



Four-Tier Diagnostic Test to Assess Student Misconceptions About the Human Circulatory System

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Abstract

Misconceptions persist and hinder the achievement of learning goals. The purpose of this study is to identify and explain issues that arise when students attempt to comprehend the circulatory system concept. A multiple-choice questionnaire based on the Four-Tier Diagnostic Test question model that has been validated serves as the instrument. Students have the validity tested by distributing it and using the R-Table is greater than the R-Count. Three experts delivered an average value of 0.73, which was then used in Aiken's Test. The study reveals that the majority of students (36.2%) have a low level of understanding of the human circulatory system. This is due to students' tendency to memorize scientific terms and difficulty understanding the system. The percentage of students in the FP and FN categories is relatively low, with 14.9% and 10.2% respectively. This suggests that students' understanding of the concept is similar to the percentage of M (27.6%). SK, which comprises 11.1% of overall student responses, is the lowest compared to LK, M, and collaboration of FP and FN categories. This low SK percentage can be attributed to limited hands-on activities, inadequate teaching methods, and insufficient emphasis on the circulatory system's importance in overall health.

Keywords: Four-Tier Diagnostic Test; Human Circulatory System; Misconception

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INTRODUCTION

The circulatory system is one of the science topics taught to high school students that discusses the systems and functions of circulatory organs and diseases. It is crucial because, as students obtain an understanding of how their bodies function, knowledge of the circulatory system will enable them to take a more proactive and conscious response to their health. Making wise lifestyle choices can help prevent high blood pressure and heart disease, which are sometimes referred to as the "silent killer." Related to one in four cases, hypertension ranks as Indonesia's fifth most common cause of death rates (Maryana et al., 2021). Unfortunately, it is one of the topics that students find difficult to learn because it involves complex biological processes and understanding abstract concepts about what happens in the circulatory system (Nurfithriah, 2023).

By the issue, it is frequently discovered that students experience misconceptions in learning the topic. This was found in research that more than half of the students being observed have misconceptions because of several unknown terminologies (Khairaty et al., 2018a; M. Rohmah et al., 2023). Misconception is a false perception or understanding of science or ideas that should be and have been tested and validated by the expert (Suprpto, 2020). The student's

understanding of the subsequent concept will be impacted by misconceptions that occur in one concept. For example, it is impossible to prevent the potential of illness when an individual cannot understand how his body works. This problem must be resolved immediately due to the difficulties of being changed (Zhao et al., 2023).

One method for assessing and comprehending students' misconceptions of science is the diagnostic test. The diagnostic test is designed as a tool to identify students' strengths and weaknesses during the learning process. This information will then be taken into account while determining the appropriate course of action for the students. This diagnostic exam has been designed to precisely assess students' learning strengths and shortcomings. It is widely used in educational, medical, and psychology circles. The purpose of this test is to determine the subjects that students find most and least difficult to study and the caution of a learning difficulty (Esomonu & Eleje, 2020).

Research on assessing misconceptions through diagnostic tests about the circulatory system has been conducted and developed for several age groups, as research on other subjects. This innovation is meant to make up for shortcomings in prior diagnostic tools. Research using open-ended questions and interviews shows inefficiencies due to teachers' teaching methods, the inability to detect true misconceptions, and the time it takes to implement (Izza et al., 2021). To reduce the inefficiency of time use, diagnostic tests utilize the use of multiple-choice questions and several-tier diagnostic tests. In general, tiered diagnostic tests are related to the use of reasoning in answering questions. It is widely used to assess scientific knowledge in students' understanding. For example, a two-tier diagnostic test found that students had misconceptions about all tests that were tested with the highest category on the function of blood cells (Vitharana, 2021). Another finding was that a three-tier diagnostic test was developed from a two-tier diagnostic test by adding a confidence level to help researchers understand students' understanding of concepts, guessing, not understanding, and misconceptions (S. I. Wahyuni, 2022). By the three-tier diagnostic test, it was found that students' answers were dominated by the misconception category (Maulana et al., 2023). Unfortunately, the use of a three-tier diagnostic test was ambiguous due to the use of an overarching confidence level, necessitating the development of a four-tier diagnostic test.

The four-tier diagnostic test is a development of the three-tier diagnostic test by adding confidence levels to each answer and reason. It is structured by four tiers with the first tier being the cognitive level or scientific knowledge multiple choice questions and followed by the second tier as the confidence rating level. With each level of confidence in the tier, there is an increase in the ease of detection and accuracy of student understanding mapping (Syarafina & Zainul Mustofa, 2020). It is also utilized to show misunderstandings in depth by preventing students from guessing (Soeharto et al., 2019). Another consideration of using the four-tier diagnostic test is the advantages such as distinguishing between a lack of concept (lack of knowledge) which has a low error value and being able to differentiate students' confidence between answering questions and reasoning so that researchers can diagnose more deeply which parts require more attention in planning further learning (Nasyidiah et al., 2020). With the need for accuracy and time effectiveness in diagnosing misconceptions in students, a four-tier diagnostic test was used in this study to assess students' understanding which was then specified in the misconceptions that occurred.

METHOD

This quantitative study employed a cross-sectional survey design that was used to explore factors using observation and data collection methods. Quantitative research is characterized by being more organized, methodical, and transparent from start to finish, and it is also more resistant to field circumstances (Ahlyar et al., 2020). In education, a survey design is a test administered without any particular handling of the sample, data manipulation, or research settings. It can just identify patterns in the data rather than provide thorough

explanations or cause-and-effect linkages (Creswell, 2012). The instruments of the research were developed through three stages which are the preparation stage, the implementation stage, and the completion stage.

Preparation Stage

This is the stage to make the instruments used in the research. It starts with topic analysis through curriculum analysis and literature review to make the preliminary study. It used 14 open-ended questions to gather students' ideas and avoid inappropriate answers, ensuring they understood the content. Then the answers were generalized and developed into 28 multiple-choice questions in the form of the four-tier diagnostic test, a modified version of the three-tier diagnostic test, which consists of two parts: questions that measure cognitive understanding and reasons for answering. The four-tier diagnostic test comprises cognitive level questions, followed by confidence rating level questions, assessing scientific knowledge, and multiple-choice questions. To make the researcher sure that the misconception can be detected, the third tier is the reason behind answering the first tier, and ended by the fourth tier is the confidence rating level of the third tier. It effectively differentiates between low-error concept lack and students' confidence, enabling researchers to identify areas requiring more attention for further learning planning (Nasyidiah et al., 2020). Additionally, the teachers can accurately group concepts and focus on lacking, reducing misconceptions, and enhancing learning outcomes (Nurlita, 2022).

