloom's Taxonomy and to describe students' performance at each cognitive level. This study employed a quantitative descriptive design. The research sample consisted of 62 students from classes VII D and VII G at SMPN 2 Tumpang, selected through convenience sampling. Data were collected through a five-item essay test. The results showed a mean score of 67.58, with the largest proportion of students in the understanding category (42%). The remembering (C1) and evaluating (C5) indicators showed relatively higher scores, while students' performance in understanding (C2), applying (C3), and analysing (C4) was still in the low category. These findings indicate that instruction on the solar system should incorporate visual learning media and more interactive learning strategies to improve students' overall conceptual understanding.

Keywords: Conceptual Understanding, Solar System, Bloom's Taxonomy, Essay Test, Junior High School Science

Graphical Abstract



INTRODUCTION

Science is a subject studied by junior high school students, covering concepts related to Earth and space, including the solar system (Urdanivia et al., 2023). Mastering basic concepts is the first step before moving on to more complex concepts, so students can fully understand science (McCarthy and McNamara, 2021). Science education emphasises not only the mastery of facts but also conceptual understanding, critical thinking skills, problem-solving, and the ability to connect scientific concepts to everyday life (Nur'ariyani et al., 2023). Thus, science education can help students develop scientific literacy so they can make decisions based on scientific understanding (Febriayana et al., 2021).

A concept is an idea formed based on specific characteristics and can be used to categorise and understand objects, events, or phenomena. In the learning process, students' conceptual understanding requires not only memorising information but also grasping the meaning, characteristics, and relationships among the concepts being studied (Fatmawati, 2022). Understanding is derived from the word understand, which means to understand thoroughly or to be knowledgeable. Conceptual understanding can be defined as an individual's ability to connect and interpret a concept they have previously acquired, and then restate it in their own words (Marisa, 2023). Conceptual understanding is an outcome that every individual is expected to achieve during the learning process (Dilapanga et al., 2022). In line with this, the revised Bloom's Taxonomy by Anderson and Krathwohl (2001) classifies the cognitive domain

into six levels of thinking processes: remembering (C1), understanding (C2), applying (C3), analysing (C4), evaluating (C5), and creating (C6) (Murtiyasa and Sari, 2022). According to this classification, conceptual understanding is also reflected when individuals can identify connections, provide explanations, and apply knowledge in different contexts (Motlhabane, 2025). Hulu and Siswanti (2024) found that stronger conceptual understanding is associated with more developed thinking skills, whereas students with limitations in this area may struggle to integrate new information with their prior knowledge structures.

One complex 7th-grade science topic that requires deep conceptual understanding is the solar system (Ervana et al, 2024). The solar system is a system of celestial bodies with the Sun as the central star and various celestial bodies bound by its gravitational force. The solar system consists of eight planets: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune, as well as various other celestial bodies, namely natural satellites, asteroids, comets, and meteoroids (Christodoulou et al, 2024). The subject matter of the solar system is complex because it involves various concepts, namely the characteristics of its constituent planets, which are divided into inner and outer planets, celestial phenomena such as orbital motion, rotation, Earth's revolution, lunar phases, solar eclipses, and the mechanisms of celestial bodies' movements that cannot be observed directly (Lestari, 2025). Students cannot directly observe either astronomical phenomena or the mechanisms behind their movements. Therefore, mental representations and spatial reasoning play a crucial role in constructing a mental picture of the phenomena being studied (Sifaunnazah et al, 2025). This material is also important for developing students' ability to understand the Earth's position in the universe, natural phenomena resulting from the motion of celestial bodies, and the relevance of science concepts to everyday life (Islamiyah et al, 2024). Given its complexity and the need for visualisation, developing relevant skills is crucial for teaching this material (Turan & Timur, 2023).
One assessment tool that allows for a more in-depth examination of conceptual mastery is the essay-style question. Essays allow students to articulate their answers in their own words, explain their reasoning, and demonstrate their thought process in solving a problem (Fauzi and Inayati, 2023). Unlike multiple-choice tests, essay tests assess not only answer accuracy but also the quality of students' arguments, reasoning, and depth of conceptual understanding (Hart et al., 2021). The complex nature of the solar system curriculum, which requires students to logically explain relationships between concepts, makes essay tests an appropriate instrument for measuring conceptual understanding of this material (Hikmawati et al, 2026).

Several previous studies have shown that students' conceptual understanding of the solar system is still suboptimal. Febriyana et al. (2021) found that students' conceptual understanding of this material remains low, with very low percentages on several key indicators, due to the nature of solar system material, which involves celestial objects and mechanisms of motion that cannot be observed directly.

Meanwhile, other studies examining the cognitive domain of Bloom's Taxonomy in science education generally still focus on analysing documents or test items, rather than directly measuring students' cognitive abilities. Sholihah and Astuti (2025)

analysed the distribution of cognitive levels in questions from 7th grade science textbooks based on the revised Bloom's Taxonomy and found that the proportion of questions remains uneven across cognitive levels, with C5 (evaluating) questions being extremely scarce, accounting for only 1.1% of all test items and thus failing to adequately reflect higher-order thinking skills. In line with this, Jannah et al (2023) examined the items in the Grade 5 Science End of Semester Summative Assessment (ASAS) based on the revised Bloom's Taxonomy and found that the questions developed only covered cognitive levels C1 through C4, with a dominance of C2 (understanding) questions at 60%, while levels C3, C5, and C6 were not included at all in the instrument. These two studies demonstrate that cognitive analysis in science education has thus far been primarily directed toward evaluating the quality and distribution of test items, rather than identifying students' cognitive ability profiles themselves.

Regarding the solar system curriculum, Vari and Fauzi (2026) developed a test instrument to measure students' critical thinking. This study focused on developing and feasibility-testing the critical thinking instrument, rather than mapping students' cognitive achievements across the full range of Bloom's Taxonomy, from remembering to evaluating. Furthermore, research on the solar system curriculum has also focused on developing instructional materials to improve learning outcomes (Putra et al, 2024). Consequently, research that specifically identifies students' cognitive abilities in the solar system curriculum using essay-based test instruments covering the entire revised Bloom's Taxonomy levels (C1–C5) remains relatively limited.

