Analysis of Misunderstanding and Misconceptions in Students on the Human Respiratory System Using Two-Tier Diagnostic Test

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Abstract
Natural Science in Primary School aims to build a strong basic understanding in students to solve scientific problems. However, misunderstandings and misconceptions on basic concepts can hinder students in understanding more complex material. This study aims to identify students' lack of understanding and misconceptions about the human respiratory system in grade V students from five elementary schools in Banyumas Regency and two elementary schools in Cilacap Regency. The research method was descriptive quantitative with total sampling technique, involving 113 students (55 male and 58 female) from seven elementary schools. The instrument used was a two-tier diagnostic test consisting of 5 true-false questions, followed by a confirmation question regarding the students' level of confidence in the chosen answer. The results showed that many students did not understand the concepts in the human respiratory system well, especially in basic concepts such as the function of human respiratory organs and the gas exchange process between oxygen and carbon dioxide. Although misconceptions were found in relatively low numbers, general incomprehension was still quite high. Factors that influence these misconceptions and misunderstandings include inadequate reasoning, suboptimal cognitive development and low interest in science materials. In addition, there are differences in understanding tendencies between male and female students, where males are more prominent in technical aspects, while females tend to be better at verbal aspects. The study concludes that a more visual and exploratory teaching approach is needed to improve students' understanding of basic science concepts more thoroughly.

Article History:

Keywords:
misunderstanding, misconceptions, human respiratory system, two-tier diagnostic test, gender, elementary school

1. Introduction

Science at the primary school level aims to build students' basic understanding of important scientific concepts, including the human respiratory system. These concepts include vital processes such as gas exchange, the function of respiratory organs, and the mechanism of action of organs in the human body. A good understanding of these concepts is an important foundation for students to master more complex material at the next level of education and increase awareness about the importance of maintaining respiratory health. According to Widyastuti (in Dewi & Ibrahim, 2019), concept understanding is the ability of students to master a certain material or concept, which is reflected in the cognitive aspect. With a good understanding, students are able to recognize, explain, describe, compare, contrast, classify, give examples, draw conclusions, and restate the concept using their own language, while understanding the learning process they go through. Concept understanding, as explained by Dewi

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(in Dewi & Ibrahim, 2019), is a person's ability to accept and interpret generalized mental images of various similar phenomena based on the knowledge that has been obtained. Lack of understanding and the emergence of misconceptions in science learning are important issues that can hinder students in understanding scientific concepts correctly.

Students often apply causal reasoning incorrectly, often based on unscientific understandings, which highlights the need for teaching approaches that emphasize causal mental models (Badenhorst et al., 2021). According to Suparno in Fatimah et al., (2020), erroneous or incomplete reasoning can result from faulty logic in drawing conclusions, while less thorough observations can also lead to inappropriate conclusions. Incomprehension occurs when students are unable to explain or understand basic concepts, while misconceptions indicate an incorrect understanding but are believed to be correct. Both of these can hinder students' ability to solve scientific problems and relate new knowledge. One of the biggest challenges in learning the human respiratory system is the high level of student misconceptions and misunderstandings caused by a lack of understanding of concrete and abstract terms and concepts. This is exacerbated by the limitations of learning media that can visualize the material concretely (Utamy & Rosdiana, 2023). Guerra-Reyes et al., (2024) explained that the identification of student misconceptions is the first step to encourage conceptual, procedural, and attitudinal changes in science learning. This research also emphasizes that misconceptions do not only come from students but also from teaching models that tend to be traditional.

Research conducted by Myanda and Riezky (2020) revealed that the use of monotonous learning methods can make it difficult for students to understand abstract concepts. In addition, the factor of differences in science abilities in the classroom also needs to be considered, including gender aspects. Rahman in Patricia & Zamzam (2019) explains that due to societal conventions, traditions and values, gender creates differences between men and women in terms of duties, functions, traits, positions, relationships and rights. This difference is a reality that cannot be ignored. As future educators, it is important to understand these differences in order to create effective learning for all students. Gender plays an important role in the learning process, especially in influencing how students process information. Ali (2019) added that female students tend to be comfortable in structured learning environments, while male students are more accustomed to unstructured environments, which also affects their learning styles.

