

Identification of High School Students' Misconceptions on The Biogeochemical Cycle Topics

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Abstract. Misconceptions are a learning problem that not only impacts student acceptance in the form of delays in receiving new knowledge, but also causes misinformation in society, especially in the publication media. This study aims to identify students' misconceptions by using a three-tier diagnostic test on biogeochemical cycle topics. The first step in identifying misconceptions is to develop an identification instrument using the Treagust development method in several stages, starting from identifying the material, analyzing common misconceptions, and compiling questions at each tier. The results of the development of the instrument show that the three tier diagnostic test instrument has a content validity ratio (CVR) and content validity index (CVI) validity of 1 and a reliability of 0.90 for answer choices and 0.86 for reason choices. The valid and reliable instruments were tested on 210 students in 6 accredited schools A, B, and C in South Sumatra, Indonesia. The results showed that on biogeochemical cycle topics, there were two sub-topics categorized as experiencing high misconceptions, fifteen in the moderate category, and eight in the low category. Misconceptions occur in the sub-topics in a cycles of water, carbon and oxygen, sulfur, and nitrogen. The results of the analysis also showed that the highest misconception of 64% was in the reduction and oxidation sub-topic of the sulfur cycle. These findings can be used as input for educators in South Sumatra and Indonesia in general in teaching biogeochemical cycle material to avoid similar misconceptions in the future.

Keywords: Biogeochemical cycles, CVR and CVI validity Misconceptions, Three Tier Diagnostic Test,

Introduction

Misconception as a learning problem affects students' acceptance of subsequent learning materials. It occurs because of students' inability to construct newly acquired knowledge with objects, events, or the surrounding environment (Budhi & Hasan, 1999). The impact of misconceptions is not only felt by students in the form of delays in receiving new knowledge (Gungordu et al., 2017; Hasan et al., 1999; Yang & Sianturi, 2020), but also by society in developing and spreading misinformation through publication media such as television, magazines, and newspapers (Gungordu et al., 2017).

Misconceptions can be defined as concepts that are different from experts' or scientists' in general (Handika et al, 2015); Hasan et al., 1999; Iryani; 2018; Suwanto, 2017). However, in some cases, misconceptions can be a deviation of understanding from the actual concept (Hidayat & Kasmiruddin, 2020). Errors in the concepts in students can be caused by differences in the translation of visual and auditory information the causes of which can come from information on the internet, in textbooks, from teachers, teaching methods, and information that develops in the environment (Gungordu et al., 2017; Suparno, 2013).

Another problem related to misconceptions is that misconceptions about one subject matter will lead to errors and misconceptions about other concepts. This happens due to the attachment of the concept to the learning material. If left unchecked, it will have an impact on the acceptance of the next material concept. One of the learning materials that experiences quite a lot of misconceptions is the topic of biogeochemical cycles in Biology subjects (Purwanti & Kuntjoro, 2020; Yulianti, 2017). Biogeochemical recycling material contains the cycle process of chemical elements or compounds from abiotic to biotic components and back again to abiotic components which involves chemical reactions in the environment (Campbell, 2008). Misconceptions about biogeochemical cycle material in several studies (Dikmenli, 2010; Purwanti & Kuntjoro, 2020) reached more than 50%. An example of a misconception that occurs is in the matter of the nitrogen cycle that students consider decomposers in soil organisms only as decomposers not as recyclers of organic matter.

There are multiple ways to identify misconceptions in students, i.e., interviews, questionnaires, open and closed questions, and multiple-choice tests; and one-tier to multitier tests. However, in terms of the ability to identify misconceptions and time efficiency when analyzing data, the three-tier diagnostic test is more reliable (Kustiarini et al., 2019). It is a diagnostic test tool that has three levels of questions. The first tier is a multiple choice, the second is a variety of reasons from the first level, and the third is a choice of beliefs, answers, and reasons for students at the first and second levels (Syahrul & Setyarsih, 2015).

Research using the three-tier test was conducted by Dewi & Widodo (2016) on the material of the respiratory system, Imelda & Subramaniam (2010) on the wave concept and Cetin & Geban (2011) on acid-base material, and Nurulwati, (2019) on the concept of straight motion. However, research on identifying misconceptions in biogeochemical cycles using a three-tier diagnostic test with the steps of developing questions using the Treagust framework has never been carried out. This is because developing misconception questions usually only reaches the two-tier that is developing multiple-choice content items with free responses. The advantages of using the Treagust framework are (1) reducing the possibility of guessing; (2) allowing combining several aspects in one phenomenon, where the first tier is the menological domain, while the second tier is the conceptual domain; (3) easier to manage and calculate compared to other methods, so it is very useful to use in class.