The novelty of this study lies in using a Bloom's Taxonomy-based essay test instrument to map students' cognitive ability profiles. The achievement profiles for each indicator set this study apart, as the results can serve as a basis for teachers to design more targeted learning strategies based on students' cognitive ability profiles.

Thus, this study aims to identify students' cognitive ability levels regarding the solar system using an essay test instrument and to describe their conceptual understanding for each cognitive indicator based on Bloom's Taxonomy revised by Anderson and Krathwohl (2001).

METHOD

This study employs a quantitative, descriptive approach. Data were collected during the 2026–2027 academic year at SMP Negeri 2 Tumpang. The population in this study comprised all seventh-grade students, while the sample consisted of 62 students from classes VII D and VII G. The sampling technique used was convenience sampling, which is a method of selecting a sample based on the availability of respondents and recommendations from subject teachers, while taking into account conditions that support the conduct of the study.

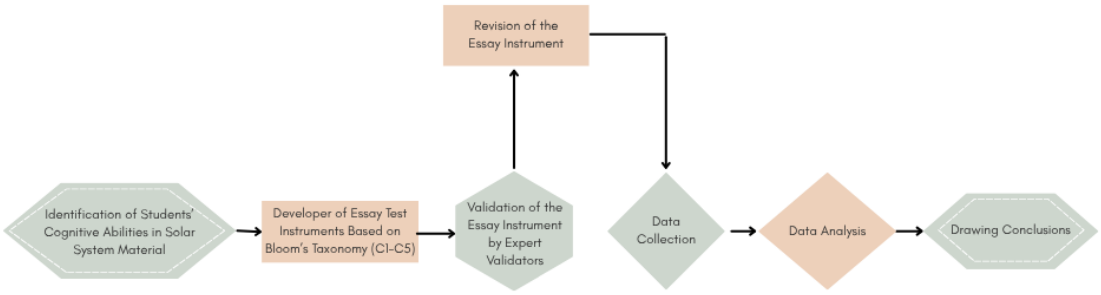


Figure 1. Research Phase Diagram

The research instrument consisted of an essay test comprising five questions. The items were developed based on Bloom's Taxonomy, as revised by Anderson and Krathwohl (2001), which encompasses five cognitive domains: recall (C1), understanding (C2), application (C3), analysis (C4), and evaluation (C5). Data were collected through an essay test to assess students' conceptual understanding, as well as through documentation, including photographs of research activities, to provide supporting data. Before being used in the study, the essay test instrument was first validated by a faculty expert in test item development. The assessment involved assigning a score to each item's validity using a validation sheet. The validity percentage was calculated using the following formula:

$$P = \frac{\Sigma \text{ Xi}}{\Sigma \text{ X}} \times 100\%$$

Notes:
P = Acceptability percentage
Σ Xi = Total score obtained from all items (expert assessment results)
Σ X = Maximum possible score

Next, the percentage results are interpreted based on the instrument acceptability criteria as presented in Table 1 (Arikunto, 2023).

Table 1. Instrument Validity Criteria

Value Interval	Criteria
81% - 100%	Highly Feasible
61% - 80%	Feasible
41% - 60%	Moderately feasible
21% - 40%	Less feasible
0% - 20%	Not feasible

The difficulty level of the essay questions in this study was determined through several stages. The initial stage involved collecting data on students' test results, followed by calculating how many students answered each essay question correctly. This data was used to determine the proportion of students who answered the questions correctly, which was then expressed as a difficulty index. Based on the students' test results, the

researcher could determine whether the essay questions were easy, moderate, or difficult. The difficulty level was calculated using the following formula:

$$P = \frac{\mathrm{B}}{\mathrm{N}}$$

Notes:
P = Difficulty level
B = Number of students who answered the question correctly
N = Total number of students

Next, the interpretation of the difficulty level of essay items is based on the difficulty index values obtained from the analysis. These index values are used to categorise each essay item's difficulty level. The lower the index value, the more difficult the item is. Conversely, the higher the index value, the easier the essay item is. The criteria for the difficulty index of essay items are presented in Table 2.

Table 2. Difficulty Index

Difficulty Index (P)	Criteria
0,00 – 0,30	Difficult Item
0,30 – 0,70	Moderate Item
0,70 – 1,00	Easy Item

Each section is assessed on a scale of 1–4 based on the cognitive indicators of Bloom's Taxonomy as outlined by Anderson and Krathwohl (2001), which classifies the cognitive domain into five levels of thinking processes.

Remembering

Remembering is the most basic cognitive process in the revised Bloom's Taxonomy. This ability relates to the process of recognising and recalling information that has been learned. In learning, remembering serves as the foundation for students to acquire and apply knowledge in more complex cognitive processes. Indicators of the ability to remember include listing, identifying, recognising, quoting, naming, matching, and marking information related to the material being studied.

Understanding

Understanding is a student's ability to construct meaning from information or material that has been studied. This ability is demonstrated not only by recalling information but also by explaining and interpreting it. Students demonstrate understanding when they can organise information, connect it to relevant concepts, and restate a concept's meaning in their own words. Indicators of understanding include interpreting,

explaining, summarising, classifying, comparing, providing examples, and elaborating on the information or concepts studied.

Applying

Applying is a cognitive skill related to the use of knowledge, concepts, or procedures to solve a problem or complete a task. This skill shows that students not only understand a concept but can also apply it to specific problems. The cognitive processes involved in applying include executing and implementing knowledge or procedures. Indicators of the ability to apply include using, carrying out, executing, performing, practising, selecting, organising, initiating, and solving problems based on knowledge that has been learned.

Analysing

Analysing is a cognitive ability to break down information, problems, or objects into more specific parts and determine the relationships between those parts. This ability shows that students can identify relevant information, distinguish between different parts, and connect each part to gain a more comprehensive understanding. The cognitive processes involved in analysing include differentiating, organising, and attributing. Indicators of analytical ability include breaking down, distinguishing, comparing, organising, connecting, integrating, structuring, and identifying relationships between parts.

Evaluating

Evaluating is a cognitive skill that involves considering or assessing information, statements, procedures, or solutions based on specific criteria and standards. This skill requires students to use their existing knowledge to determine the accuracy or quality of an object or problem. The cognitive process of evaluating includes checking and critiquing. Indicators of the ability to evaluate include assessing, checking, testing, critiquing, justifying, weighing, and determining the accuracy of a statement or solution based on appropriate criteria.