Table 1. Expert Validation in Aiken's Test Result

Item	V	Validity	Item	V	Validity
Q1	1.00	High	Q15	1.00	High
Q2	1.00	High	Q16	0.67	Moderate
Q3	1.00	High	Q17	0.33	Low
Q4	1.00	High	Q18	0.67	Moderate
Q5	0.67	Moderate	Q19	1.00	High
Q6	1.00	High	Q20	1.00	High
Q7	0.33	Low	Q21	0.33	Low
Q8	0.33	Low	Q22	0.67	Moderate
Q9	0.67	Moderate	Q23	0.67	Moderate
Q10	0.67	Moderate	Q24	0.67	Moderate
Q11	0.67	Moderate	Q25	0.33	Low
Q12	0.67	Moderate	Q26	1.00	High
Q13	1.00	High	Q27	0.67	Moderate
Q14	1.00	High	Q28	0.33	Low
Average: 0.73 (Moderate)					

Before being used in real research, the instrument was validated. It is used to accuratize the instrument so it can be used properly and have better functions and results (Sanaky, 2021). The validity of the questions was assessed through a correlation test to ensure their suitability. The validation was done involving three experts. The questions were assessed based on language and grammar structure, feasibility of use with students, and cognitive level. The question is scored 1 if experts deem it appropriate, and 0 if not. Then, the results as shown in Table 1 are analyzed by Aiken's test with the Formula 1.

$$V = \frac{\sum s}{n(C-1)} \quad (1)$$

With the description;

- V is the agreement index from the experts' rate
- $\sum s$ is the average of the score gained from the rater minus the lowest score can be chosen ($s = r - lo$)
- n is the total or number of experts
- C is the number of categories that are chosen

Table 2. Student Validation Test Result

Item	Tier	Pearson Correlation	Interpretation	Item	Tier	Pearson Correlation	Interpretation
1	1	0.628	Valid	15	1	0.525	Valid
	3	0.246	Valid		3	0.748	Valid
2	1	0.288	Valid	16	1	0.452	Valid
	3	0.471	Valid		3	0.535	Valid
3	1	0.421	Valid	17	1	0.559	Valid
	3	0.413	Valid		3	0.442	Valid
4	1	0.535	Valid	18	1	0.528	Valid
	3	0.681	Valid		3	0.375	Valid
5	1	0.332	Valid	19	1	0.593	Valid
	3	0.543	Valid		3	0.586	Valid
6	1	0.343	Valid	20	1	0.355	Valid
	3	0.399	Valid		3	0.605	Valid
7	1	0.438	Valid	21	1	0.46	Valid
	3	0.282	Valid		3	-0.248	Not Valid
8	1	0.226	Valid	22	1	-0.099	Not Valid
	3	0.423	Valid		3	0.433	Valid
9	1	0.336	Valid	23	1	0.017	Not Valid
	3	0.509	Valid		3	0.663	Valid
10	1	0.541	Valid	24	1	0.607	Valid
	3	0.251	Valid		3	0.672	Valid
11	1	0.275	Valid	25	1	0.421	Valid
	3	0.573	Valid		3	-0.174	Not Valid
12	1	0.501	Valid	26	1	0.477	Valid
	3	0.352	Valid		3	0.496	Valid
13	1	0.429	Valid	27	1	0.452	Valid
	3	0.387	Valid		3	0.609	Valid
14	1	0.703	Valid	28	1	0.448	Valid
	3	0.687	Valid		3	0.538	

The result will categorized as less or low valid if the value is $0 \leq 0.4$, medium or moderate if the value is $0.4 < V \leq 0.8$, and high or very valid if the value is $0.8 < V \leq 1$ (Fajriyanti & Sayekti, 2022). The average result of Aiken's Test was 0.73 in the moderate category. It indicates that it can be used as a valid measuring tool (Slamet & Wahyuningsih, 2022). The questions were revised to enhance their validity based on expert feedback and then distributed as the student validation test. The questions were revised, approved by the supervisor, and tested on 83 students. The questions were validated with the formula $r_{\text{count}} > r_{\text{table}}$, with the value of the r_{table} being 0.213. The results are shown in Table 2.

Through the validity test given to the students, it was seen that 24 out of 28 questions given were valid between level 1 and level 3. However, due to the low validity, the questions of 21, 22, 23, and 25 were considered to be removed due to concerns about its potential impact on the accuracy of the future test. The order of questions then changes, with valid questions below invalid questions shifting to the top. Crucially, the reliability test was carried out to see how consistently the test to be used. High test reliability is evident through consistent results

from multiple tests, indicating the degree of variability in measurement errors. The results of the reliability test are shown in Table 3.

Table 3. Reliability Test on Valid Questions Result

Tier	N of Item	Cronbach's Alpha
1	24	0.882
3	24	0.897

The reliability test is conducted only for valid questions, ensuring consistency and stability. This is by the consistency of the questions that have question validity criteria, where if the questions are not valid, then the consistency of the questions is considered to be reduced. Instruments in these two tiers are said to have very high correlation coefficient values because they are in the range of $0.80 < r \leq 1.00$ (Riyani et al., 2017). This instrument is highly consistent, making it suitable for real research to implement or diagnose misconceptions about the human circulatory system.

Implementation Stage

This research sample focused on junior high school students who had studied the circulatory system. Apart from that, the sample targeted in this research were students who studied science with the latest curriculum, namely the *Kurikulum Merdeka*. 233 samples with an eighth-grade background used to represent the population were collected from several junior high schools in Bandung Regency, West Java Province. The large sample sizes are employed to ensure a more diverse representation of information. The researcher utilized convenience sampling to select the sample. Convenience sampling is a sample-selected technique regarding the willingness and availability of samples to take part in the research (Wang & Cheng, 2020). This method is particularly appealing if time and resources are limited, or when it aims to gather initial insights quickly without complex sampling strategies (Golzar & Noor, 2022).

Completion Stage

To complete the data, a descriptive statistical test was used to describe the data. The data were analyzed by scoring tier 1 up to tier 4. The data were categorized into student conceptions namely Scientific Knowledge (SK), False Positive (FP), False Negative (FN), Misconception (M), and Lack of Knowledge (LK) as seen in Table 4.

