Using a Two-tier Diagnostic Test to Analyze Students' Misconceptions and Misunderstandings of Solar System

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Abstract
Students' understanding of the concept of the solar system is very diverse due to the abstract nature of the material, which can lead to misconceptions and misunderstandings of the concept. This study aims to identify the concept understanding of grade VI elementary school students on solar system material, with the main objectives of (1) identifying students' misconceptions and misunderstandings on the concept, and (2) measuring the frequency of misconceptions and misunderstandings. The research method used a survey with an instrument in the form of a two-tier diagnostic test consisting of true-false answers and assisted by a certainty of response index with three levels of student confidence in their understanding. The respondents were 133 grade VI students from seven elementary schools. Data were analyzed descriptively quantitatively using percentages and bar charts. The results showed that more than half of the students had misconceptions and misunderstandings on the concept of the solar system, especially on the concept of the phase of the moon, the position of the sun in the sky, and the perception of meteors as "shooting stars". This study found that gender differences affect elementary school students' concept understanding. Male students tend to experience higher misconceptions than female students. Conversely, female students experienced higher concept misconceptions than male students. This study recommends the use of augmented reality-based learning media to help overcome students' misconceptions and misunderstandings on the concept of the solar system.

Article History:

Keywords:
Misconceptions, misunderstandings, solar system, two-tier diagnostic test, certainty of response index, science

1. Introduction

The solar system is important in science learning because it provides experiences that are useful in improving understanding of scientific concepts (Kanli, 2015). Concept understanding is included as a skill indicator of student competence (Fitriati et al., 2021). Through the correct understanding of scientific concepts, students can learn more complex science topics. The concept of the solar system is related to disciplines such as physics, geology, chemistry, and mathematics, so it is important in science learning (Kanli, 2014). As a discipline, the concept of the solar system often causes misconceptions in students in science learning (Serttaş & Türkoğlu, 2020). It is important for students to understand appropriate science concepts so that science learning objectives can be achieved.

The goal of learning science in the education curriculum is for students to understand the correct scientific concepts (Serttaş & Türkoğlu, 2020). The study also states that among the objectives of the science curriculum is to increase understanding of the concepts of astronomy, biology, physics, chemistry, earth and its environment. Teachers have a strategic role to help students understand these solar system concepts (Korur, 2015). Therefore, it is important for teachers to understand the concepts to be conveyed so that there are no misconceptions or misunderstandings of concepts in students (Serttaş & Türkoğlu, 2020).

Students' opinions or ideas that are not in accordance with scientific theories and explanations are known as misconceptions, preconceptions, and alternative conceptions (Vosniadou & Skopeliti, 2017). There are still many students who experience misconceptions about science learning, for example the concept of the solar system (Kanli, 2015; Yuliati, 2017). Misconceptions experienced by students can be a challenge in achieving science learning goals (Korur, 2015). When students experience misconceptions in basic concepts, there is a greater possibility that students experience misconceptions in more complex concepts (A'yun & Nuswowati, 2018).

Students who experience misconceptions are not accidental, but students' efforts to integrate scientific concepts that contradict the correct concepts (Vosniadou & Skopeliti, 2017). If misconceptions are not found immediately, then students' understanding of a concept will be hampered (Khairaty et al., 2018). Therefore, it is important for teachers to identify misconceptions or misunderstandings of concepts that students have through teaching adjustments so that these problems can be overcome (Korur, 2015).

The concept of the solar system in science is an abstract concept derived from students' personal experiences without a scientific explanation (Kanli, 2015). The lack of structured observation, appropriate guidance, and practice makes students experience misconceptions (Korur, 2015). Another factor that causes students to experience misconceptions is the conceptual understanding of the teacher (Kanli, 2014). Gender differences can also affect students' concept understanding (Adolphus & Omeodu, 2016; Sagala et al., 2019; Nworgu et al., 2013).

There have been many studies that discuss misconceptions or misunderstanding of concepts experienced by students. Research related to misconceptions on the concept of the solar system about the occurrence of seasons, moon phases, moon phases in eclipses, the position of the sun in the sky (Kanli, 2014; Korur, 2015); comets, shooting stars, star orbits, astrology, sunspots, and solar energy sources (Kanli, 2015); the sun moves behind mountains, the earth does not move, the role of the moon, the rotation of the earth (Vosniadou & Skopeliti, 2017); comets and constellations (Serttaş & Türkoğlu, 2020); rotation and revolution of the earth, lunar and solar eclipses, stars (Laksana, 2016). Some of these studies used survey and experimental methods accompanied by sample attachments, education levels, assessment instruments, and data collection instruments, one of which used a two-tier diagnostic test.