Students' conceptual understanding was assessed using an essay test consisting of five items. The quantitative data obtained from the test were analysed using the following formula:

$$PK = \frac{\sum \text{Student Score}}{\text{Maximum Score}} \times 100\%$$

PK = Percentage of conceptual mastery
Σ Student Score = Cumulative student scores
Maximum Score = The highest total score a student can achieve

Next, the percentage scores obtained were interpreted using the qualification ranges for students' levels of conceptual understanding, based on descriptive statistical calculations as referenced in Dewiatmini (2021).

Table 3. Levels of Conceptual Understanding

Value Interval	Level of Understanding
85 < X ≤ 100	Very High
70 < X ≤ 85	High
55 < X ≤ 70	Moderate
40 < X ≤ 55	Low
0 < X ≤ 40	Very Low

RESULTS AND DISCUSSION

Based on these calculations, the expert evaluation of the essay instrument indicated acceptability rates of 81.33% and 76.53%, which fall into the highly feasible and feasible categories, respectively. These results indicate that the essay instrument meets the acceptability criteria based on the expert evaluation. Furthermore, to ensure that the instrument can measure conceptual understanding, an examination was also conducted on item validity, reliability, difficulty level, and discriminative power. This analysis was conducted to provide an overview of each item's quality in measuring students' cognitive abilities in the solar system subject.

Table 4. Validity Test Results for the Essay Test Instrument

Question Number	r-measurement	R-table	Criteria
1	0,441	0,250	Valid
2	0,437	0,250	Valid
3	0,559	0,250	Valid
4	0,503	0,250	Valid
5	0,401	0,250	Valid

Based on the data in Table 4, the validity analysis of the five items shows that all items have a positive correlation with the total score. The respective coefficients were 0.441 for the first item, 0.437 for the second item, 0.559 for the third item, 0.503 for the fourth item, and 0.401 for the fifth item. At the 5% significance level, all coefficients exceed the critical value (R-table), so the five items are considered valid. The reliability, as measured by Cronbach's Alpha, was 0.707; since this score is greater than 0.6, the reliability is classified as very high.

Table 5. Difficulty Levels of the Instrument

Question Number	Difficulty Index (P)	Criteria
1	0,92	Easy
2	0,50	Moderate
3	0,58	Moderate
4	0,56	Moderate
5	0,81	Easy
Average	**0,67**	**Moderate**

Based on the data in Table 5, five items were categorised as moderate, while two were categorised as easy. Proportionally, most items were categorised as moderate, indicating that the test items were designed to fairly assess students' cognitive abilities across various domains. Given the predominance of moderate-difficulty items, the essay test instrument is deemed to have an appropriate level of difficulty for assessing students' cognitive abilities regarding the solar system.

Pradita et al. (2023) explain that discriminant validity represents the extent to which a test item can distinguish between high-achieving and low-achieving students. The higher the discriminant validity index, the better the item reflects variation in test-takers' abilities. Calculations using Microsoft Excel show that items 1 and 5 fall into the good category with scores of 0.38 and 0.34, respectively. Meanwhile, items 2, 3, and 4 fall into the adequate category with scores of 0.24, 0.23, and 0.25, respectively. Overall, the test instrument's average discriminative power falls into the good category. This indicates that a sufficient proportion of the test items can distinguish students based on their cognitive ability levels. Thus, the essay test instrument used can provide a more diverse picture of students' cognitive ability levels regarding the solar system.

Data analysis was conducted using quantitative descriptive methods. This approach was used to describe the level of conceptual understanding of 7th-grade junior high school students regarding the solar system material based on the essay test results, both in terms of aggregate achievement and according to each level of cognitive process. The results are presented in the following table:

Table 6. Conceptual Understanding Test Results

Number of Students	Maximum Score	Minimum Score	Average
62	90	40	67,58

Based on the data in Table 6, there is a fairly wide range of conceptual understanding. Out of 62 students, the highest score was 90, and the lowest was 40. The average score for all students was 67.58, which falls into the moderate category. This indicates that students' conceptual understanding of the solar system material is moderate. These findings suggest that students understand the material studied, but this ability still needs to be developed to reach a higher level.

The research findings on conceptual understanding of the solar system material were grouped into categories of conceptual understanding levels. This grouping was done to show the distribution of students' conceptual understanding levels based on the results of the essay tests they completed. The distribution of students in Figure 2, which presents the analysis results, corresponds to the total in Table 1.

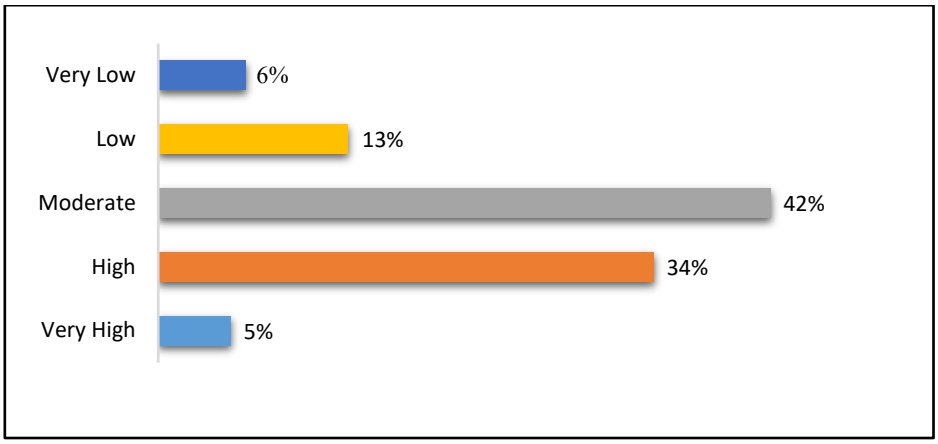


Figure 2. Categories of Students' Conceptual Understanding

As shown in Figure 2, students' conceptual understanding is distributed across five categories. Of the 62 students, the largest proportion falls into the moderate category (42%), followed by the high category (34%). Next, the low category accounts for 13%, the very low category for 6%, and the very high category for 5%. These data show that students' conceptual understanding is dominated by the moderate category, indicating that most students understand the basic concepts of the solar system, but their understanding is not yet fully in-depth. This finding implies that conceptual understanding needs to be strengthened through learning activities that help students connect and apply concepts more deeply.