Research conducted by Utamy & Rosdiana (2023) Based on a preliminary study conducted through interviews with science teachers in a junior high school in Driyorejo sub-district, children often experience misconceptions on the topic of the respiratory system. These myths usually lead to confusion between organs with similar names, such as pharynx and larynx. In addition, because foreign language phrases are difficult to understand and often lead to misconceptions, students take longer to understand the subtopic of respiratory system problems. Previous research has mostly focused on the secondary education level, while research on misconceptions at the elementary school level is still very limited. The importance of identifying students' misconceptions early on lies in the effort to replace erroneous understanding with correct scientific concepts. To determine students' conceptual understanding of respiratory system material, appropriate evaluation instruments are needed. The use of diagnostic tools such as two-tier diagnostic tests is recommended as they can help improve learning effectiveness. Rea-ramirez & Clement (1997) claims that students' conceptual maps can be analyzed to aid learning design because the conceptual framework for understanding the respiratory system contains naive and alternative ideas related to the target concept. In addition, teaching methods that utilize cognitive conflict have been shown to encourage students to realize errors in their understanding, thus supporting a deeper conceptual learning process (Vosniadou, 2020).

This study aims to analyze students' misunderstanding and misconceptions related to human respiratory system material. The results of this study are expected to be the basis for designing more interactive and effective learning strategies in overcoming these obstacles. A student-centered learning approach, by encouraging discussion of ideas in class and exposing students to discrepancies in their conceptions, is considered more effective in helping students overcome misconceptions (Silva & Almeida, 2017). In addition, this research is also expected to contribute to the development of curriculum and visual-based learning media that can improve students' understanding comprehensively.

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2. Method

This study employed a quantitative descriptive research method. The research subjects comprised 113 fifth-grade students from seven elementary schools, consisting of 55 male and 58 female students. These students were drawn from five elementary schools in Banyumas Regency and two in Cilacap Regency. Total sampling was used to select the study participants. The research instrument was a two-tier diagnostic test, comprising five true-or-false questions followed by a confirmation question to assess the level of student confidence in their selected answers. The question items in the two-tier diagnostic test instrument can be seen in Table 1 below:

Table 1. Items in the Two-Tier Diagnostic Instrument

No	Indikator Pertanyaan	Kebenaran Jawaban		Tingkat Keyakinan		
		Benar	Salah	Yakin	Tidak Yakin	Tidak Tahu
1	Fungsi utama paru-paru dalam sistem pernapasan adalah melakukan pertukaran antara oksigen (O2) dan karbon dioksida (CO2).					
2	Darah yang telah mengandung oksigen setelah melewati paru-paru akan langsung kembali ke jantung.					
3	Pertukaran antara oksigen dan karbon dioksida terjadi di alveolus yang ada di paru-paru.					
4	Diafragma adalah otot yang berfungsi membantu menggerakkan udara masuk dan keluar dari paru-paru.					
5	Tujuan bernafas adalah untuk menyediakan oksigen dan mengeluarkan karbon dioksida ke udara.					

Using SPSS, the test instruments were subjected to validity and reliability checks. Validity was determined using Pearson's Product Moment analysis with a sample size of N = 113 and a significance level of 0.05. The results showed that the values of variables 1 (0.602), 2 (0.529), 3 (0.559), 4 (0.547), and 5 (0.472) were all above the rtable value of 0.190 so that the instruments concerned were valid. The reliability test uses Cronbach's Alpha analysis which results in a value of $\alpha > 0.419$ which indicates that the variable concerned is quite reliable. The criteria for evaluating both levels are shown in Table 2.

Table 2. Two-Tier Test Scoring Criteria

Student Answer		**Score**	**Comprehension Level Category**
First Tier	**Second Tier**		
True	Convinced	2	Understand the Concept
False	Convinced	1	Misconception
True	Not Sure	0	Not Understood
False	Not Sure	0	Not Understood

(Adaptation of Safitri et al., 2021)

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Table 3. Calculation Results of the Validity Test of the Test Instrument