In the last twenty years, finding out students' misconceptions using two-tier (Treagust, 1988; Kanli, 2015) has been effective in analyzing students' misconceptions. In these studies, the use of two-tier diagnostic tests is effective based on its ability to reduce errors caused by inaccuracy and chance factors. Through the two-tier diagnostic test, students will be assessed based on the level of truth and confidence so that misconceptions and conceptual misunderstandings can be identified in students. Research on misconceptions tends to examine junior high school, high school, prospective teachers, and teachers (Kanli, 2014; Kanli, 2015; Korur, 2015; Kirbulut & Geban, 2014; Serttaş & Türkoğlu, 2020; Vosniadou & Skopeliti, 2017). There are still few studies that discuss student misconceptions in elementary schools, especially those that use two-tier diagnostic tests and include the influence of gender differences in students' concept understanding.

Two-tier diagnostic test has weaknesses in distinguishing students who understand concepts, do not understand concepts and misconceptions (A'yun & Nuswowati, 2018). Therefore, to overcome this weakness, the CRI (Certainty of Response Index) technique is included as a development or assistance to the two-tier diagnostic test. CRI is a technique to determine the level of student conceptions such as understanding concepts, misunderstandings, and misconceptions through the level of confidence or certainty of students in answering the questions given (A'yun & Nuswowati, 2018; Fadillah, 2017; Gumilar, 2016; Waluyo et al., 2019).

It is important for teachers to identify misconceptions or misunderstandings of concepts that students have through teaching adjustments so that these problems can be overcome (Korur, 2015). A

valid data collection instrument is needed to analyze misconceptions and misunderstandings of concepts in students. Based on this explanation, this study aims to analyze the misconceptions and misunderstandings of elementary school students on the solar system using a two-tier diagnostic test assisted by certainty of response index and the effect of gender differences on concept understanding.

2. Method

This study used a survey method with the aim of analyzing primary school students' misconceptions and conceptual misunderstandings in the solar system. The population consisted of grade VI primary school students from 7 schools in Banyumas and Cilacap regions, Indonesia. The sample was selected using purposive sampling method consisting of 133 students with male students (n=66) and female students (n=67) with the criteria of students who received science learning in the concept of solar system. All students voluntarily participated in this study.

The data collection instrument used a questionnaire sheet based on the two-tier diagnostic test. Two-tier diagnostic test is the development of multiple-choice items with a design comparable to the logical thinking test format (Tobin & Capie, 1981). The two-tier diagnostic test instrument consisting of statement indicators and correctness of answers (true-false) is then assisted by the CRI (Certainty of Response Index) technique to measure the level of student confidence. Through the category of belief levels such as sure, not sure, and don't know, it will be processed with the truth of the answer into the level of student conception. The categories of students' conceptions include understanding the concept, misunderstandings, and misconceptions. The list of questionnaires with the two-tier diagnostic test assisted by the CRI technique can be seen in table 1.

Table 1. Questionnaires with the two-tier diagnostic test assisted by the CRI

Indicator Statement	Answer Correctness		Level of Confidence		
	True	False	Sure	Not Sure	Don't Know
The sun is directly overhead at noon					
The moon is only visible at night					
The solar system consists only of the sun, planets and moon					
A meteor is a shooting star					

The results of the validity test of the two-tier diagnostic test questionnaire instrument assisted by the certainty of response index can be seen in table 2.

Table 2. Validity of the Instrument

Item No.	$r_{calculated}$	r_{table}	p-value	Indicators Validity
1	0,713	0,170	0,00	Valid
2	0,658	0,170	0,00	Valid
3	0,586	0,170	0,00	Valid
4	0,801	0,170	0,00	Valid

Based on the table, it can be seen that $r_{calculated}$ is greater than r_{table} with a significance level of 5%. Based on the significance value of 2 tiles, p-value is less than 0.05. So, it can be concluded that the four statements in the CRI-assisted two-tier diagnostic test questionnaire instrument are valid. In the reliability test, it was found that cronbach's alpha > 0.6 which means that the two-tier diagnostic test questionnaire instrument assisted by the certainty of response index was declared reliable. Can be seen in table 3.