Table 4. Student Conceptions Category Based on Four-Tier Diagnostic Test Decision

Tier 1	Tier 2	Tier 3	Tier 4	Decision
True	Confident	True	Confident	SK
True	Confident	False	Confident	FP
False	Confident	True	Confident	FN
False	Confident	False	Confident	M
True/False	Confident/Not Confident	True/False	Confident/Not Confident	LK

Answers are coded “1” as the score for a correct answer, and “0” for a false answer. If the students are sure or confident with the answer, it will be scored as “1”, and if not confident will be “0”. So, the code of scientific knowledge will be (1-1-1-1); “False Positive”, the first tier will be coded as “1”, while the third tier will be coded as “0”. So, the code of false positive will be (1-1-0-1); “False Negative”, the first-tier will be coded as “0”, while the third-tier will be coded as “1”. So, the code of false positive will be (0-1-1-1); “Misconception”, is the false answer of first and third-tier. So, the code will be (1-0-1-0); “Lack of Knowledge”, the sequence of the code is based on the answer. The true answer will be coded as “1” and the false is “0”. Then the data were briefly explained through graph figures and tables that can be seen in the results and discussion session.

RESULTS AND DISCUSSION

Understanding the concept is the cornerstone of learning science with purpose. Students who receive meaningful learning are better equipped to explain and apply a concept. Learning science also goes beyond mere memorization and concept knowledge; it involves comprehending a concept's relationship to other concepts (Safitri et al., 2021). Understanding science concepts also influences students' ability to solve problems in science learning (Ulfa et al., 2023). In this research, the student's conception of the human circulatory system is assessed through the four-tier diagnostic test.

The questions were developed based on *Kurikulum Merdeka*, and the topic was divided into two subtopics which structure and function of the human circulatory organ (Subtopic 1) with the concept of heart, blood vessels, and blood. Another subtopic (Subtopic 2) with the concept of atherosclerosis and heart attack, stroke, hypertension, and how to maintain a healthy circulatory system. Initially, section 1 profiles student conceptions of the human circulatory system, categorized into Scientific Knowledge, False Positive, False Negative, Misconception, and Lack of Knowledge. Section 2 is specified to discuss the highest percentage of misconceptions. This analysis helps teachers understand students' understanding and improve learning processes.

Profile of Student Conceptions About the Human Circulatory System

Understanding concepts is important in learning. By understanding the right concepts, students can get maximum learning results. Understanding concepts can form one's knowledge from several existing concepts (Karyanto, 2022). By implementing the test, it was found that student conceptions occurred in every concept. The overall percentage of student conceptions of the human circulatory system from all data is summarized in Figure 1.

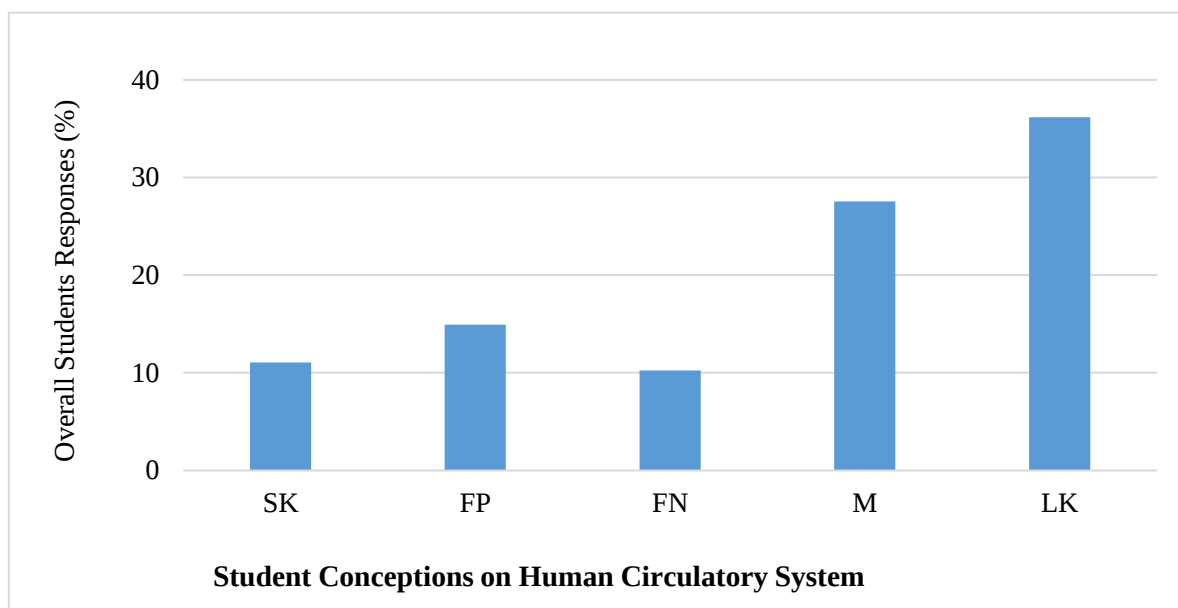


Figure 1. The Overall Student Conceptions on the Human Circulatory System

Based on figure 1, assessed based on the student's level of understanding from the highest, namely SK, FN, FP, and M to the lowest, namely LK. The figure reveals that the percentage of LK dominates (36.2%) from other conceptions. The highest result of this category was consistently found in each concept and even questions referring to the condition, where students answered correctly or incorrectly but had low confidence. This affects the risk of wrong decisions and confusion in ongoing learning (Hansson et al., 2017). High LK levels also happen due to the new four-tier diagnostic test used for the students, low validity and reliability in the preliminary study, and unlearned concepts.

This issue is attributed to students' tendency to memorize scientific terms and difficulty understanding the human circulatory system (Khairaty et al., 2018). This study's findings are comparable to Khairaty (2018), who stated that grade 11 students' misconceptions and lack of knowledge are higher than scientific knowledge, influenced by teacher confirmation regarding the concepts understood by the students. Another finding by Wahyuni, et al. (2020), shows that the average of LK students (10.9%) is higher than SK (8.0%) in terms of SK percentage, and it is consistent with previous research.

The percentage of students in the FP and FN categories is relatively low, with 14.9% and 10.2% of responses respectively, indicating that understanding the concept is similar to the percentage of M (27.6%). This result revealed inversely proportional to Syarafina & Mustofa (2020) where the average percentages of partial understanding or referring to FP and FN categories dominated with 78.8% of overall student responses. False positives and negatives in science education can hinder understanding, reinforce misconceptions, and disengage students, limiting learning opportunities and preventing challenging problem-solving. So, the detailed analysis of FP and FN responses can reveal students' specific knowledge gaps or errors, enabling targeted learning (Celhay et al., 2024).