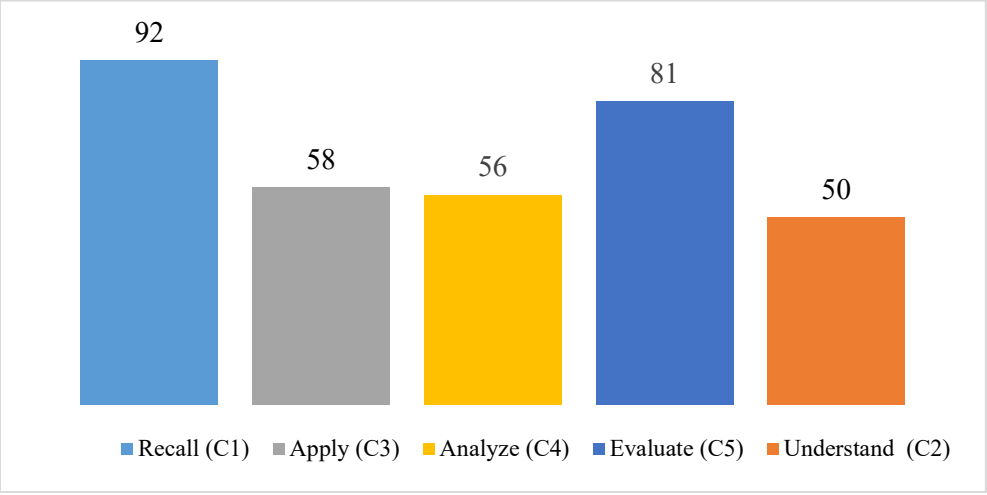


Figure 3. Overall Level of Understanding

As shown in Figure 3, test results were assessed using a scoring rubric with a score range of 1–4 for each student's answer. The scores obtained were then processed into achievement scores for each cognitive indicator. The results showed that the recall indicator (C1) achieved the highest score (92), followed by evaluating (C5) at 81, applying (C3) at 58, analysing (C4) at 56, and understanding (C2) at 50. Overall, understanding is dominated by recall and evaluation, while understanding, applying, and analysing still show relatively lower achievement levels. These differences in achievement provide insight into the variation in students' cognitive abilities regarding the solar system material, based on assessment results using a 1–4 scoring rubric. These findings imply the need to strengthen learning in understanding, applying, and analysing through activities that encourage students to interpret information, apply concepts in contextual situations, and connect information to explain a phenomenon, along with developing assessment instruments with controlled levels of difficulty and cognitive demands.

Memorising (C1)

According to Anderson and Krathwohl (2001), remembering is the process of retrieving information stored in long-term memory and serves as the foundation for developing higher-order cognitive abilities. In this study, this aspect was measured through the first question, which was phrased as follows:

"List the names of the planets in the Solar System, as shown in the picture above, in order from the closest to the furthest from the Sun!"

Through this test item, students are prompted to recall the order of the planets based on their proximity to the Sun. The accuracy of their responses reflects how firmly factual information about the order of the planets has been stored in the respondent's knowledge structure.

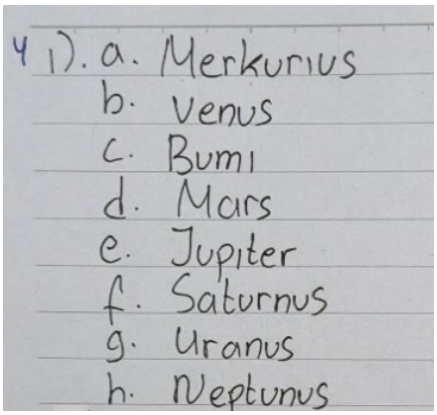


Figure 4. Examples of High-Level Students' Answers for the Recall Indicator (C1)

Based on the answer in Figure 4, the students listed all the planet names in full and in order of their distance from the Sun, from Mercury to Neptune. The students not only recalled all the planet names but also arranged them in order according to the solar

system concepts they had learned. This indicates that the students could recall relevant factual information about the names and order of the planets in the solar system material they had studied. This finding aligns with Dilapangan et al. (2022), who posit that knowledge serves as the foundation for developing cognitive activities at the next level. Thus, the students' answers reflect a recall ability that accurately involves the knowledge they have learned.

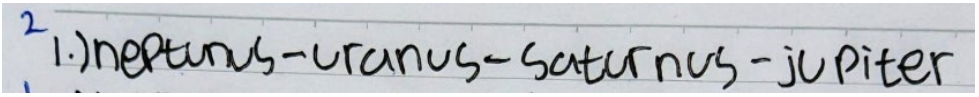


Figure 5. Examples of Low-Level Students' Answers for the Recall Indicator (C1**)**

Meanwhile, as shown in Figure 5, students still struggled to correctly name the planets or list them in the correct order. The errors found indicate that students wrote the order of the planets in reverse, thus failing to follow the question's instructions. Although students attempted to list all the names and the order of the planets provided, this was not relevant to the planets' distances from the Sun. This suggests that students have not yet been able to accurately recall knowledge regarding the names and order of the planets in the solar system curriculum. This finding suggests that students' ability to recall and restate factual knowledge about the solar system is not yet optimal because they require visualisation skills to construct mental representations of the objects being studied. This finding aligns with Febriyana et al. (2021), who found that the abstract nature of solar system material can hinder students' knowledge construction. Thus, the students' answers reflect that their recall ability is not yet optimal in retrieving the knowledge they have learned regarding the names and order of the planets in the solar system material.