Table 3. Reliability Statistics

Cronbach's Alpha	N of Items
0,631	4

The data obtained with the two-tier diagnostic test questionnaire instrument were then analyzed descriptively quantitatively. The type of data used is primary data because it is obtained directly from the research subject. Data analysis was completed with a bar chart to show the percentage of misconceptions and misconceptions experienced by students. The percentage of misconceptions and misunderstanding of concepts is presented in general form and the differences in the abilities of male and female students. The results of the data analysis discussed three categories of conceptions such as conceptual understanding, misunderstandings, and misconceptions specifically and generally.

The equation is used to calculate the percentage of student responses to questions, the level of student confidence, and classifying students into groups of understanding, misconceptions, misunderstandings, as well as identifying questions categorized as misconceptions or misunderstandings (Sudijono, 2010).

$$P = \frac{f}{N}\ x\ 100\%$$

3. Results and Discussion

3.1 Results

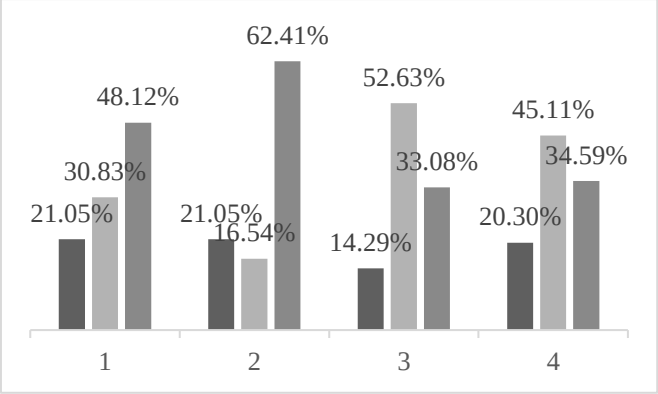
The results of the percentage of grade VI primary school students (n=133) on conceptual understanding, misunderstandings concept, and misconceptions can be seen in table 4.

Tabel 4. Percentage of Conceptual Understanding, Misunderstandings Concept, and Misconceptions

Student Conceptions	Percentages (%)
Conceptual Understanding	19,17
Misunderstandings Concept	36,28
Misconceptions	44,55

Specifically, based on the data, the percentage of solar system conceptions is categorized into 3 (three), namely understanding the concept, misunderstandings, and misconceptions. Students have understood the concept of the solar system by 19.17%, this figure is low. Then there are 36.28% of students who do not understand the concept of the solar system. On the other hand, the misconceptions experienced by students amounted to 44.55%. The dominating percentage is in the category of misconceptions and incomprehension of concepts. This shows that almost half of the students had misconceptions and more than a third of the students did not understand the concept of the solar system.

Figure 1. Percentage of Each Item in Conceptual Understanding, Misunderstandings Concept, and Misconceptions



In general, based on the data on the percentage of students' misconceptions on the concept of the solar system, the question with the highest level of misconception is question number 2, with a misconception of 62.41%. In this question, students believe that “the moon can only be seen at night”

which shows that many students still have misconceptions in knowing the phases of the moon that allow the moon to be visible during the day. On the other hand, the question with the lowest level of misconception is question number 3, with a misconception percentage of 33.08%. This question states that "The solar system only consists of the sun, planets and moon". Although question number 3 had the lowest level of misconception, one-third of all students had misconceptions.

Based on the data on the percentage of students' misunderstandings, the question with the highest level of misunderstandings is question number 3, with a percentage of 52.63%. The percentage results indicate that more than half of the students have misunderstandings about the objects that make up the solar system. Then the question with the lowest level of conceptual misunderstanding is question number 2 with a percentage of 16.54%.

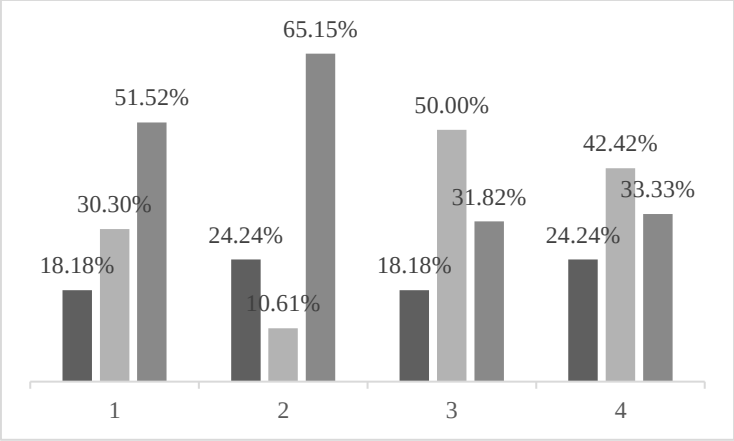
The results of the percentage of male students (n=66) on the concept of understanding the concept, misunderstandings, and misconceptions can be seen in table 5.