This research also shows that SK comprised 11.1% of overall student responses, the lowest compared to the LK, M, and collaboration of FP and FN categories. The study compares previous three-tier diagnostic tests by Rohmadani, et al. (2021), finding a lower percentage of SK (15.1%) is compared to other categories like LK, M, and FP/FN. Another finding by Wahyuni (2022) used the three-tier diagnostic test showed that the percentage of SK was always lower than the percentage of M in every representative concept. Students often lack an understanding of the human circulatory system, limiting their interest in science and future exploration and innovation. A strong foundation is crucial for scientific progress. The low SK percentage among students can be attributed to limited hands-on activities, inadequate teaching methods, and insufficient emphasis on the circulatory system's importance in overall health (Khan et al., 2023). To more specific delve deeper into students' understanding of specific circulatory system concepts, a student conception analysis was conducted on each concept. There are 4 concepts in subtopic 1 used to represent student conceptions described in Table 5.

Table 5. The Profile of Student Conceptions in Subtopic 1

Concept	The Level of Students' Conception (%)				
	SK	FP	FN	M	LK
Heart	11.44	16.17	12.16	26.61	35.19
Blood Vessels	11.48	19.1	10.09	26.18	33.15
Blood	11.16	21.78	4.51	25.21	37.34
Average	11.36	19.01	8.92	26	35.22

The structure and function of human circulatory organs, including the heart, blood vessels, and blood, involve various questions. The study's results about the heart are inversely proportional to a four-level diagnostic test conducted by Syarafina & Mustofa (2020) on a similar student sample which revealed that the percentage of SK and FP was higher than that of M and LK. The study's specificity in examining the impact of heart shrinkage or structural changes on function may be due to differences in test indicators compared to the previous study. This is related to students' ability to think at a high level or what is commonly known as Higher Order Thinking Skill (HOTS). HOTS is a method of deep thinking that involves critical and creative problem-solving through analysis activities to manage information, make decisions, and manage information effectively (Markhamah, 2021). Concept 2, which discusses blood vessels, shows the percentage of M is higher than SK. This is comparable to a previous study by Rohmadhani (2021) that shows that 49% of eleventh graders scored M, while

only 4.9% scored SK, possibly due to adequate learning resources and teacher rechecking information accuracy.

The concept of blood is a popular topic among students in both LK and FN. The same results by Khairaty (2018) are obtained in multiple contexts in the questions that the percentage of false negatives regarding the condition when students held the deficiency information. The high percentage of FN in students can be attributed to their habit of learning concepts without problem-solving and integration, indicating the need for mastery (Susetyadi et al., 2019). The second subtopic is about diseases related to the circulatory system. The concepts of atherosclerosis and heart attack, stroke, hypertension, and how to maintain a healthy circulatory system consist of several questions to represent the subtopic as shown in Table 6.

Table 6. The Profile of Student Conceptions in Subtopic 2

Concept	The Level of Students' Conception (%)				
	SK	FP	FN	M	LK
Atherosclerosis and Heart Attack	14.06	10.84	9.87	27.25	37.98
Stroke	10.16	14.31	12.45	29.33	33.76
Hypertension	7.73	14.88	12.59	26.90	37.91
How to Maintain a Healthy Circulatory Organ	12.59	10.16	12.02	29.04	36.19
Average	11.13	12.54	11.73	28.12	36.46

Subtopics on disease have also been discussed in several studies, although they have different context indicators with the instruments in this study. In this study, the question indicators refer to the effects or impacts on the structure of organs affected by the disease and how to maintain the organs of the circulatory system. With earlier research by Maulana et al.(2023), the consistency is found in the percentage of LK students to be greater than in other student conceptions or understanding categories. In addition, it was found that the percentage of M student responses was greater than SK, FP, and FN. Through the three-tier diagnostics on eleventh-grade students by Wahyuni (2022), it was found that M was higher according to this study, caused by lack of mastery of information, lack of student accuracy in understanding questions, and lack of student ability in using and managing information sources such as the internet (Wahyuni, 2022). A more specific description of the misconception is explained in section 2.

Student Misconceptions About the Human Circulatory System

In studying biology, students often experience the misconception that they are required to master a concept and its relationship with other concepts. Understanding basic concepts in learning can support students' understanding to be able to learn quality. Therefore, misconceptions that become obstacles to continuing the learning process must be eliminated. The way that can be done is to diagnose the understanding of students who do not/have not understood the concept as a reference for correcting the misconceptions that occur (Yuliati, 2017). This research focuses on misconceptions as a result that are often found in students' understanding of science. By using the four-tier diagnostic test, the graph is present to show the misconception in each question in Figure 2.

Based on Figure 2, students had misconceptions about each question. The percentage of misconceptions was particularly high for representative concepts such as question 1 about the heart (36.48%), question 19 about the blood vessels (38.63%), question 16 about the blood (39.84%), question 15 about atherosclerosis and heart attack (31.76%), question 21 about the stroke (42.16%), question 11 about hypertension (30.47), and question 14 about how to maintain a circulatory organ. The highest percentage of each concept would be the next discussion as it the important to understand the idea correctly especially if it would be used as

prior knowledge. Prior knowledge is essential for understanding subsequent concepts (Wahyuni, 2022). For example, when students do not understand the structure and functions of organ systems, it is difficult to know how the disease attacks organs, and it affects the decision-making in the preventive step. The highest percentage of subtopic 1 regarding the structure and function of the circulatory system was the concept blood question number 1 as can be seen in Table 7.