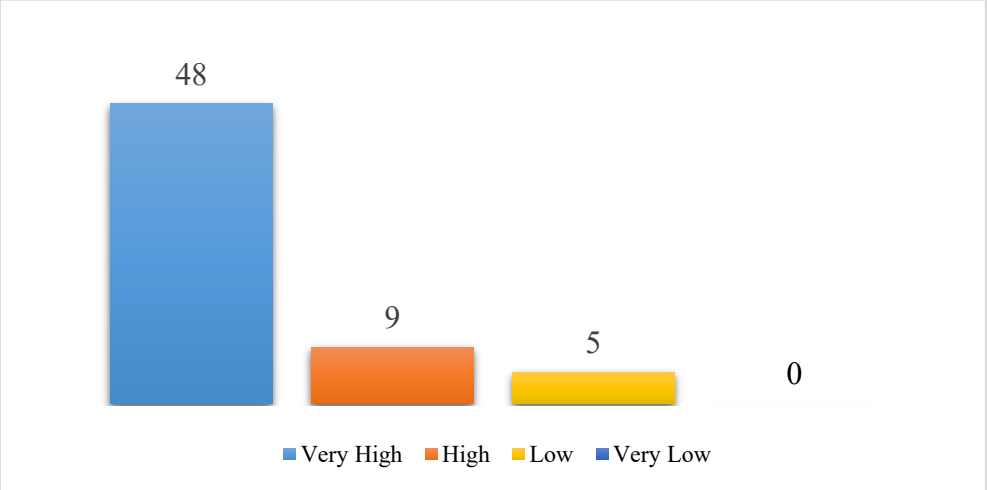


Figure 6. Distribution of Students' Achievement for the Recall Indicator (C1)

As shown in Figure 6, most students demonstrated good recall ability. Fifty-seven students already possessed a high level of recall ability, while only five students were still at a low level. These data indicate that most respondents have mastered basic information about the identities and arrangements of the planets. The fact that some

students are still in the low category suggests that conceptual understanding has not been uniformly mastered. Thus, for C1, we can examine higher cognitive levels, given that recall skills have largely been mastered.

Understanding (C2)

According to Anderson and Krathwohl (2001), understanding prioritises constructing meaning from information as the primary process. Individuals do not merely recall information; rather, they must explain, interpret, compare, and draw conclusions about a concept. In this study, this aspect was measured through the second question, which was formulated as follows:

"Why do you think the Earth doesn't move in a straight line away from the Sun, but instead orbits it?"

Through this question, students are guided to explain why the Earth continues to orbit the Sun based on the concepts of the Sun's gravitational force and the Earth's inertia (forward momentum) that they have learned. Students with a strong conceptual understanding can provide more accurate answers than those whose conceptual understanding is not yet solid. An example of an answer from a student with a high level of conceptual understanding can be seen in Figure 7.

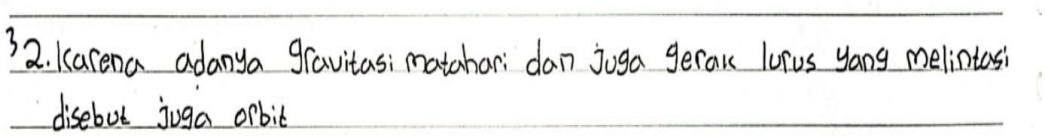


Figure 7. Example of a High-Level Student's Answer for the Understanding Indicator (C2)

Based on the answers in Figure 7, the students explained that the Earth remains in orbit because the Sun's gravitational force pulls on it and its own motion keeps it moving along its orbital path. These responses indicate that students not only recall information about Earth's revolution but can also explain how the Sun's gravitational force and Earth's motion work together to cause Earth's revolution. This suggests that students have understood the interconnections among concepts in the solar system curriculum. This defines conceptual understanding as the ability to integrate and interpret knowledge and then re-express it in one's own words. Thus, the students' answers reflect a solid grasp of the Sun's gravitational force and Earth's motion, enabling them to use these concepts to explain why Earth continues to orbit the Sun.

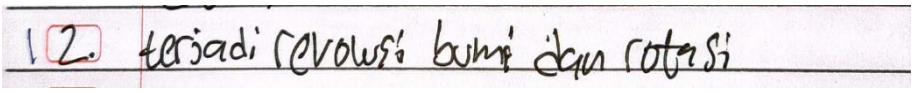


Figure 8. Example of a Very Low-Level Student's Answer for the Understanding Indicator (C2)

Meanwhile, in the answer shown in Figure 8, the student has not explained why the Earth continues to orbit the Sun in accordance with scientific concepts. The response mentions the terms revolution and rotation but does not explain why the Earth continues to orbit the Sun. Neither gravitational pull nor the Earth's tendency to move was integrated into the answer. This indicates that while certain terminology has been recognised, causal relationships between concepts have not yet been adequately established. These findings align with research by Hulu and Siswanti (2024), which reported that limited conceptual mastery can make it difficult for students to integrate new information into their existing knowledge structures. Thus, the students' answers indicate that their comprehension skills are not yet optimal because they have not been able to explain and connect concepts related to the solar system in a relevant way.

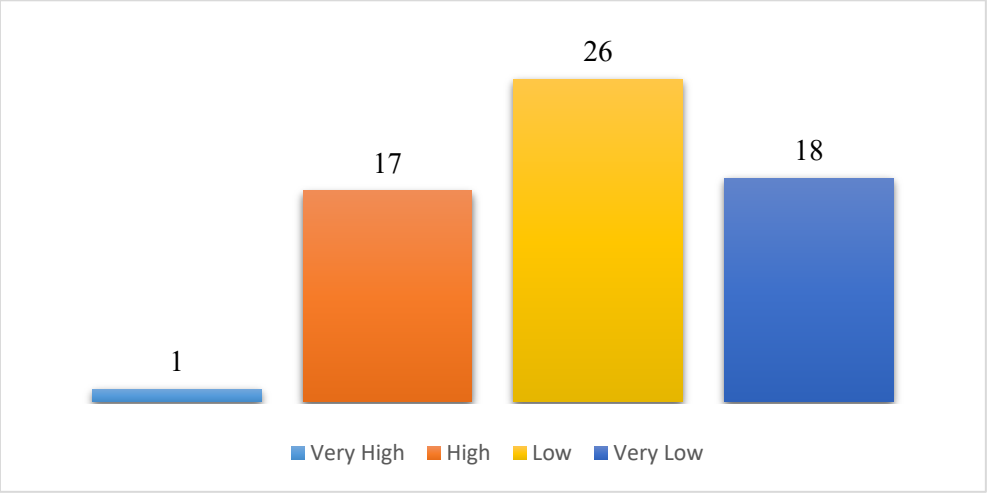


Figure 9. Distribution of Students' Achievement for the Understanding Indicator (C2)

As shown in Figure 9, C2 tends to fall into the low and very low categories, with most of the 44 students in the low category. Upon further review, the C2 questions were found to be of moderate difficulty, suggesting that question difficulty may have influenced students' ability to answer the essay questions. Questions 1, 2, 3, 4, and 5 can be linked to comprehension ability because they vary in difficulty. Therefore, the effect of varying difficulty levels ultimately cannot be attributed solely to low student ability. This finding implies the need for practice questions with more controlled difficulty levels to obtain a more accurate picture of students' comprehension abilities.