Table 5. Percentage of Male Students Conceptual Understanding, Misunderstandings, and Misconceptions

Student Conceptions	Percentages (%)
Conceptual Understanding	21,21
Misunderstandings Concept	33,33
Misconceptions	45,46

Specifically, based on the data, the percentage of male students on the conception of the solar system is categorized into 3 (three), namely understanding the concept, misunderstandings, and misconceptions. Students have understood the concept of the solar system by 21.21%, this figure is low. Then there are 33.33% of students who do not understand the concept of the solar system. On the other hand, the misconceptions experienced by students amounted to 45.46%. The dominating percentage is in the category of misconceptions and not understanding the concept. This shows that almost half of male students have misconceptions and one-third of male students have a misunderstanding of the solar system concept.

Figure 2. Percentage of Male Students for Each Item in the Conceptual Understanding, Misunderstandings Concept, and Misconceptions



In general, based on the data on the percentage of male students' misconceptions on the concept of the solar system, the question with the highest level of misconception is number 2, with a

misconception of 65.15%. On the other hand, the question with the lowest level of misconception is question number 3, with a misconception percentage of 31.82%.

Based on the data on the percentage of male students' misunderstandings, the question with the highest level of misunderstandings is question number 3, with a percentage of 50.00%. The percentage results indicate that some male students have misunderstandings about the objects that make up the solar system. Then the question with the lowest level of conceptual misunderstanding is question number 2 with a percentage of 10.61%.

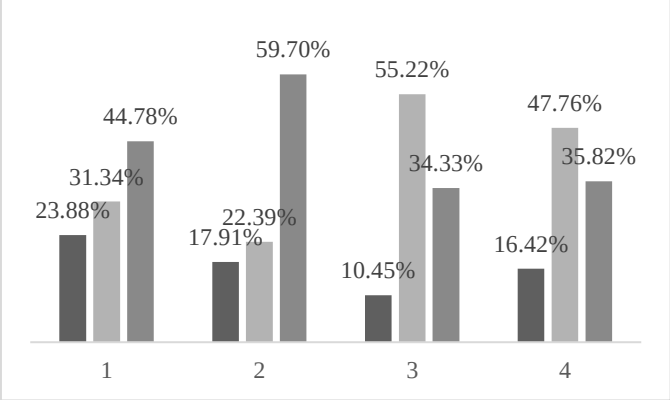
The results of the percentage of female students (n=67) on the concept of understanding the concept, misunderstandings, and misconceptions can be seen in Table 6.

Table 6. Percentage of Female Students Conceptual Understanding, Misunderstandings, and Misconceptions

Student Conceptions	Percentages (%)
Conceptual Understanding	17,16
Misunderstandings Concept	39,18
Misconceptions	43,66

Specifically, based on the percentage data on female students, the conception of the solar system is categorized into 3 (three), namely understanding the concept, misunderstandings, and misconceptions. Students have understood the concept of the solar system by 17.16%, this figure is low. Then there are 39.18% of students misunderstanding the concept of the solar system. On the other hand, the misconceptions experienced by students amounted to 43.66%. The dominating percentage is in the category of misconceptions and incomprehension of concepts. This shows that almost half of female students experience misconceptions and more than a third of female students experience a misunderstanding of the solar system concept.

Figure 3. Percentage of Female Students for Each Item in the Conceptual Understanding, Misunderstandings Concept, and Misconceptions



In general, based on the data on the percentage of female students' misconceptions on the concept of the solar system, the question with the highest level of misconception is number 2, with a misconception of 59.70%. On the other hand, the question with the lowest level of misconception is question number 3, with a misconception percentage of 34.33%.

Based on the data on the percentage of female students' misunderstandings, the question with the highest level of misunderstandings is question number 3, with a percentage of 55.22%. The percentage results indicate that more than half of female students experience misunderstandings about

the objects that make up the solar system. Then the question with the lowest level of conceptual misunderstanding is question number 2 with a percentage of 22.39%.

Based on the comparison of the percentage of misconceptions of male and female students, there are differences in conception ability. Male students tend to experience higher misconceptions than female students with a percentage of 45.46%. This shows that almost some students have misconceptions about the concept of the solar system. However, female students experience higher conceptual misconceptions with a percentage of 39.18%.