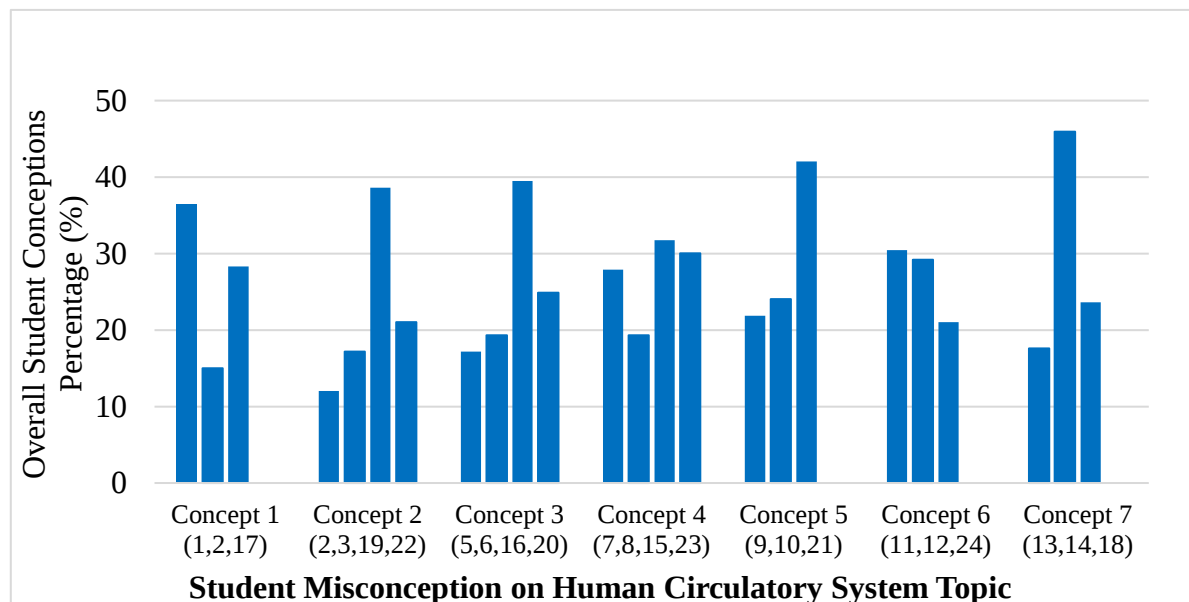


Figure 2. Student Misconceptions About the Human Circulatory System

Table 7. The Highest Percentage of Misconceptions about Heart

Tier	Actual Question 1	Misconception Results
1	What was the consequence of a leak in the valve that connects the left ventricle to the left atrium?	Right Answer (SK): B A B A
	A. The pressure in the atrium decreases	A A A A (36.5%)
	B. The heart works harder	A A C A (12.9%)
	C. Body cells do not receive oxygen	A A D A (4.7%)
	D. Heart rate decreases	C A A A (7.1%)
2	Are you sure of your answer?	C A C A (3.5%)
	A. Sure B. Not sure	C A D A (2.3%)
3	What was the scientific reason for your answer above?	D A A A (27.1%)
	A. There was no blood flow for the heart to pump	D A C A (1.2%)
	B. Blood flow throughout the body was inefficient	D A D A (4.7%)
	C. There was a decrease in the capacity to transport substances	
	D. There was no blood flow and the organs did not work	
4	Are you sure of your answer?	
	A. Sure B. Not sure	

By Table 7, it is seen that significant students thought that the pressure in the left atrium would drop as a result of a leak in the valve that connects the left ventricle and left atrium, which is also known as valve regurgitation (option A). They reasoned that the ventricle would not be filled with enough blood flow (option A). This draws attention to a false impression. The left atrium's fall in pressure is mostly the result of the ventricle's subpar operation. During ventricular contraction, blood travels backward from the ventricle to the atrium when the mitral

valve breaches. It is inlined as Laksono (2019) stated, that the flow of the blood of mitral valve leakage causes the pressure in the left atrium to increase. Meanwhile, option B which describes the effect of a leaky valve between the left ventricle and left atrium would make the heart work harder as the body's blood flow would be less effective. It also leads to the reason, that despite being tiny in scope valve leakage is crucial to its operation, for example, valve regurgitation refers to the blood traveling backward through the valves. It is important to understand because Arovah (2015) stated that inefficient treatment of blood received, may eventually cause heart failure due to several issues, including an increased burden on the heart.

Previous studies have assessed how well students comprehend the heart concepts. The result of the research was the percentage of M was higher than SK. This result was in line with what Wahyuni (2020) found in eleventh-grade students and was attributed to several factors, including terminology, the use of learning strategies, the lack of confirmation of student understanding, and possibly the fact that students thought the subject matter was challenging. However, there is no doubt that students can also have a good understanding. Through descriptive research on ninth-grade students by Nainggolan (2017), it is known that SK causes the percentage of misconceptions concerning books, instructors, and the environment with a proportion of almost 50% and M with a percentage over 20%. Question 19 as the highest misconception percentage representative concept was also found in concept 2 regarding the blood vessels as written in Table 8.

Table 8. The Highest Percentage of Misconceptions about Blood Vessels

Tier	Actual Question 19	Misconception Results
1	Which of the following was not a reason for blood vessel size and blood flow? A. Obstacles to blood flow in blood vessels B. Physical and emotional stress response C. Level of total cholesterol in the blood D. Oxygen and nutrient balance	Right Answer (SK): C A C A A A A A (30%) A A B A (21.1%) A A D A (22.2%) B A A A (4.4%)
2	Are you sure of your answer? A. Sure B. Not sure	B A B A (3.3%) B A D A (20%)
3	What was the scientific reason for your answer above? A. Blood was liquid and does not depend on the size of the blood vessels B. Oxygen adjusts the size of blood vessels C. Cholesterol does not affect the size and flow of blood vessels D. Physical and emotional stress are independent of blood vessel size	D A A A (1.1%) D A B A (11.1%) D A D A (6.7%)
4	Are you sure of your answer? A. Sure B. Not sure	

In prior studies, blood vessels have been one of the topics examined to determine pupils' degree of comprehension. 38.6% of respondents had misunderstandings about this subject, which is greater than the proportion of SK. This contradicts a prior study, which found by Syarafina (2020) that the percentage of SK is higher than the M percentage due to the possibility of using the notion of illustration in the environment rather than scientific knowledge, also known as p-prime comprehension. Misconceptions concerning the idea of blood vessels can also arise when a person lacks fundamental understanding. Previous research discovered by Wahyuningsih (2016) that five of eleven students had misconceptions regarding the anatomy and function of blood arteries because they were unsure where the structure was placed. Furthermore, research utilizing CRI discovered by Kurniasih (2017) that 20% of total

student responses still had misunderstandings about blood arteries caused by inaccuracies in visual interpretation that were common with other images.

In the concept of blood vessels, students had the highest misconception regarding the reason why blood flow affects the size of blood vessels. An alarming number of students (30%) believed that blockage of blood flow (choice A) would not affect the size of the vessel because blood is fluid and can flow through any size (reason for choice A). This demonstrates a major misperception. Although blood is fluid, a blocked blood artery produces a decrease in blood flow. Similarly, plaque-induced narrowing of blood arteries can create resistance to blood flow. Another misconception involves the role of cholesterol in the bloodstream. Total cholesterol is the sum total of cholesterol-carrying particles in the blood including good cholesterol (HDL) and bad cholesterol (LDL) (Fadillah & Murniawati, 2023). Meanwhile, healthy cholesterol is a component that cleanses the blood. Good cholesterol prevents fat or particles from aggregating in the circulation, hence high amounts can reduce the total cholesterol ratio (Erizon & Karani, 2020). As a result, high HDL levels can help minimize the overall risk of arterial blockage while also maintaining normal blood vessel size. Thus, it is possible to conclude that total cholesterol is not the cause of blood flow, which has a direct effect on blood vessel size. Another high level of misconceptions is found in blood components (concept 3) as shown in Table 9.