Correlations							
		x.1	x.2	x.3	x.4	x.5	VAR00001
x.1	Pearson Correlation	1	.239*	.155	.244**	.066	.602**
	Sig. (2-tailed)		.011	.101	.009	.487	.000
	N	113	113	113	113	113	113
x.2	Pearson Correlation	.239*	1	.183	.142	-.120	.529**
	Sig. (2-tailed)	.011		.052	.134	.205	.000
	N	113	113	113	113	113	113
x.3	Pearson Correlation	.155	.183	1	.020	.224*	.559**
	Sig. (2-tailed)	.101	.052		.837	.017	.000
	N	113	113	113	113	113	113
x.4	Pearson Correlation	.244**	.142	.020	1	.113	.547**
	Sig. (2-tailed)	.009	.134	.837		.235	.000
	N	113	113	113	113	113	113
x.5	Pearson Correlation	.066	-.120	.224*	.113	1	.472**
	Sig. (2-tailed)	.487	.205	.017	.235		.000
	N	113	113	113	113	113	113
VAR00001	Pearson Correlation	.602**	.529**	.559**	.547**	.472**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	113	113	113	113	113	113

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 4. Test Instrument Reliability Calculation Results

Reliability Statistics	
Cronbach's Alpha	N of Items
.419	5

Table 5. Question Reliability Criteria

Correlation Coefficient (CC)	Criteria
$0.80 < CC \leq 1.00$	Very High Reliability
$0.60 < CC \leq 0.80$	High Reliability
$0.40 < CC \leq 0.60$	Moderate Reliability
$0.20 < CC \leq 0.40$	Low Reliability
$CC \leq 0.20$	Very Low Reliability

Quantitative data gathered from students' responses to the two-tier diagnostic test instrument was analyzed. The purpose of this analysis was to identify students' misunderstandings and misconceptions regarding the human respiratory system. Based on the evaluation of their diagnostic test responses, students were categorized as either understanding the concept, not understanding the concept, or having misconceptions. The categories for the two-tier test are presented alongside the corresponding response types below.

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Table 6. Two-Tier Test Answer Response Type

First Tier	Second Tier	Category
True	Convinced	Understand the Concept
False	Convinced	Misconception
True	Not Sure	Not Understood
False	Not Sure	Not Understood

Furthermore, the level of concept understanding, concept incomprehension, and misconceptions of students were analyzed using the following percentage calculation formula (Kusuma et al., in Karengga, 2023):

$$Pi = \frac{fi}{N} \times 100\%$$

Description:
Pi : Percentage of the number of students in category i
fi : The number of students who have category i answer patterns
N : Total number of students who took the test

Then, researchers can determine the category of the level of misconceptions experienced by grade V students on the material of the human respiratory system. The grouping of student misconception levels is presented in table 7.

Table 7. Category of Student Misconception Level

No	Percentage	Category of Misconception Level
1	0% ≤ score ≤ 30%	Low
2	30% < score ≤ 60%	Medium
3	60% < score ≤ 100%	High

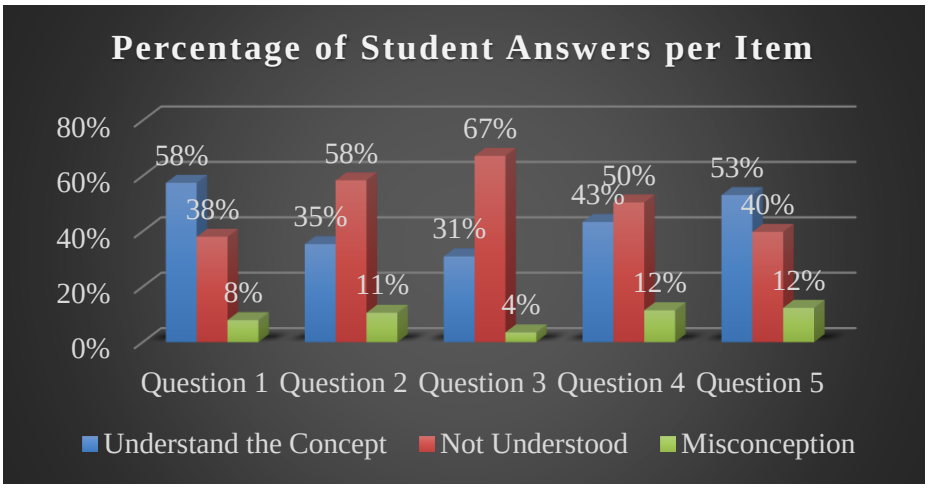
From the classification of misconception levels above, it can be seen that students are divided into three misconception categories, namely high, medium and low. This suggests that teaching procedures need to be more focused on students' understanding of the concept of the respiratory system.