Based on the discussions, the purpose of this study was to identify students' misconceptions on biogeochemical cycle topics using a three-tier diagnostic test instrument developed with the Treagust (1998) framework. It is hoped that the findings from this study can serve as input for educators in South Sumatra and Indonesia in general in teaching biogeochemical cycle material so that similar misconceptions do not recur in the future.

Methods

This study aims to identify students' misconceptions about the biogeochemical cycle through a valid and reliable three-tier diagnostic test instrument. It was developed with Treagust development method in 3 stages, namely identifying content, exploring student

misconception information, and developing a three-tier instrument. The activities in the first stage were identifying proportional knowledge, creating concept maps, linking proportional knowledge to concept maps, and validating content. In exploring students' misconceptions, the activities were conducting interviews and testing students' prior knowledge. Furthermore, in developing the instrument, content validity ratio (CVR) and content validity index (CVI) validation was carried out by experts including 3 Sriwijaya University lecturers and 2 high school biology teachers to ensure the validity of the instrument content. CVR is a ratio that measures the content validity of a variable. Content validity evaluates how well an instrument (such as a test) covers all its relevant parts of the construct to be measured. While the CVI looks at content validity based on the test items used (Ayre & Scally, 2013). Finally, instrument reliability was measured using the KR-20 method to assess the level of instrument reliability.

The development of the Three Tier Diagnostic Test Instrument produces 25 items with indicators from the sub-topics of the water cycle, carbon and oxygen cycle, sulfur cycle, and nitrogen cycle. The results of the CVR validity analysis on the three-tier diagnostic test instrument showed that the 25 items developed were relevant and feasible for detecting students' misconceptions with a CVR value of 1. The reliability of the three-tier diagnostic test instrument developed was reliable with a coefficient value of 0.90 for answer choices and 0.86 for reason choices. The final results of valid and reliable questions were then tested to identify students' misconceptions on the topic of biogeochemical cycles.

The research sample using this three-tier diagnostic instrument was class X students who were taken using a random sampling technique, so that six high schools accredited A, B, and C in Ogan Komering Ulu district: SMA Negeri 1 OKU, SMA Negeri 11 OKU, SMA Negeri 5 OKU SMA Negeri 5 OKU, SMA Trisakti Baturaja and SMA Sentosa Bhakti Baturaja. The total number of samples was 210.

Results and Discussion

The results of the identification of various misconceptions among students from the 25 items were described in Table 1. For high school students accredited A, B, and C, it was shown that two items were included in the high category of misconceptions, fifteen in the moderate category, and eight in the low category. The results of the three-tier diagnostic test instrument can be seen in Table 1 which consists of understanding the concept (UC), misconceptions (M), and not understanding the concept (NUC).

Table 1. Results of the Three-Tier Diagnostic Test about Flow of Energy in Ecosystems Material

Item Test	NUC(%)	UC(%)	M(%)	Misconception Criteria
1	12	26.6	61.3	High
2	12	53.3	34.7	Moderate
3	22	48	30	Moderate
4	24	48	28	Low
5	23.3	46	30.7	Moderate
6	19.3	58.6	22	Low
7	25.3	52.6	22	Low
8	25.3	45.3	29.3	Low
9	30	38.6	31.3	Moderate
10	33.3	37.3	29.3	Low
11	32	27.3	40.7	Moderate
12	18.7	47.3	34	Moderate
13	36	32	32	Moderate

14	26	41.3	32.7	Moderate
15	37.3	29.3	33.3	Moderate
16	29.3	40	30.7	Moderate
17	25.3	45.3	29.3	Low
18	30.7	38.6	30.7	Moderate
19	35.3	34	30.7	Moderate
20	32.7	38.6	28.7	Low
21	28.7	45.3	26	Low
22	31.3	4.6	64	High
23	38.7	24	37.3	Moderate
24	24.7	38	37.3	Moderate
25	22	42.6	35.3	Moderate

According to Table 1, the percentage for each category is calculated using the following calculation:

$$\%UC = \frac{\sum UC}{\sum \text{Item Test}} \times 100$$

$$\%NUC = \frac{\sum NUC}{\sum \text{Item Test}} \times 100$$

$$\%M = \frac{\sum M}{\sum \text{Item Test}} \times 100$$

Keterangan :

%UC	= Student Percentage understanding the concept
%NUC	= Student Percentage not understanding the concept
%M	= Student Percentage misconceptions
$\sum UC$	= Jumlah Peserta didik yang paham konsep
$\sum NUC$	= Jumlah Peserta didik yang tidak paham konsep
$\sum M$	= Jumlah Peserta didik yang miskonsepsi
$\sum \text{Item Test}$	= Jumlah Item test

Therefore, 39.33% of students were categorized as understanding the concept, 33.65% of students were categorized as misconceptions, and 27.01% of students were categorized as not understanding the concept. The percentage of misconceptions based on sub-material on biogeochemical cycles is shown in Table 2.