Table 9. The Highest Percentage of Misconceptions in White Blood Cells

Tier	Actual Question 16	Misconception Results
1	What affects the size of the nucleus in white blood cells? A. Food consumed B. Intensity of physical exercise C. Immune response to infection D. Carbon dioxide content	Right Answer (SK): C A D A A A A A (45.6%) A A B A (13.0%)
2	Are you sure of your answer? A. Sure B. Not sure	A A C A (19.3%) B A A A (1.1%)
3	What was the scientific reason for your answer above? A. Nutrients required for nucleus development B. Carbon dioxide was useful for gene transport C. Physical exercise affects hormone production D. Cell division when the nucleus responds to health stress	B A B A (2.2%) D A A A (6.5%) D A B A (9.8%) D A C A (8.7%)
4	Are you sure of your answer? A. Sure B. Not sure	

Research on the concept of blood on this topic has also become a particular concern. On this issue, the proportion of M is greater than the percentage of SK across all student replies. This is directly proportional to the CRI research by Rohmah (2024), in grade eleven, which states that the percentage of students with category M is higher than SK, owing to students' difficulties in understanding some subtopics and insufficient learning resources such as incomplete book references. CRI with a three-tier diagnostic test instrument in eleventh-grade students was also found by Dewi et al. (2017), that the percentage of students who understood the concept of blood was smaller than the percentage of M, which may be due to the environment and the teacher's limitations in understanding the concept well. The blood concept questions focus on a single component of blood, white blood cells. In question 16, many students responded that the food they consume can alter the size of the white blood cell nucleus because nutrients are required for nucleus formation (45.6%). In this situation, the food ingested offers energy and other raw materials for the structure's formation, but it cannot

directly instruct the nucleus' size change. In addition, white blood cells feature a nucleus that regulates all cell activity.

The size of the nucleus in white blood cells affects how these cells work in the body. For example, the size of the nucleus in eosinophils causes effective pathogen destruction because it has toxic granules, the nucleus in neutrophils causes them to move more effectively in the body to reach the site of infection, and the inner nuclei of basophils that allow the regulation of blood clotting by activating the blood coagulation system (Larasuci, 2018). Furthermore, in the innate immune system, granulocytes (neutrophils) play an important role in blocking and fighting infections, destroying phagocytosis, and overcoming infections that develop. In response to health stress on cells, the nucleus also plays a role in activating stress pathways by halting cell division, allowing the cell to focus on repairing or removing damaged components before continuing to divide. High misconceptions were also found in the questions about atherosclerosis and heart attack (concept 4) in question 15 as shown in Table 10.

Table 10. The Highest Percentage of Misconceptions about Atherosclerosis and Heart Attacks

Tier	Actual Question 15	Misconception Results
1	What are the side effects of slow oxygen rates from atherosclerosis?	Right Answer (SK): C A D A
	A. Decreased resistance to blood flow	A A A A (37.8%)
	B. Decreased acidity in the body	A A B A (21.6%)
	C. Decreased function of the respiratory system	A A C A (5.4%)
	D. Decreased oxygen demand by cells	B A A A (5.4%)
	Are you sure of your answer?	B A B A (19.0%)
2	A. Sure B. Not sure	B A C A (5.4%)
3	What was the scientific reason for your answer above?	D A A A (13.5%)
	A. Cell function was influenced by the elasticity of blood flow	D A B A (19.0%)
	B. Cells are affected by the clarity of acid in the body	D A C A (2.7%)
	C. Cells adjust their size to the body's needs	
	D. Cells produce energy to maintain organ function	
	Are you sure of your answer?	
4	A. Sure B. Not sure	

In question 15, the M percentage is five times higher than the SK figure. Although research on the association between atherosclerosis is still rare, previous research reveals that the findings of this study are consistent, even though misunderstandings about this notion persist. According to CRI research by Nainggolan (2017), 50.75% of class IX pupils had misunderstandings regarding circulatory organ disorders, namely the hardening of fat molecules that cause blood vessel constriction (atherosclerosis). However, data shows that pupils already understand atherosclerosis. Using a questionnaire instrument on medical students yielded comparable results to research by Vemuri et al. (2020), indicating that students lacked competence in comprehending the idea, with 61% of all student replies correctly answered.

This concept focuses on question number 15, which was found to have the most significant misperception among 37.9% of all student replies. Students believed that atherosclerosis created slow oxygen rates, which reduced blood flow resistance. This idea violates scientific understanding. Atherosclerosis can reduce blood flow to the body's organs by hardening blood vessels with plaque on the artery walls. Plaque buildup in arteries can create impediments and raise the resistance to blood flow, requiring the heart to work harder to

overcome the resistance and pump blood adequately. Atherosclerosis is a disorder in which plaque buildup narrows the arteries, which transport oxygen-rich blood throughout the body (Handayani, 2021). This constriction severely reduces blood flow, impeding the supply of oxygen and vital nutrients to organs. As a result, organs do not function efficiently owing to limited oxygen availability. Misconceptions about stroke (concept 5), were evident in several questions, but question 21 had the highest level and as shown in Table 11.

Table 11. The Highest Percentage of Misconceptions about Stroke

Tier	Actual Question 21	Misconception Results
1	Mr Ardi had a stroke which caused his body to shut down (could not be moved). Why does this happen? A. Decreased autoimmune B. Muscle function failure C. Inflammation of the nervous system D. Damage to the brain	Right Answer (SK): D A D A A A A A (6.1%) A A B A (7.1%) A A C A (5.1%) B A A A (11.2%)
2	Are you sure of your answer? A. Sure B. Not sure	B A B A (16.3%) B A C A (5.1%)
3	What was the scientific reason for your answer above? A. The damage that occurs cannot be overcome B. no blood flowing/stopping C. Brain cells regenerate D. Lack of oxygen and nutrient supply	C A A A (17.3%) C A B A (19.4%) C A C A (12.2%)
4	Are you sure of your answer? A. Sure B. Not sure	

There is little research on pupils' comprehension of stroke. The results were inversely proportional to the previous study by Hux et al. (2000), involving 190 random samples, but according to agreement, the percentage of M was not much different from the percentage of SK, with a percentage of around 30%, most likely due to terminology confusion. Another research was conducted by Vemuri, et al. (2020), to identify common misunderstandings about stroke. Using the questionnaire as a tool for medical students reveals that they already have a high percentage of SK (63.8%).

