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An Analysis of Prospective Science Teacher Students' Misconceptions on Photosynthesis and Plant Respiration

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Abstract

Misunderstanding in drawing conclusions about a concept caused by errors and incomplete thinking is called misconception. The existing misconception can lead to ongoing misconception if it is not immediately corrected. This study aimed to analyze how the level of misconceptions that occured in prospective science teachers. This study was conducted using a mixed-method with an explanatory sequential design. Methods of collecting data were Three Tier Multiple Choice (TTMC) test questions to analyze the misconception and in-depth interview to determine the factors causing misconceptions. The instrument used in this study was TTMC diagnostic test. Technique used for analyzing misconceptions data were descriptive percentages and for analyzing factors causing misconceptions data were in-depth interview. The results show that 60.4% of prospective science teacher students had misconceptions, which means that the misconceptions that occured were in the high category. Factors causing misconceptions were dominated by incompleteness in understanding the material, the influence of previous learning, the references used contain the wrong concept, low interest in deepening the material to find out the correct concept. This study is expected to help teachers and prospective teachers to decide what learning methods can be used to prevent misconceptions. Remediation can be done to find out where the misconceptions occur so that it can be corrected more quickly.

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INTRODUCTION

Misconception is incomplete thoughts on a thing or concept which is being studied, which can happen to anyone, not only to student, but also to a teacher or a prospective teacher. In a lesson, teacher and prospective teacher experience misconception in the delivery of material both in Science and Non-Science fields. Misconception that occur in the field of Science often occur in topics of Physics, Chemistry, or Biology (Bektas, 2015; Moodley & Gaigher, 2019).

Understanding concepts in Science material (Physics, Chemistry, Biology) is very important for prospective science teachers. In fact, many prospective science teachers have difficulty in understanding the science concepts, in other words, not all prospective science teachers understand the concepts well. Difficulties in mastering concepts are caused because the existing concepts are abstract, and are interrelated with one another (Monita & Suharto, 2016). The concept of Science is also meaningful and permanent, when the concepts cannot be understood properly it will lead to misunderstanding or misconception about the concept itself (Ahopelto *et al.*, 2011; Gunes *et al.*, 2012; Ören *et al.*, 2012).

Prospective science teachers learn to build a concept that is learned through formal education which they take in several stages as well as through the basic knowledge they have previously, which is commonly used in building insightful perspectives on something (Pamungkas *et al.*, 2019) Prospective science teachers who misunderstand a concept during formal education can have a lasting impact on the cognitive structure of their prospective students (Taşlıdere, 2013).

Photosynthesis and plant respiration are one of the science learning materials in the field of Biology which are incorporated in the educational curriculum and have been applied in many countries including Indonesia. Photosynthesis material is always taught repeatedly from elementary school to college (Karpudewan et al., 2017). Photosynthesis and plant respiration are abstract subject matter and require more effort to understand the material, for that reason the material for photosynthesis and plant respiration is often have misconceptions.

Several studies had been conducted to reveal the misconceptions that occur in prospective teachers related to photosynthesis and plant respiration. Ameyaw (2016) stated that 31.5% of students did not know that glucose is the raw material for cellular respiration, and water is produced as a by-product in aerobic respiration. Similarly, 23.6% and 29.9% of respondents said Adenosine Triphosphate (ATP) is not released at the end of aerobic respiration, and anaerobic respiration does not occur in both case, plants and animals respectively. It is also known that 36.7% of respondents did not know that anaerobic respiration does not require oxygen for the reaction to take place. Çokadar (2012) stated that through study conducted there were misconceptions about the definition of photosynthesis 42% and respiration 29% for prospective science teachers, 5% and 2% for prospective classroom teachers. Urey (2018) said that prospective science teachers in Turkey wrote the definition of photosynthesis using a chemical approach had 50% of misconception and 33% of biological approach. Susanti (2018) declared that prospective biology teachers had misconceptions in the concept of photosynthesis 37.9%, energy 34.5%, the role of light 45% and the site of photosynthesis 39.6%.