Table 2. Percentage of Misconceptions for Each Sub-Material in Biogeochemical Cycles

No	Misconception Submaterial	Percentage of Misconceptions
1	Water cycle	34.45
2	Carbon and oxygen cycle	31.23
3	nitrogen cycle	31.45
4	4 Sulfur cycle	50.65
5	Phosphorus cycle	29.70

The following is a diagram of understanding the concept (UC), misconceptions (M), and not understanding the concept (NUC) in Figure 1 that in SMA accredited A, B, and C.

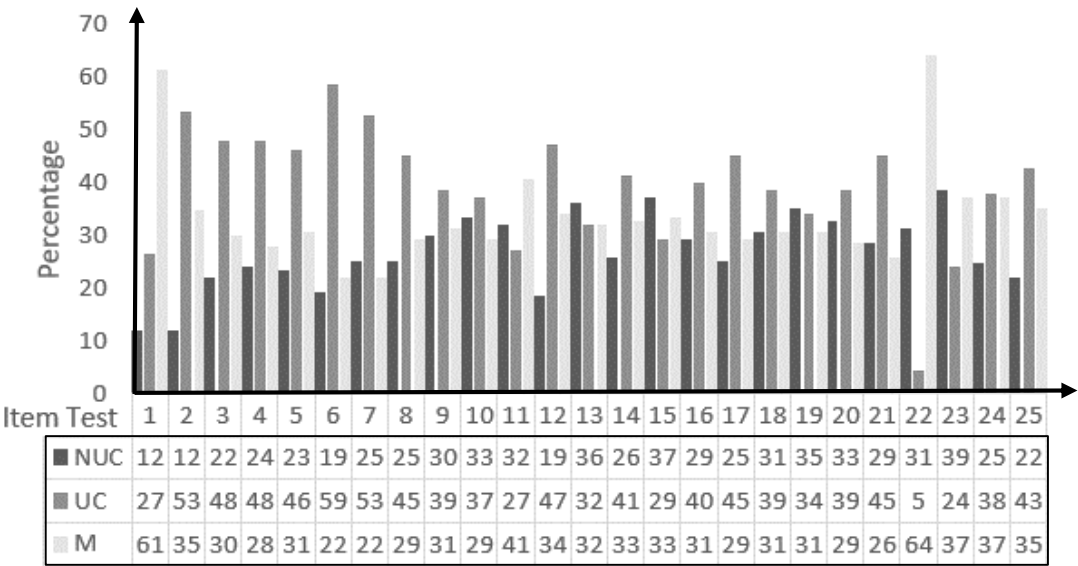


Figure 1. Students Understanding the Concept of Senior High School Accredited A, B, and C

Following are the findings of students' misconceptions through a three-level diagnostic test instrument. Students' misconceptions about biogeochemical cycles include the amount of water on earth, where students think that the amount of water on earth decreases because it is used for living needs. This is based on students who answered item number 1.

"Water plays an important role in supporting the needs of living things and all living things use water every day. Therefore, the amount of water on earth will decrease because it is used for daily needs."

This answer is in line with the research of Assarf & Orion (2018) which states that students consider the amount of water before human use is not the same as the amount of water after human use, thereby establishing the concept of reduced water on earth. In fact, the exact concept of water resources in nature is relatively fixed, but the time of availability changes, because water undergoes a rotation process, called the hydrologic cycle or the water cycle.

The second misconception is about the evaporation process, students think it only occurs in seawater. This is based on the answers to question number 2.

"The picture of the hydrological cycle shows the process of evaporation of seawater and transpiration of plants, but students answer with the process of evaporation of seawater and photosynthesis in plants on the grounds that plants emit O₂ and seawater undergoes evaporation".

This answer is in line with research by Assarf & Orion (2018) which states that evaporation only occurs in seawater while other living things do not experience evaporation. The exact concept of plants experiencing evaporation is called the transpiration process where water vapor from living tissues evaporates through the stomata, cuticle holes, and lenticels (Silaen, 2021).

The third misconception is about the role of bacteria in the biogeochemical cycle, students think that bacteria in the cycle are only decomposers. This is based on the answers to question number 11.

"Based on the carbon cycle flow chart above, the organisms playing a role in the processes that occur in the sign labeled Z are bacteria because they are decomposers of dead organisms."

This answer is in line with research conducted by Asshoff et al. (2010) finding out that decomposers in soil organisms only act as decomposers not as recyclers of organic matter. The exact concept is that aside from being decomposers, soil bacteria or microbes have an important role in the biogeochemical cycle as recyclers of organic compounds (Basu et al, 2021).