The most common misconception about stroke was discovered in question number 21, accounting for 42.6% of all student replies. While the proportion of wrong answers was fairly equal, 19.4% of all student responses contained a mistake. They thought that a stroke resulting in paralysis on one side of the body (hemiplegia) was caused by nervous system inflammation (option C), which was caused by a lack of blood supply. Stroke is a condition where the blood vessels in the brain become blocked and even cause the blood vessels to burst which can cause the brain to lack oxygen and even die (Maryana et al., 2021). A hemorrhagic stroke, on the other hand, is characterized by a brain leak that floods the cell tissue spaces in the brain, disrupting circulation and the body's ability to move sideways. This condition causes the brain to lose oxygen and nutrients that are normally carried by the blood (Setiawan et al, 2021). The error in question number 21 conflates nervous system inflammation with stroke. Although inflammation raises the risk of blood clots and damages blood vessels, it is not the primary cause of stroke. Concept 6 (hypertension) is the next idea in the sickness subtopic, as indicated in Table 12.

The most common misconception was related to question 11. According to option D, 43.7% of all student replies thought that the only sign of hypertension might be persistent stress and emotions (choice C). This draws attention to a crucial misunderstanding. The chronic illness known as hypertension, or high blood pressure, is characterized by persistently high

blood pressure that pushes against the artery walls (Cristanto et al., 2021). Stress is not the only cause that can momentarily raise blood pressure, and extended emotional states by themselves may not always be used to diagnose hypertension. Frequently, hypertension is misdiagnosed since it seldom manifests with any symptoms.

Table 12. The Highest Percentage of Misconceptions about Hypertension

Tier	Actual Question 11	Misconception Results
1	Before being diagnosed, how can someone be detected as having hypertension (high blood pressure)? A. Pain in the back of the head B. Stiffness in the neck and bones C. Swelling in the legs D. Prolonged emotions and stress Are you sure of your answer?	Right Answer (SK): A A B A B A A A (2.8%) B A C A (7.0%) B A D A (1.4%) C A A A (2.8%) C A C A (19.2%)
2	A. Sure B. Not sure What was the scientific reason for your answer above?	D A A A (8.4%) D A C A (43.7%)
3	A. Inappropriate blood flow B. Differential dilation of blood vessels C. Differential increase in blood pressure D. Increased release of controlling hormones	D A D A (29.6%)
4	Are you sure of your answer? A. Sure B. Not sure	

On the other hand, certain individuals with severe hypertension may have nosebleeds, dizziness, headaches, and shortness of breath (Telaumbanua & Rahayu, 2021). By impairing normal blood circulation, constricting blood vessels, weakening blood vessel walls, and applying pressure to the brain, high blood pressure can lead to issues in the circulatory system. Blood arteries expand in response to relatively high pressure and contract to return blood pressure to normal. Although there is currently relatively little study on student misunderstandings, studies using questionnaires on 190 samples by Vemuri (2020) indicate that students already have a solid understanding of this topic. As indicated in Table 13 misconceptions can arise about the upkeep of a healthy circulatory system (concept 7).

Table 12 (question 14) above illustrates the misconceptions that students make when attempting to describe how nicotine affects the function of the heart. According to several students, nicotine can trigger heart attacks by lowering oxygen levels to the point where oxygen is no longer able to satisfy the requirements of cells for function. This particular misperception is probably brought about by the ones that were previously shown to be associated with blood vessels, atherosclerosis, and heart attacks. Students struggled to make the connection between how blood circulates in blood arteries and this issue. Students' misperception of the mechanism behind heart attacks then reinforces this. Additionally, pupils associate the effect of nicotine on oxygen without searching up the term "heart attack" since smoking is similar to the respiratory system. The primary addictive component of cigarettes is nicotine, a stimulant that can enhance organ function by raising blood pressure and heart rate (Maryana et al., 2021).

Nicotine causes the adrenal glands to release more adrenaline or epinephrine (Nurhaeni et al., 2022). Blood pressure and heart rate both increase as a result of this hormone. Even if at first this could look like a better performance, the heart is under more stress. Constriction of blood vessels is another effect of adrenaline. This may result in less blood flowing to the heart and other essential organs. Although it doesn't directly lower oxygen, nicotine also raises heart rate and can constrict blood vessels, which can indirectly reduce oxygen delivery to the tissues. Increased pressure puts more strain on the heart, and narrowed blood arteries can make it harder

for the heart to pump blood. Research regarding nicotine in the circulatory system was not found, due to the expansion of the concept in the instruments carried out. In general, nicotine is related to the respiratory system. This is consistent with results from a two-tier exam administered by Myanda (2020) to eleventh-grade students, which indicates that pupils already comprehend the material and that just 21% of all student replies contain misunderstandings as a result of a highly comprehensive knowledge introduction.

Table 13. The Highest Percentage of Misconceptions about Maintaining a Healthy Circulatory System

Tier	Actual Question 14	Misconception Results
1	Pay attention to the warnings on the following cigarette packs! Source: www.kaskus.co.id How can inhaling cigarettes cause a heart attack? A. Nicotine reduces oxygen levels B. Nicotine precipitates carbon dioxide C. Nicotine causes tissue damage D. Nicotine increases blood pressure	Right Answer (SK): D A C A A A A A (28%) A A B A (4.7%) A A D A (5.6%) B A A A (12.2%) B A B A (6.5%) B A D A (5.6%) C A A A (10.3%) C A B A (9.4%) C A D A (17.8%)
2	Are you sure of your answer? A. Sure B. Not sure	
3	What is the scientific reason for your answer above? A. Oxygen is not able to meet the needs of cells to work B. Carbon dioxide deposits cannot bind hemoglobin C. Blood pressure increases due to the release of the hormone adrenaline D. Tissue damage occurs due to inflammation of the body	
4	Are you sure of your answer? A. Sure B. Not sure	

Learning involves interaction between students, educators, and resources to achieve desired concepts. Misconceptions can be caused by internal and external factors. In this study, an interview with a teacher was conducted to diagnose problems, particularly in subtopic two related to circulatory system diseases. To diagnose the problems found in this study coherently, an interview with the teacher was conducted regarding the student conceptions found, especially in subtopic two that related to the diseases related to the circulatory system. The interview shown below was held after the researcher analysed the data.

Interview with teacher 1 about the study results

Researcher: From the data obtained, there is a percentage of misconceptions in each question, especially in the subtopic of diseases related to the circulatory system. Did you have any difficulty in explaining the topic?

Teacher: I did not explain the subtopic, I gave students the task of summarizing and asked them to collect it.