Identification of misconceptions can be done by providing diagnostic test. Diagnostic test is used to identify and to determine which parts of the material have weaknesses and as a tool to find the cause of misconceptions (Septiana *et al.*, 2014). Three-tier multiple choice (TTMC) is a form of diagnostic test that is usually used to identify misconceptions. The TTMC has items to measure the level of confidence in the answers given to each question (Aydeniz *et al.*, 2017; S & Sanjaya, 2015; Sen & Yilmaz, 2017; Taslidere, 2016). Three-tier multiple choice diagnostic test has three levels at the first level there are questions, the second level is the reason for the answers given and at the third level is the level of confidence in providing answers. The diagnostic test that have been used by several researchers to reveal the existence of misconceptions in photosynthesis still uses simple multiple choice questions, open questions and two-tier multiple choice.

This study has two main objectives: First, analyzing the misconceptions that occur in prospective science teacher students using the TTMC diagnostic test. Second, knowing the factors that cause misconceptions.

METHODS

The method used in this study was a mixed-method with an exploratory sequential design. The strategy in this study was carried out in 2 combined phases: the first phase was carried out by collecting data through diagnostic test which are then analyzed quantitatively, in the second phase, the data was collected through in-depth interview and then the data from both phases were analyzed qualitatively.

The subjects in this study consisted of 100 prospective science teacher students of Univeritas Negeri Semarang consisting of 1st semester students, 3rd and 5th. The misconceptions of prospective science teacher students were tested using a three-tier multiple choice (TTMC) diagnostic test consisting of 25 questions. Misconception identification assessment was carried out by combining each answer with the CRI response scale criteria using the criteria according to (Arslan *et al.*, 2012) shown in Table 1.

Table 1. Criteria for Concept Understanding based on CRI

Tier I	Tier II	Tier II	CRI Value	Category
Right	Right	Sure	> 2.5	Understanding Concept (UC)
Right	Right	Not Sure	< 2.5	Not Really Understanding Concept (NRUC)
False	False	Not Sure	< 2.5	Not Understanding Concept (NUC)
Right	False	Not Sure	< 2.5	Not Understanding Concept (NUC)
False	Right	Not Sure	< 2.5	Not Understanding Concept (NUC)
Right	False	Sure	> 2.5	Misconception level I (MC I)
False	Right	Sure	> 2.5	Misconception level II (MC II)
False	False	Sure	> 2.5	Misconception level III (MC III)

Descriptive percentage analysis was used to determine the percentage in each category of understanding concept, not really understanding concept, not understanding concept and misconception (Mustaqim et al., 2014). The formula used in finding the percentage is as follows:

$$P = \frac{f}{N} x100\%$$

Which means, P : the percentage of each category, f: the frequency of students who fit with the category, N : The total number of individuals who were being sample.

Classification of the misconception level is divided into 3 criteria according to (Prodjosantoso *et al.*, 2019) which can be seen in Table 2.

Table 2. Misconceptions Criteria

Score (%)	Criteria
61 - 100	High
31 – 60	Moderate
0 – 30	Low

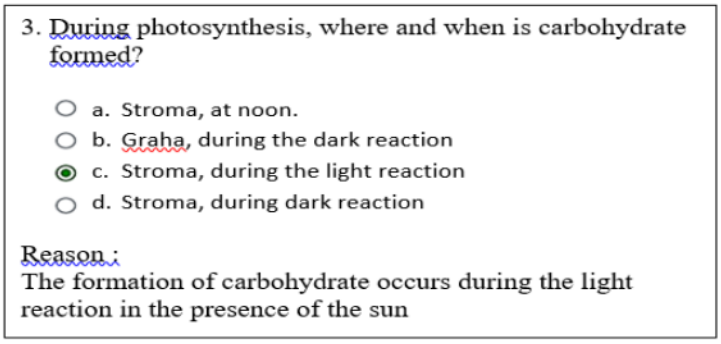
RESULTS AND DISCUSSION

Based on the results of the TTMC diagnostic test which was followed by 100 prospective science teacher students who had been analyzed and grouped by categories of misconceptions, it is shown in Table 3.