3. Results and Discussion

3.1 Results

Based on the results of data analysis from the two-tier diagnostic test instrument consisting of 5 questions, which has been given to five elementary schools in Banyumas Regency and two elementary schools in Cilacap Regency, students' concept understanding can be seen as shown in Figure 1.

Figure 1. Graph of Percentage of Students' Comprehension Level on Each Question Item



Based on the data on the percentage of not understanding the concept on the concept of the human respiratory system, the question with the highest percentage of not understanding the concept is question number 3, which reads “the exchange between oxygen and carbon dioxide occurs in the alveolus in the

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lungs". In this question, 67% of students did not understand the concept of the gas exchange process that occurs in the alveolus. This shows that most students still have difficulties in understanding the role of the alveolus in respiration. In contrast, the question with the lowest percentage of not understanding the concept was question number 1, which reads "the main function of the lungs in the respiratory system is to exchange between oxygen (O2) and carbon dioxide (CO2)." In this question, 38% of students did not understand the concept. Although this is the lowest percentage, there are still a number of students who do not fully understand the main function of the lungs in the respiratory system. Overall, question 3 requires more attention to improve students' understanding of gas exchange in the alveolus, while question 1 shows that the majority of students already understand the function of the lungs, but there are still some who need to be given concept reinforcement.

Based on the data on the percentage of misconceptions on the concept of the human respiratory system, the question with the highest percentage of misconceptions is question number 5 "the purpose of breathing is to provide oxygen and release carbon dioxide into the air." In this question, the level of misconception reached 12%. In this question, the misconception rate reached 12%. This shows that quite a lot of students have a wrong understanding of the main purpose of breathing as a respiration process. In contrast, the question with the lowest percentage of misconceptions was question number 3, which reads "the exchange between oxygen and carbon dioxide occurs in the alveolus in the lungs." The misconception rate on this question was only 4%, which was the lowest among the other questions. Despite the low misconception rate, the majority of students still have difficulty in understanding this concept, especially in the category of not understanding the concept. Thus, question 5 requires more attention to improve students' understanding of the purpose of breathing, while question 5 shows that there are relatively few misconceptions about gas exchange in the alveolus, but students' overall understanding still needs to be improved. The results of this study differ from the results of research conducted by Karengga (2023) which showed that students experienced high difficulties, namely as many as 6 students did not understand the concept of diaphragm. Students who misunderstand how human lungs work tend to experience errors in answering the next question. This can be seen from students who consistently choose the same answers related to the inspiratory and expiratory breathing processes in the chest and abdominal breathing types. Students who are incomplete or misunderstand the definition of the types and processes of breathing tend to have difficulty in analyzing the flow of these types of human breathing.

TP > P > M and TP > M: The number of students classified as not understanding the concept (TP) exceeds both those who have misconceptions (M) and those who understand the concept (P). Additionally, the number of students who understand the concept (P) is higher than those with misconceptions (M). However, the majority of students still fall into the category of not understanding the concept (TP), as demonstrated by question number 3, where 67% of students failed to grasp the concept. This is followed by students with misconceptions, reaching a maximum of 12% on question number 5. Meanwhile, the proportion of students who fully understood the concept remains relatively low, though in certain questions, such as question number 1, the percentage of students who understood the concept was fairly high at 58%.

The result of this study is to determine the relationship between the level of not understanding the concept and misconceptions of students based on the gender of public elementary schools in Banyumas Regency and Cilacap Regency. The data on the results of the analysis of not understanding the concept of male and female students on each item can be seen in Figure 2 below:

Figure 2. Comparative Percentage of Male and Female Students' Incomprehension of Concepts Based