Applying (C3)

According to Anderson and Krathwohl (2001), the ability to apply refers to the ability to use concepts, principles, or procedures that have been learned to solve a problem in a specific situation. In this study, this aspect was measured using the third question, which was formulated as follows:

"Identify which parts of the Earth are currently experiencing day and which are experiencing night! Explain your reasoning using the concept of the Earth's rotation!"

Through this item, students are guided to apply the principle of Earth's rotation to determine which parts of the Earth experience day and night and to explain the reasons based on the scientific concepts they have learned. Therefore, the answer is not sufficient if it merely mentions the phenomena of day and night; rather, it must demonstrate the use of the principle of rotation as an explanation. An example of a student's response demonstrating a high level of conceptual understanding can be seen in the following figure:

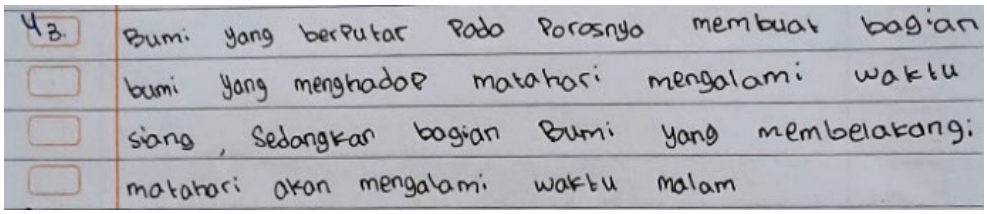


Figure 10. Examples of High-Level Students' Answers for C3

Based on the answers in Figure 10, students applied the concept of Earth's rotation to determine which parts of the Earth experience day and night. Students explained that the side of the Earth facing the Sun is the day side, while the side facing away from the Sun is the night side. They further explained that these changes are due to the Earth's rotation on its axis. Thus, the principle of rotation was used to solve the situation presented in the question. This finding aligns with Fauzi and Inayati (2023), who explain that the essay-style format gives students space to present their reasoning and thought processes when solving problems. These responses demonstrate this characteristic because knowledge of rotation does not stop at a definition but is used as a basis for explaining the phenomenon of the alternation of day and night. In this process, students can apply scientific concepts appropriately to explain the phenomena that occur.

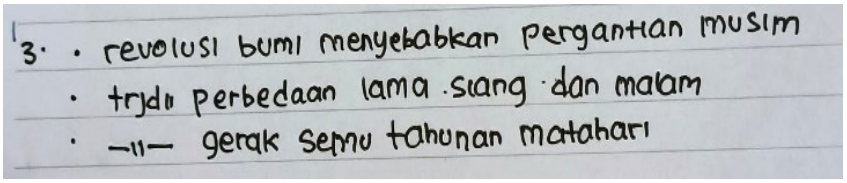


Figure 11. Example of a Very Low-Level Student's Answer for C3

The answer in Figure 11 describes the effects of revolution, including seasonal changes, variations in the length of day and night, and the Sun's annual apparent motion. This information does not address the problem that requires applying the principle of rotation to explain which side of the Earth experiences day or night. This demonstrates a lack of conceptual distinction between rotation and revolution when this knowledge must be applied to a specific case. This finding aligns with Hulu and Siswanti (2024), who show that limitations in conceptual mastery can make it difficult for students to

integrate new information with their existing knowledge structures. These responses indicate that students' ability to apply solar system concepts to explain phenomena or solve problems still needs improvement through learning that provides opportunities to apply concepts in various contexts and is supported by learning media that can visualise astronomical phenomena more realistically.

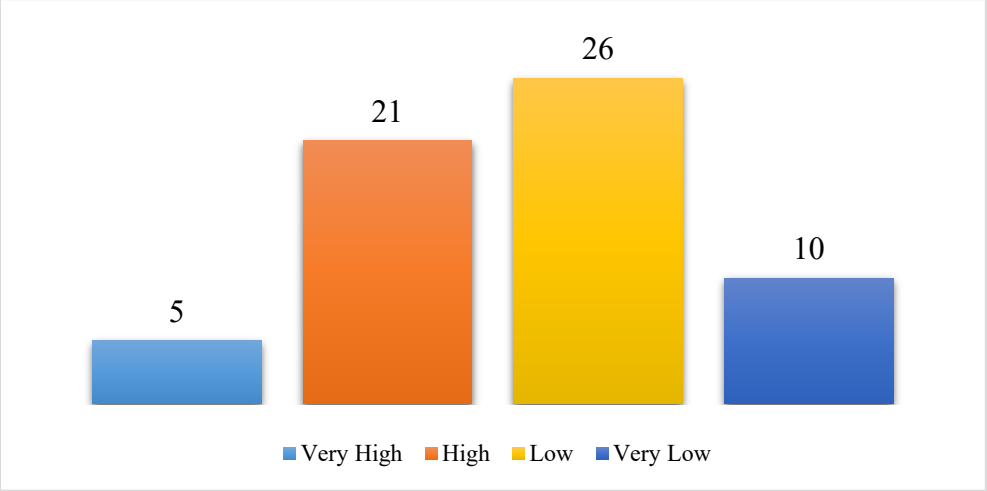


Figure 12. Distribution of Students' Achievement for the Apply Indicator (C3)

As shown in Figure 12, achievement in the Applying skill (C3) tends to fall into the low and very low categories, with most of the 36 students in the low category. Upon further review, the C3 questions were moderately difficult, suggesting that question difficulty influenced students' ability to answer the essay questions. The data indicate that students' ability to apply their knowledge of Earth's rotation remains uneven. This finding implies the need to strengthen students' application skills through practice questions that link the concept to contextual phenomena, use images or simulations, and gradually increase in complexity.

Analysing (C4)

According to Anderson and Krathwohl (2001), analysing is the ability to break down information into its constituent parts, identify the relationships among those parts, and determine how they relate to one another in forming a concept. In this study, this aspect was measured using the fourth item, which was formulated as follows:

"An analysis of the positions of the Sun, Earth, and Moon can lead to a total lunar eclipse!"