Table 3. Results of Identification of Prospective Science Teachers' Misconceptions

Concept Understanding Category	Frequency	Score (%)
Understanding Concept (UC)	28	28.04
Not Really Understanding Concept (NRUC)	2	1.88
Not Understanding Concept (NUC)	10	9.68
Misconception level I (MC I)	18	18.24
Misconception level I (MC II)	1	1.44
Misconception level I (MC III)	41	40.72

Based on the table above, it can be seen that the results of the identification of misconceptions that occur to prospective science teacher students as a whole are 60.04%, which mean that the misconceptions that occur are in the moderate category. The misconceptions experienced by prospective science teacher students are dominated by MC III which has a percentage value of 40.72%. This was because most of the prospective science teacher students gave wrong answers with the wrong reasons, but they believed in the answers. An example of the results of the answers to the diagnostic test questions for prospective science teacher students who have experienced MC III on the concept of photosynthesis is shown in Figure 1.

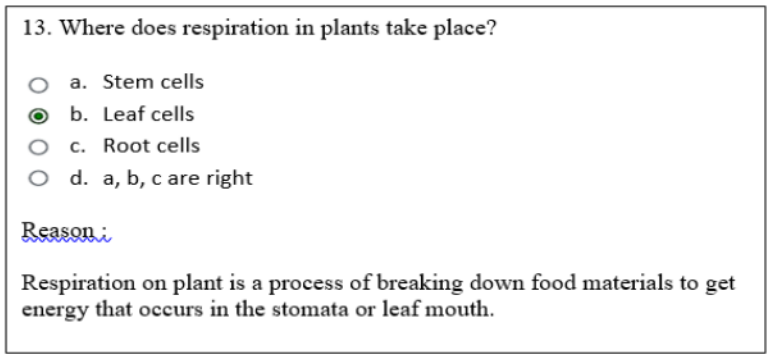

3. During photosynthesis, where and when is carbohydrate formed?

a. Stroma, at noon.
b. Graha, during the dark reaction
c. Stroma, during the light reaction
d. Stroma, during dark reaction

Reason :
The formation of carbohydrate occurs during the light reaction in the presence of the sun

Figure 1. Answer to the Diagnostic Test on the Concept of Photosynthesis

An example of an answer to diagnostic test question for prospective science teacher students who had experienced MC III on the concept of plant respiration is shown in Figure 2


13. Where does respiration in plants take place?

a. Stem cells
b. Leaf cells
c. Root cells
d. a, b, c are right

Reason :

Respiration on plant is a process of breaking down food materials to get energy that occurs in the stomata or leaf mouth.

Figure 2. Answer to the Diagnostic Test on the Concept of Plant Respiration

In this study there were several questions that had a high percentage value. The results of the analysis of misconceptions for each question experienced by prospective science teacher students are shown in Figure 3.