Researcher: After the assignment was submitted, what response did you give?

Teacher: I gave grades to students who had completed the assignment.

Researcher: Did you provide reflection or feedback that aims to ensure that students understand what they were learning during the topic? Or perhaps you have a reference for assessing how students should understand the topic?

Teacher: There was no further feedback other than students getting a grade after completing the assignment. After giving the assignment, the next topic was continued.

The interview revealed that student conceptions, particularly misconceptions, were largely due to incomplete material presentation. Assignments, which are crucial for students' understanding and achievement, can take them out of their comfort zones and promote self-study. However, the teacher did not provide feedback on learning, which can lead to misconceptions. Learning evaluations help identify and measure misconceptions, enabling teachers to assess students' abilities and identify obstacles (Yuliati, 2017). Reflection can improve metacognitive development and understanding of the right concepts (Boccio et al., 2016). Teachers play a crucial role in the teaching and learning process, ensuring that every process runs smoothly according to its intended objectives. They must consider their roles as demonstrators, class managers, mediators, facilitators, and evaluators to achieve learning objectives. Two teachers were interviewed about their teaching and learning process management.

Interview with teacher 1 about teaching methodology

Researcher : How did you teach the students? What method did you use?

Teacher : I explained the topic through a lecture method, I also provided several questions to attract them to discuss the topic.

Researcher : Did you use any science teaching aids?

Teacher : Yes, I did. I used the torso as the media of the circulatory organ for the groups so that they could elaborate on the organ by themselves.

Interview with teacher 2 about teaching methodology

Researcher : How did you teach the topic in the class? What method did you use?

Teacher : I delivered the topic by referring to the teacher's book, by watching a video about diseases related to blood circulation, also by (practicing) counting the pulse.

Researcher : Were all topics taught? Did you use any aid?

Teacher : The topic was delivered according to the book but did not use any aid such as a torso.

Teacher 1 taught the circulatory system using the lecture method, using a replica of the circulatory system and asking questions for discussion. Effective teaching involves mastering objectives, measuring methods, managing attention, presenting material, providing conclusions, and conducting evaluations. However, the lecture method is less effective in influencing students' behavior and responses to ongoing learning (Hamzah & Alfiat, 2020). Students often become passive due to teacher-dominated activities, limiting creativity and reliance on their abilities. Knowledge is directly proportional to the teacher's knowledge, and a lack of knowledge can affect both parties. To improve learning, teachers should guide students and use guided inquiry learning on contextualized topics for better critical thinking. Teacher 2 taught a topic using reference book material and innovative learning methods. Video references were theoretical, but videos can support understanding by providing explanations. Teaching aids help students understand concepts and avoid misconceptions. However, the instrument used to measure misconceptions may have been problematic due to difficulty or inappropriate question items for junior high school students. Innovation in learning methods and strategies is essential for effective teaching. This can be caused by instrument question

items that are difficult or inappropriate to use with junior high school students such as in the interview shown below.

Interview with teacher 2 about the test instrument

- Researcher : Researchers are interested in the misconceptions that exist in each question. How is the topic of the circulatory system taught in class?*
- Teacher : For the lesson that is not too in-depth, according to the student book and teacher book guidelines, I think misconceptions can occur because the instruments are difficult and complex to understand.*
- Researcher : What difficulties do you mean are in the instrument?*
- Teacher : It is based on a four-tier question form.*

Student statements

- Student : The instrument was hard because we had to link the answer with the appropriate reason.*

In addition to interviews conducted with teachers, the researcher also obtained information that the use of four-tier diagnostic tests is also not familiar to students. Unfamiliarity with the four-tier diagnostic test creates a hurdle for students. Questions with four levels have their own challenges, because in addition to students having to be able to understand and answer questions theoretically in tier 1, they also have to connect them with the right reasons in tier 3 (Nurlita, 2022). In addition, the challenge that students must overcome is that students must be able to think critically in answering questions correctly even though there are choices that seem similar or the same.

To improve their performance, teachers can introduce the test gradually, providing clear explanations of each level and offering practice questions with scaffolding and guidance. This method not only helps students become more familiar with the format of the tests but also makes them better at analyzing and evaluating data. Additionally, encouraging and giving feedback during practice sessions can raise students' confidence, which in turn will lead to better performance in real diagnostic tests.

CONCLUSION

As an obstacle to learning, misconceptions which refer to the inappropriate understanding also occur in the human circulatory system. Prior diagnostic tests have been developed but are still less efficient in term of accuracy and time, so four-tier diagnostic test is need to be carried out. This test is appropriate because has the advantage that students cannot speculate in choosing their answers. To obtain an appropriate and accurate instrument to diagnose misconceptions, the validity and reliability test was conducted through expert judgment analysed by Aiken's test and student validation analysed by SPSS. After revision, the research data was collected from several schools using an online form. Then the answers were statistically coded and categorized based on student conceptions, such as scientific knowledge, false positive, false negative, misconceptions, and lack of knowledge. The study reveals that the majority of students (36.2%) have a low level of understanding of the human circulatory system, with LK dominating (36.2%). This is due to students' tendency to memorize scientific terms and difficulty understanding the system. The percentage of students in the FP and FN categories is relatively low, with 14.9% and 10.2% respectively. This suggests that students' understanding of the concept is similar to the percentage of M (27.6%). SK, which comprises 11.1% of overall student responses, is the lowest compared to LK, M, and collaboration of FP and FN categories. This low SK percentage can be attributed to limited hands-on activities, inadequate teaching methods, and insufficient emphasis on the circulatory system's importance in overall health.

RECOMMENDATION

The instrument used in this study is appropriate as a misconception diagnosis tool. However, to get better results in future research using a Four-Tier Diagnostic Test will be more effective, if it is used directly after the topic has been studied in class. It is also recommended to pay attention to ensuring that students in the sample have studied the topic as a whole so that the misconceptions results obtained will be more accurate. It could also be important to introduce the use of a four-level diagnostic test instrument in stages. Additionally, it is important to create an assessment form for more specific expert judgment, such as the desired indicators, language use, and possibly the level of difficulty of the questions to be answered by junior high school students. It is also important to add information through interviews with teachers and/or students to get more specific and in-depth misconception results.

Through this research, it was found that the teacher is the main key to success in learning about the human circulatory system. Therefore, before the teacher starts teaching, it is expected that the teacher is able to master the learning concept well to avoid misconceptions caused by the condition of students who come from various backgrounds. Teachers are also advised to provide and deliver topics through the correct selection of teaching methods and learning resources thoroughly, especially in providing learning evaluations in the form of feedback/reflection to all students.

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