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on Each Question Item

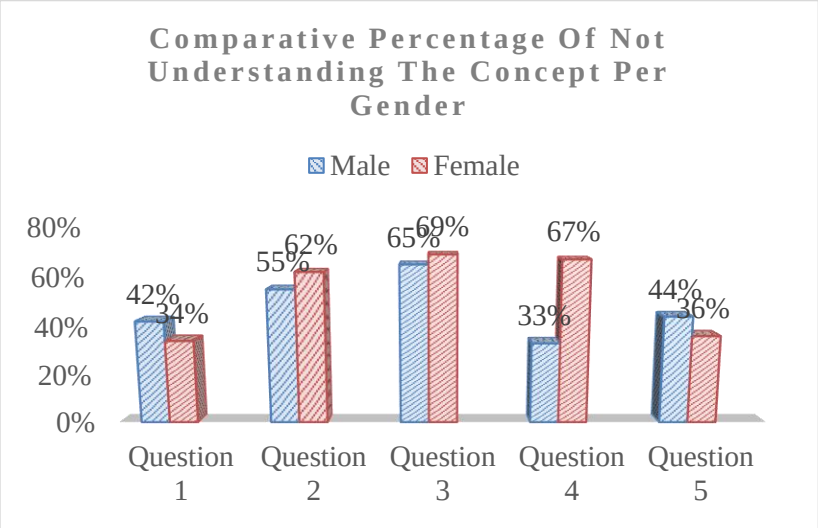
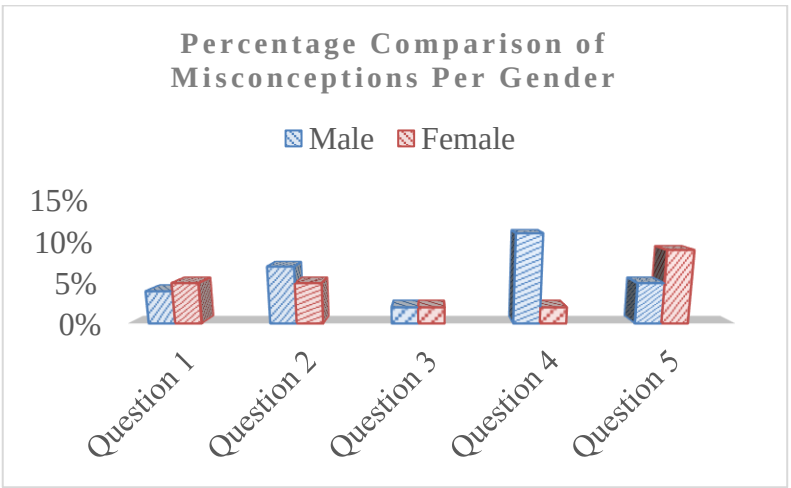


Figure 2 shows that the highest average percentage of male students did not understand the concept was in question number 3 with a percentage of 65% (high criteria) and the lowest average percentage did not understand the concept, namely in question number 4 with a percentage of 33% (medium criteria). Meanwhile, the highest average percentage of female students did not understand the concept was in question number 3 with a percentage of 69% (high criteria) and the lowest average percentage of not understanding the concept was in question number 1 with a percentage of 34% (medium criteria). Which means that most of the number of male and female students do not understand the concept in question number 3. This shows that question number 3 is a difficult question for male students and female students.

Data from the analysis of male and female students' misconceptions based on misconception categories are presented in Figure 3 as follows:

Figure 3. Percentage Comparison of Male and Female Students' Misconceptions Based on Each Question Item



Based on the data in Figure 3, male students have the highest average misconception of 11% with low criteria and female students have the highest average percentage of misconceptions of 9% with low criteria. Suparno (in Utami et al., 2017), explains that "misconception is a concept that does not align with scientific understanding or the concepts recognized by experts." Misconceptions among students can impede the learning process in schools. Students with misconceptions may not always be aware of them, as they often believe that their understanding is correct. Student misconceptions can also cause

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students' understanding of a concept to be inconsistent. Misconceptions about learning will hinder students' learning process. Therefore, training is needed to identify and analyze the misconceptions that students encounter, and two-tier diagnostic tests are the most common.

In this study, the results of data analysis based on gender showed that the average percentage of male students did not understand the concept of 48% (medium criteria) and the average percentage of female students did not understand the concept of 54% (medium criteria). Meanwhile, the average percentage of male students' misconceptions was 6% (low criteria) and the average percentage of female students' misconceptions was 4% (low criteria). This is further supported by the fact that the average percentage of concept understanding among female students (42%) was lower than that of male students (47%). Therefore, it can be concluded that in this study, female students had a lower level of concept understanding compared to male students, while the rate of misconceptions among male students was 2% higher than that of female students.