The fourth misconception is the process of respiration found in the carbon and oxygen cycles. Students assume that plants absorb O_2 and emit CO_2 at night. This is based on item number 21

"A true statement regarding plant respiration is that plant respiration occurs at night."

This answer is in accordance with research conducted by Svandova (2014) which states that students think that photosynthesis occurs during the day and respiration occurs at night and is also in line with research by Kase (2008) which states that students think that respiration in plants only occurs at night and Plants inhale CO_2 and release O_2 in the process of respiration. While the exact concept is that plant respiration occurs during the day and night, light is not a requirement for respiration.

The fifth misconception is about the role of O_2 and CO_2 gases in plants. Students assume that the gas needed by plants to do respiration is CO_2 and the gas released from respiration is O_2 . This is based on the reason for question number 21 *"Plants absorb CO_2 and release O_2 ".*

This answer is in line with research by Kase (2008) which states that plants release carbon dioxide gas and the gas taken is oxygen. The exact concept is that the gas absorbed by plants is O_2 and what is released is CO_2 .

The sixth misconception is the availability of phosphorus in the atmosphere in the phosphorus cycle in which students assume that phosphorus is found in the atmosphere. This is based on students' answers to item number 19

"One of the places where phosphorus is found is in the atmosphere."

This answer is in line with Faujiyati & Rahman (2021) which states that students think that phosphate is available in the atmosphere and absorbed by plants. The precise concept is that phosphorus is not found in the atmosphere but rather in sedimentary rocks and is independent of bacteria (Sink, 1979). The next misconception is about the evaporation process where students think that all evaporation that occurs on earth is called evaporation.

The next misconception is the role of bacteria and the names of bacteria. In the nitrogen cycle fixation process, students consider Nitrobacter to play a role in the nitrogen cycle fixation process. While the exact concept of bacteria that play a role in the fixation process of the nitrogen cycle is Rhizobium while Nitrobacter is a bacteria that plays a role in the nitrification process in the nitrogen cycle (Jetten, 2008). There is also a misconception about the role of bacteria in the sulfur cycle where students think that autotrophic and heterotrophic bacteria play a role in the sulfur cycle. While the exact concept is that chemoautotrophic bacteria are able to play a role in oxidizing H_2 and sulfur compounds coupled with the reduction of oxygen (Nakagawa & Takai, 2008). Furthermore, there are also Misconceptions about activities that break the nitrogen cycle, students think that the use of fossil fuels and applying insecticides to plants can break the nitrogen cycle. While the exact concept is that the nitrogen cycle can be interrupted due to soil pollution because if soil bacteria die due to soil contamination, then no organisms will bind nitrogen from the atmosphere. Misconceptions also exist in the determination of chemical compounds in the nitrogen cycle, students answer the chemical formula NO_2^- in defining the nitrate compounds. While the exact concept of nitrate compound is indicated by the

chemical formula NO_3^- and nitrite compounds are indicated by the chemical formula NO_2^- (Sigler & Bauder 2012).

Another misconception is related to the availability of elements in biogeochemistry. In discussing the impact of increasing carbon in the atmosphere, students assume that increasing carbon in the atmosphere has no impact at all. While the exact concept is that increasing carbon in the atmosphere will cause an increase in the average temperature on Earth (Lindzen, 1997; Sulistiyono, 2012). There are also misconceptions about nitrogen nutrients needed by plants that students consider nitrogen as a micronutrient for plants. Meanwhile, the precise concept is that nitrogen in the soil as a macronutrient plays an important role in the formation of chlorophyll during photosynthesis and makes plants look greener (Ucar et al., 2017). Another misconception is about organisms that play a role in converting sulfur into sulfate, students assume that not only bacteria but also other soil organisms can play a role in the sulfur cycle. Meanwhile, the exact concept is that only bacteria play a role in the sulfur cycle to decompose sulfur into sulfate (Retnaningrum & Wilopo, 2017). The last misconception found is on what plays a role in biogeochemical cycles, students think that what plays a more crucial role in biogeochemical cycles is only biological and chemical cycles.

Conclusion

The results of research on identifying student misconceptions using a three-level diagnostic test show that 39.33% of students fall into the concept understanding category, 33.65% of students fall into the misconception category, and 27.01% of students fall into the misconception category. in the category of not understanding the concept. Research shows that there are student misconceptions, including the assumption that the amount of water on earth is decreasing due to the activities of living things, evaporation only occurs in the sea, the role of bacteria is only as decomposers, respiration time in plants is only at night, plants only absorb oxygen and emit carbon dioxide, availability phosphorus only exists in the atmosphere. The large number of misconceptions found on the topic of biogeochemistry shows the importance of identifying student misconceptions in learning so that concepts can be evaluated and corrected before entering new learning material. This is expected to avoid obstacles in the integration of new knowledge due to misconceptions in previous learning.

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