The highest misconceptions were experienced by male students with a percentage of 65.15% in question number 2. In this question, most male students thought that the moon could only be seen at night. In fact, the moon can also be seen during the day, especially in the first and third quaternary phases, as well as in the morning or evening when the moon is in the crescent phase. Clear sky conditions and the moon's high position increase the likelihood of seeing the moon during the day.

The highest conceptual misunderstanding was experienced by female students with a percentage of 55.22% in question number 3. In this question, more than half of the female students thought that the solar system only consisted of the sun, planets and the moon. But in fact, the solar system also includes other objects such as asteroids, comets, meteoroids, dwarf planets, and interstellar dust.

3.2 Discussion

Based on the research results obtained, it shows that students' misconceptions and conceptual misunderstandings on solar system material are still a significant problem or challenge in learning at the elementary school level. This can be seen from the percentage of students who experience misconceptions of 44.55% and incomprehension of concepts of 36.28%. From this percentage, most students do not have good concept understanding skills related to solar system material.

These results are relevant to the initial objective of the research, which is to analyze students' misconceptions and conceptual misunderstandings using a two-tier diagnostic test assisted by the Certainty of Response Index (CRI). This instrument proved effective in analyzing the category of students' conceptions, although students who understood the concept were only limited to 19.17%. This indicates that there is a need for an effective, interactive and adaptive teaching approach or learning media to improve student understanding.

Scientifically, this result indicates that factors such as students' learning experience, teacher delivery, and the abstract nature of the solar system concept influence the high number of misconceptions and incomprehension of concepts in students. For example, the highest misconception was found in the statement that the moon can only be seen at night, with a percentage of 62.41%. This finding indicates students' lack of conceptual understanding of the moon phase, which basically under certain conditions can be seen during the day.

The inconsistency between this finding and the results of previous studies is interesting to understand. For example, a previous study by Kanli (2014) showed that misconceptions related to the motion of the earth and sun dominated, while this study showed higher misconceptions on the moon phase. This can occur due to the influence of differences in curriculum, learning approaches, and students' level of understanding of the relevant material.

Based on gender analysis, it shows differences in the conception patterns experienced by students. Male students tend to experience more misconceptions (45.46%) than female students (43.66%). Meanwhile, female students have higher conceptual incomprehension (39.18%) than male students (33.33%). Differences in concept understanding ability can be influenced by various factors, including social interaction in the learning process, how students understand the material, and students' habits in teaching.

Overall, this study confirms the importance of using valid diagnostic tools to detect students' misconceptions and misunderstandings. This is to reduce misconceptions and improve students' conceptual understanding of a material concept, especially the abstract solar system. In addition, further research is needed to explore the factors that influence misconceptions, including learning media and

gender-based approaches. Researchers recommend the use of augmented reality as an interactive and adaptive learning media on solar system concepts.

4. Conclusion

This study successfully achieved its objectives by analyzing the misconceptions and misunderstandings of concepts of elementary school students on solar system material using a two-tier diagnostic test assisted by Certainty of Response Index (CRI). Results showed that 44.55% of students had misconceptions and 36.28% did not understand the concept, with only 19.17% of students understanding the concept correctly. This data underscores the importance of developing diagnostic instruments that are valid and effective in detecting students' conception problems at the basic level.

This research contributes to the field of science education by providing in-depth insights into misconceptions on solar system concepts, especially in elementary school students, which have previously been more often focused on the secondary education level. By utilizing a combination of two-tier diagnostic tests and CRI, this research offers a more comprehensive approach to mapping students' understanding, allowing teachers to identify and address misconceptions more precisely. The results also revealed differences in misconception patterns based on gender, where male students experienced more misconceptions (45.46%) than female students (43.66%), while female students showed more concept misconceptions (39.18%). This opens further research opportunities to explore gender factors in science learning.

Scientifically, these findings indicate that learning solar system concepts requires more interactive and adaptive media to overcome the abstract nature of the material. One potential application is the use of augmented reality (AR), which can provide dynamic and in-depth visualization of solar system concepts. AR-based learning media has the potential to reduce misconceptions and improve student understanding.

For future research, experiments that evaluate the effectiveness of innovative learning media such as AR in improving students' understanding of solar system concepts are recommended. In addition, further exploration of other factors, such as the influence of social background, learning experiences, and teaching approaches, influencing students' misconceptions and incomprehension is needed.

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