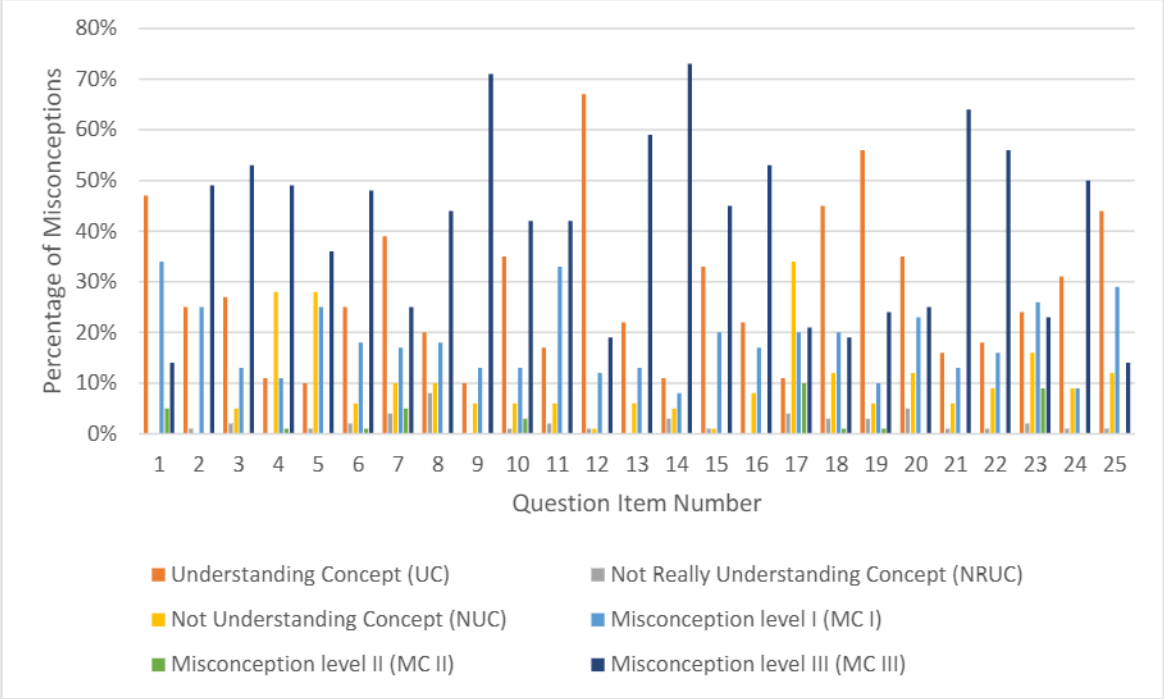


Figure 3. Graph of Identification of Misconceptions Percentage in Each Question

Misconception that occured in each question was different, and it can be seen from the graph above that there were three questions that tend to have high percentage values, namely question number 14, 9 and 21.

Question number 14

14. Which statement is most correct about plant respiration?

a. The process of exchanging carbon dioxide gas with oxygen through the stomata tissue
b. A process that will never happen when plant photosynthesizes
c. A chemical process in which energy is released using oxygen
d. The process of forming food from water and carbon dioxide molecules

Question number 14 is a question with the cognitive domain of applying (C3) which was used to find out how prospective teacher students used knowledge or ideas in giving statements related to plant respiration. Understanding the concept in this question is very low that is 11% because the prospective teacher students did not understand the concept well. While the percentage of misconception that occur is very high, namely 73% which includes to the category of misconception level III. Half of the 100 samples of prospective science teacher students chose option (a) as the correct answer, and most of them thought that plant respiration is an exchange process between carbon dioxide gas (CO_2) and oxygen (O_2) through the stomata tissue which is the only part of the leaf that has a role in respiration.

The statement given was not in accordance with the existing concept, the correct concept is that plant respiration is a decomposition process or energy release that obtained from the results of Photosynthesis in the form of glucose as the main substrate for respiration with the help of oxygen molecules that act as ATP-producing electron acceptors (Toro & Pinto, 2015). Plant respiration occurs through several parts of the plant including the leaves through the stomata tissue, stems in the lenticels and through root hair (Kimball, 2015). The answers given by prospective teacher students were the result of personal thoughts based on what they remembered about the concept, in this case

most of student looked for references after they provided answers, and some samples only gave answers without reason, but they believed in the answers given.

Question number 9

9. Which of the following statements is correct about the process of photosynthesis?
   a. Photosynthesis can take place in the dark without sunlight
   b. Sunlight energy is used until the final process of photosynthesis
   c. Photosynthesis can take place with the help of lamp's light
   d. Sunlight is very important for the process of forming starch

Question number 9 is a question with the cognitive domain of applying (C3) which was used to find out how the opinion of prospective teacher students related to the continuity of the photosynthesis process. The percentage of misconception is 71% and includes to the category of misconception level III. On average, students chose option (a) as the correct answer. There are 2 reasons for the answer where the prospective teacher students thought that the presence or absence of light does not affect the process of photosynthesis, even in the dark, photosynthesis can still take place without light, which is called dark reaction. While the rest thought that photosynthesis takes place in 2 stages: dark reaction and light reaction, the dark reaction occurs in the dark place and the light occurs in the light place, which means that photosynthesis can take place in the dark place in the absence of light.