Through this question, students are guided to analyse the relative positions of the Sun, Earth, and Moon and relate them to the formation of the Earth's shadow during a total lunar eclipse. An example of an answer from a student demonstrating a high level of conceptual understanding can be seen in the following figure:

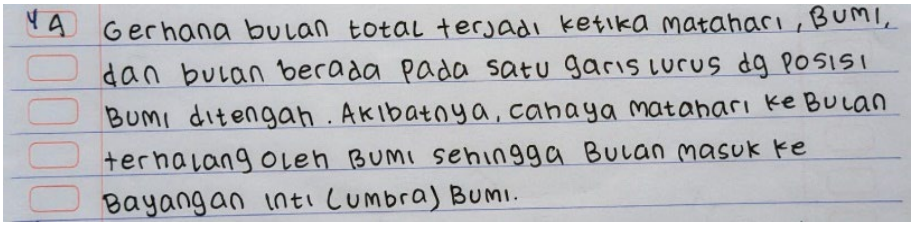


Figure 13. Example of a Very High-Level Student's Answer for C4

Based on the answer in Figure 13, students analyse the relationship among the three celestial bodies required to produce a total lunar eclipse. The Earth is positioned between the Sun and the Moon, so that the Sun's radiation toward the Moon is blocked by the Earth. The Moon then enters the Earth's umbra, or core shadow. This explanation integrates the relative positions of the celestial bodies, the path of light, and shadow formation. This answer goes beyond a mere definition of an eclipse and analyses the underlying cause-and-effect relationship that gives rise to this phenomenon. This finding aligns with the research by Sifaunnazah et al, (2025), which emphasises the importance of mental representations and spatial reasoning in studying astronomical phenomena that cannot be observed directly. The respondents' success in linking the configuration of celestial bodies to the mechanism of umbra formation indicates that the relational structure of this phenomenon has been constructed quite well.

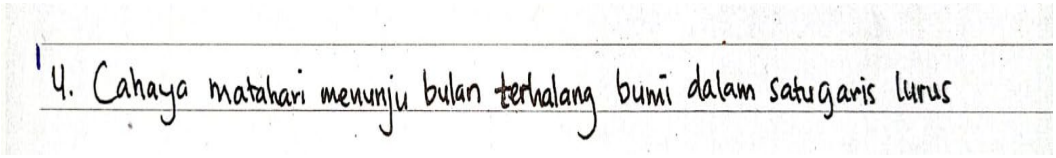


Figure 14. Example of a Very Low-Level Student's Answer for the C4

Meanwhile, in the answer shown in Figure 14, the student recognised the configuration of celestial bodies and the obstruction of light toward the Moon, but the explanation did not account for the entire mechanism. The student did not explicitly explain Earth's position between the Sun and the Moon or the role of the umbra. This indicates that while some components of the phenomenon have been partially identified, the cause-and-effect relationships among these components have not been organised into a complete explanation. Thus, the analytical ability demonstrated in this response is not yet optimal, as the student has not fully identified the cause-and-effect relationships or analysed the interconnections between concepts when explaining the phenomenon of a total lunar eclipse.

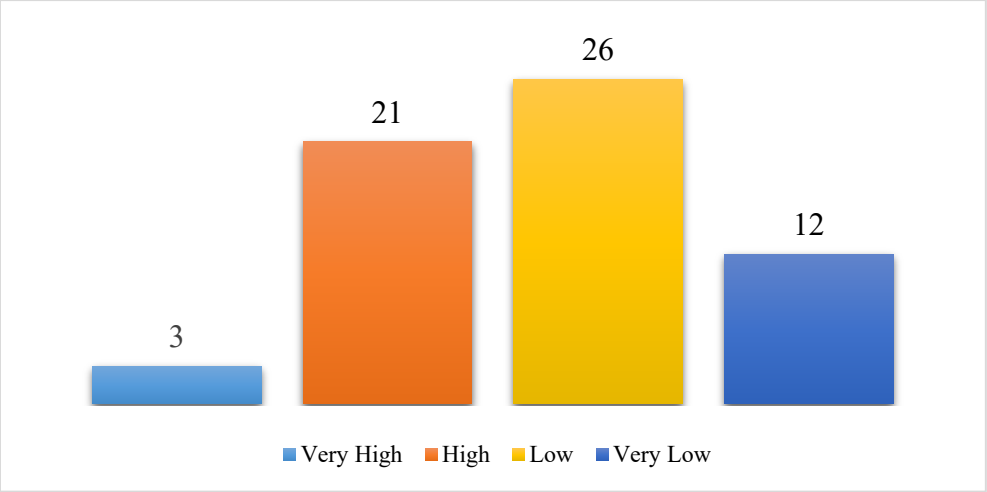


Figure 15. Distribution of Students' Achievement for the C4

As shown in Figure 15, understanding of the "Analysing" indicator (C4) tends toward the low and very low categories, with most of the 38 students falling into the low category, despite the C4 question being rated as moderately difficult. Thus, the question's difficulty level may have influenced students' ability to answer the essay question. These data indicate that students' ability to identify relationships among components and trace the cause-and-effect relationships of astronomical phenomena still needs development. The implication of this finding is that students' analytical skills need to be strengthened through gradual and contextual practice with questions, particularly those involving the interpretation of information, the identification of relationships among components, and cause-and-effect reasoning

Evaluation (C5)

According to Anderson and Krathwohl (2001), evaluating is the ability to assess a concept based on specific criteria and analyse it logically. In this study, this aspect was measured using the fifth question, which was formulated as follows:

"In your opinion, does the Sun play an important role in life on Earth? Explain your reasoning!"