Hightower (in Utami et al., 2017) mentioned that many studies on gender differences in math and science have been conducted from 1980 to 2001, which showed the dominance of women in math and science. However, it was found that gender differences had no impact on learning success. The article does not provide a clear picture of whether girls or boys are better at learning math, and the facts show that many people are successful in their careers.

3.2 Discussion

This study aims to analyze students' misunderstanding and misconceptions related to the concept of the human respiratory system, especially at the primary school level, and to see how they compare by gender. The main findings showed that most students were still in the category of "not understanding the concept," with the highest percentage in question number 3 relating to the process of gas exchange in the alveolus. This highlights students' difficulties in understanding biological concepts that involve abstract processes and complex scientific terms. In addition, students' level of misconceptions tended to be lower compared to concept misunderstanding, with the highest misconception found in question number 5 regarding the main purpose of breathing.

High conceptual misconceptions, especially on the concept of gas exchange in the alveolus, indicate that this material requires a more interactive and visual teaching approach to make it easier for students to understand the abstract mechanisms that occur in the human body. This result is consistent with the opinion of Utamy & Rosdiana (2023), who emphasize the need for visual-based learning media to help students understand abstract concepts in the respiratory system.

The majority of elementary schools have implemented a curriculum that balances academic performance with character development (Fitriati et al., 2021). The application of learning technologies such as augmented reality (AR) can be a strategic solution to overcome students' conceptual incomprehension and misconceptions. Garzón et al., (2021) stated that AR allows students to visualize difficult scientific concepts through interactive experiences, thus reducing misconceptions by presenting scientifically accurate representations. In addition, Ibáñez & Delgado-Kloos (2018) showed that AR can help students compare their initial understanding with scientific representations, thus promoting conceptual correction effectively. AR can enhance students' ability to understand complex concepts through two- and three-dimensional spatial simulations.

This technology allows students to see and interact with three-dimensional models of human respiratory organs, such as lungs and alveolus, which can be visualized dynamically. Through AR, students can directly observe the process of gas exchange in the alveolus, the function of respiratory organs, and possible disorders, so that they not only memorize, but also understand these concepts in depth. In addition, AR can support the development of students' positive characters, such as curiosity, perseverance, and critical thinking skills, which are in line with the curriculum objectives.

The use of AR in science learning has great potential to bridge the gap between abstract concepts and students' real-life experiences. In addition to providing an interactive and engaging learning experience, this technology can also be used to support cognitive conflict-based learning. In this case, students are invited to compare their initial conceptions with the scientific reality visualized through AR, such as a simulation of the respiration process, so that misconceptions can be reduced, and students' conceptual understanding can be strengthened.

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Thus, the integration of technology such as augmented reality in science learning is not only relevant in improving learning effectiveness but also supports curriculum development that balances cognitive aspects and student character. Further research is needed to develop and test the implementation of AR in different learning scenarios, including evaluation of its impact on students with different learning styles based on gender.

4. Conclusion

The two-tier diagnostic test instrument has been shown to effectively map students' levels of concept understanding, categorizing them into understanding the concept, not understanding the concept, and misconceptions. Analysis of students' responses in this study revealed that many students still struggle to grasp the concept and exhibit misconceptions about the human respiratory system, despite having been taught the material. These findings highlight the need for educators and the education system to focus on improving the quality of learning.

This research advances the understanding of the distribution of students' incomprehension and misconceptions in basic biology materials at the primary school level, while offering a two-level diagnostic instrument as an evaluation tool to detect students' level of understanding. The results emphasize that a more interactive, visual-based, and student-tailored learning approach can improve teaching effectiveness.

However, this study has limitations because it was only conducted in seven elementary schools and covered one science material. Further studies on other materials are needed to broaden the insights related to students' misconceptions. Teachers also need to identify students' preconceptions and difficulties before teaching human respiratory system material. In addition, the application of appropriate learning methods, selective use of media and learning resources, and integration of technology such as augmented reality (AR) can help visualize abstract concepts, reduce misconceptions, and significantly improve student understanding.

This research opens up opportunities to develop more comprehensive learning strategies and support an educational process that focuses on student needs. Future studies are recommended to explore the application of modern technology in science learning to provide a more interactive and immersive learning experience, and address the challenges students face in understanding scientific concepts.

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