The correct concept in the process of photosynthesis still requires light even though it is not in the form of sunlight, with the help of visible light that comes from the light of lamp photosynthesis will continue, in condition the existing energy must be able to meet the energy needs needed by plants to carry out photosynthesis, where blue light with the waves lenght (470 - 500 nm) and red (650 - 760 nm) that can be used for photosynthesis. Red light is light that is effective in photosynthesis and growth (Hasanah *et al.*, 2018; Naomi *et al.*, 2018). For the concept of the dark reaction, photosynthesis does not mean that photosynthesis takes place in the dark, but is a fixation reaction or CO2 binding using energy in the form of ATP and NADPH derived from the light reaction (Johnson, 2016; Suyatman, 2020). The answers given were based on the knowledge that had been obtained from various sources such as the internet, web, blogs.

Question number 21

21. Where is chlorophyll in plants?
   a. Only on the stem
   b. On the leaves and stems only
   c. All parts of the plant that are green
   d. On the leaves only

Question number 21 is a question with the cognitive domain of applying (C3). In this question, students were asked to determine where the chlorophyll is located in plants. 64% of students experienced misconception level III. Prospective teacher students chose option (d) as the correct answer. The reason given by prospective teacher students was that chlorophyll is a green leaf substance that is only located on the leaves.

The concept expressed was not in accordance with the existing concept where chlorophyll as a green substance is located not only in leaves, but also in almost all green parts of plants, which are leaves, stems, and fruit (Yudiati et al., 2021). Chlorophyll in plants is located in chloroplasts scattered throughout the plant body. Campbell (2010) said that all parts of green plants have chloroplasts including stems, leaves and fruit. The green substance or green color that exists in leaves or other plant parts is caused by the presence of chlorophyll in the chloroplasts. The answers and reasons given by them were based on their knowledge based on what they had read from

various existing reference sources such as the internet, the web, books, practicum books, the surrounding environment, and social media. Some of prospective teacher students stated that as long as they gained knowledge in this material, all they did was listen without following up by seeking deeper information on their knowledge.

Based on the results of in-depth interview that have been conducted with prospective science teacher students who experienced the most misconception, the results show that prospective science teacher students who experienced misconception were caused by several factors: (1) imperfect thinking in understanding the material, this is in accordance with the results of the study. Hala (2018) which stated that the factors that cause misconception that are low reasoning abilities, low retention of knowledge obtained in undergraduate program, lack of learning resources, incomprehensible terms, and low interest of Biology teachers in cell concepts; (2) the influence of previous learning, this is also in accordance with the results of a study conducted by Gudyanga (2014) which revealed that teachers found to be a contributing factor based on incompetence in this case teachers who provided material with the wrong concept led to ongoing misconception; (3) the reference used contained the wrong concept; (4) low interest in deepening the material to know the correct concept.

CONCLUSION

Analytical study on the existence of misconception in prospective science teacher students using the TTMC diagnostic test and the factors causing misconception has been successfully carried out. Based on diagnostic test data, it was found that 60.04% of prospective science teacher students had misconception about photosynthesis and plant respiration. The misconceptions that occured were dominated by misconception level III with a percentage of 40.72%, for the lowest level percentage fitted in the category of misconception level II with a percentage of 1.44%. Most of the misconceptions occured in the concept of respiration, the process of photosynthesis and the location of chlorophyll. Misconception in the cognitive aspect applying (C3) occured a lot in this study because the cognitive development of each student could affect the pattern of understanding something.

Factors causing misconception in this study include imperfect thinking in understanding the material, the influence of previous learning, the references used contain wrong concepts, and low interest in deepening the material to find out the correct concepts.

This study is expected to be a warning to teachers and to prospective teachers that literacy is very important to minimize misconceptions and based on the results of this study can make teachers and prospective teachers pay more attention to any concepts in photosynthesis and plant respiration material require special attention so that misconceptions are not more sustainable. Teachers and prospective teachers can also relate the material being taught to real life, or by designing learning as well as possible so that it can be understood. Remediation can also be done to find out where the misconception is experienced and immediately fix them.

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