Through this question, students are guided to evaluate the Sun's role in life on Earth based on concepts from the solar system they have studied. Students with strong evaluative skills can provide logical assessments supported by reasoning consistent with scientific concepts. Conversely, students with insufficient conceptual understanding generally struggle to construct appropriate arguments to support their assessments. An example of a student's answer demonstrating a high level of conceptual understanding is presented in the following figure:

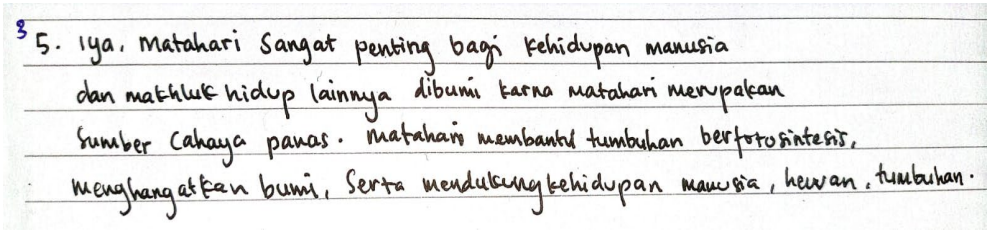

5. iya, matahari sangat penting bagi kehidupan manusia dan makhluk hidup lainnya dibumi karna matahari merupakan sumber cahaya panas. matahari membantu tumbuhan berfotosintesis, menghangatkan bumi, serta mendukung kehidupan manusia, hewan, tumbuhan.

Figure 16. Example of a High-Level Student's Answer for the Evaluate Indicator (C5)

Meanwhile, in the answer shown in Figure 16, students evaluated the role of the sun in life on Earth by providing assessments supported by reasons based on scientific concepts. Students explained that the sun plays a very important role because it provides light and heat, supports photosynthesis in plants, warms the Earth, and supports the survival of living organisms. These answers show that students not only expressed their opinions regarding the importance of the sun but also provided logical reasons consistent with the solar system concepts they had learned. According to Anderson and Krathwohl (2001), evaluation is defined as making judgments based on specific criteria. Thus, the students' answers reflect their ability to provide assessments supported by arguments consistent with the solar system curriculum.

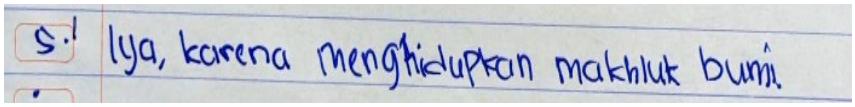

5. iya, karena menghidupkan makhluk bumi.

Figure 17. Example of a Very Low-Level Student's Answer for C5

Meanwhile, in Figure 17, students have not yet fully evaluated the Sun's role in life on Earth. The answers merely state that the Sun is important because it sustains living organisms, without scientific reasoning or arguments explaining its role as a source of light and energy, a facilitator of photosynthesis, a regulator of Earth's temperature, or a supporter of the continuity of life. This finding aligns with the research by Sinaga et al. (2025), which notes that most teaching and learning processes still rely on conveying material in a textual manner, causing students to struggle to visualise and construct mental representations of astronomical objects and phenomena. This finding is one factor hindering students' ability to understand relationships between concepts and provide scientific explanations. This limitation prevents students from formulating comprehensive arguments when evaluating the importance of the Sun's role in life on Earth. Consequently, students' responses indicate that their evaluative skills remain suboptimal, as their assessments are not supported by logical reasoning aligned with scientific concepts regarding the solar system.

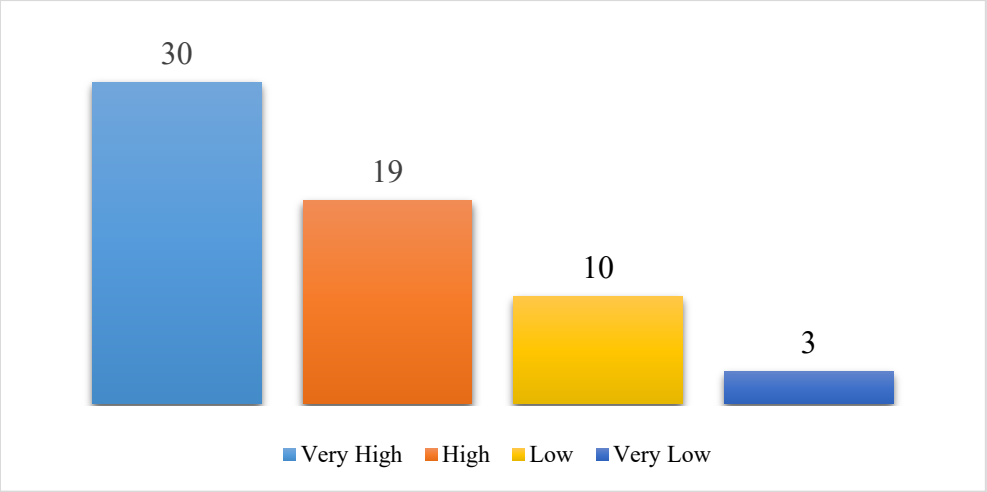


Figure 18. Distribution of Students' Achievement for the Evaluating Indicator (C5)

Referring to Figure 18, the results for the Evaluating indicator (C5) show that students have mastered evaluation skills. Of the 62 students, 49 already possess a high level of evaluation ability, while 13 students are still in the low category. Upon further review, the C5 questions were found to be easy. Thus, the difficulty level of the questions influenced students' ability to answer the essay questions. The data indicate that most students can assess a problem based on the solar system concepts they have learned. A limitation of this indicator is the use of an essay test instrument, which assesses evaluation skills only through test items designed specifically for the solar system material. Thus, the results cannot yet fully reflect students' evaluation skills more broadly on different topics, as the difficulty levels range from easy to moderate. This finding implies that while the instruments are standardised, their quality requires improvement; preliminary results indicate that C2–C4 scores remain relatively low.

CONCLUSIONS

The results of this study indicate that the Bloom's Taxonomy-based essay test instrument is suitable for identifying students' cognitive abilities regarding the solar system. The results indicate that students' cognitive abilities fall into the moderate category, with recall (C1) and evaluation (C5) showing relatively higher achievement than comprehension (C2), application (C3), and analysis (C4), which still need to be strengthened. These findings suggest that students can master factual information but still need reinforcement in connecting, applying, and analysing concepts related to solar system phenomena. Therefore, the results of this study can serve as a basis for teachers to design more contextual learning experiences and utilise visualisations or simulations to help students more easily understand the complex phenomena of the solar system.

AI-ASSISTED TECHNOLOGY STATEMENT

While preparing this work, the authors used Grammarly to check for grammatical errors and ChatGPT to create the Graphical Abstract. After utilising these tools, the authors reviewed and edited the content as needed and took full responsibility for the publication's content.

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