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UNDERGRADUATE STUDENTS' MENTAL MODEL OF CELL BIOLOGY

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ABSTRACT

A descriptive study of future teacher students' mental models of essential concepts in Cell Biology was carried out through explanatory mixed-methods. Some students (n=40) of Biology Education Universitas Negeri Semarang were involved as the research subject. We used a diagnostic test, structured interview guides, and field notes to describe students' mental model. In the early stage, we prepare a diagnostic test performed essential concepts of Cell Biology. Secondly, we define students' mental models map based on their answers. Thirdly, we identify factors which affect students' mental models. Exploration of mental models was conducted through structured interviews with students representing each category. The interview focused on reasoning and argumentation students' abilities in answering the question on the test item. The research finding describes that students' mental model in Cell Biology is grouped into three categories, macro-mental to think based of basic content, micro-mental in correlation of content, and intuitive-mental or misconception. This finding can be used in improving research-based learning in Cell Biology.

Keywords: cell biology; mental model; undergraduate students

INTRODUCTION

One aspect was the focus of many research studies in science education is reform of science teaching as a learning process of science content and science learning as training and retention process of science content. This idea suggests that science learning process should pay more attention to students understanding science content. In this regard, explicitly American Association for the Advancement of Science/AAAS (2009) suggested that science learning should prioritize teaching for understanding.

Indicator of teaching for understanding successfully is students' ability in a wide range of thinking and reasoning, like how to explain, collecting evidence, providing an example, analyzing, making analogy and reasoning, and applying scientific concepts in new situations (Greca& Moreira, 2000; Janssen, et al. 2009; Fry & Marshall, 2008; Johnson-Laird, 2010; Macbeth, et al., 2014). As an implication, the learning process in higher education should switch to higher order learning scheme (Fry & Marshall, 2008, Khasanah, et al., 2016). Higher order learning emphasizes on students understanding and creativity, such as being able to comprehend and construct knowledge based on facts, analyze the connection between knowledge with other relevant knowledge.

Learning in science has a very important role in concepts understanding, application of concepts, analytical thinking, and develop students' insights about daily life phenomena. The process of phenomena understanding in science has a positive contribution to reasoning ability development. Science learning process in college cannot be reached only by rote information, but it must be supported by logical reasoning and ana-

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lytical thinking.

Study result (Fisher, et al., 2011) indicated that although students understand about the definition of diffusion and osmosis when students were given problems related diffusion and osmosis phenomena, it was found that most participants are not able to respond appropriately. Another study (Strickland, et al., 2010) describe differences of understanding among students after they learn about acids and bases. Wilson, et al.(2006) found that most biology students are not able to provide a comprehensive argument why someone is weight loss on a diet, although students have been learning about respiration and metabolism. More students memorize chemical reactions in cells only rather than trying to find factors caused chemical reactions can take place.

A variety of students' ability to interpret essential science concepts is a serious problem. Learning science should be planned more than studying textbooks and listen to information, but must provide the opportunity for students to develop critical thinking skills to understand natural phenomena (Lynd-Balta, 2006; Fencl, 2010). By providing the opportunity for the student to understand science phenomena, they will be able to process, assemble, and represents science precisely. This study reported the description of the student teachers mental model in Cell Biology essential concepts.

METHODS

The subject of this study was forty student teachers (n=40) of Biology Education Department, Universitas Negeri Semarang who have taken Cell Biology course.

The design of the study is explanatory mixed-methods. The study was implemented in three steps. In first, we gave a diagnostic test performed essential concepts of Cell Biology. Secondly, we define students' mental models map based on their answers. Thirdly, we identify factors which affect students' mental models. Exploration of mental models was conducted through structured interviews. We interviewed students representing specific answers. Figure 1 as below shows the research method.

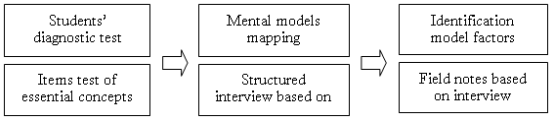

Figure 1. Research method

Diagnostic test as an instrument consists of 9 test items argumentative multiple choice. Students should give an argument for each test item answer. The diagnostic test includes essential concepts of the Plasma Membrane and Organelle Producing Energy. The essential concept is divided into three categories, i.e. basic concepts, application of concepts, and relationships between concepts. The diagnostic test was given after learning process.

Data of diagnostic test results were analyzed based on student answers. The qualitative descriptive technique was used to analyze data. Data is described and categorized in two types of answers, correct answer and false answer.

Data from interviews and field notes were analyzed qualitatively, by tracing and identify "why the student is answering like that"? The results of the interview were used to classify students' mental model.

RESULTS AND DISCUSSION

Basic Concepts

Question 1:

The plasma membrane found in prokaryotes and eukaryotes. In eukaryotic cells, where plasma membrane to be found? Table 1 shows the variation of student answers.

Table 1. Students' understanding of plasma membrane in eukaryotic cell

Category	Number of students	%
True answer: Vakuola, Golgi complex, lysosome	5	12.5
False answer: Mitochondrion, endoplasmic reticulum, ribosome	14	35
Nucleus, mitochondrion, microtubules	2	5
Chloroplast, centrosome, endoplasmic reticulum	8	20
Golgi complex, ribosome, nucleus	11	27.5
Number of students	40	100

Question 2:

What causes simple diffusion can occur?

Variation of student answers can be seen in Table 2.

Table 2. Distribution of students' understanding of simple diffusion

Category	Number of students	%
True answer:		
There are porous in fat layers	27	67.5
False answer:		
Protein helps diffusion membrane	7	17.5
The fat layer is permeable	0	5
Water can bind to protein	0	20
Higher concentration of intracellular fluid	6	15
Number of students	40	100

Question 3:

If we consume foods containing glucose, how can glucose contribute to the movements?

Table 3 shows the variation of student answers.

Table 3. Students' understanding of glucose role in energy producing

Category	Number of Students	%
True answer:		
Chemical potential energy of glucose changed into CO_2	9	22.5
False answer:		
Glucose molecule transformed into energy and O_2	8	20
Glucose molecules react with ATP to form energy	17	42.5
Glucose molecule change ATP into energy and H_2O	3	7.5
Chemical potential energy of glucose changed into O_2	3	7.5
Number of students	40	100

Concepts Application

Question 4:

A vessel is sealed with a semipermeable membrane (there is a picture). On side one filled water and concentrated dyes. The side two only contains water. The high surface of both sides is the same. After two hours, what will happen to the water in side1 and 2?

Variation of student answers has shown in Table 4.

Table 4. Students' understanding of semipermeable membrane

Category	Number of students	%
True answer:		
Water in side 2 will be higher than side 1	6	15
False answer:		
Water in side 1will be higher than the 2	26	65
Height of both sides will remain the same	4	10
Water in side 1 will be higher and will return the same	2	5
Water in side 2 will be higher and will return the same	2	5
Number of students	40	100

Question 5:

Margarine is made from vegetable oils in solid form through a chemical process. What happens to the plant oils that initially a liquid can turn into a solid as in margarine?

Variations student answers can be seen in Table 5.

Table 5. Students' understanding of temperature effect on phospholipids

Category	Number of students	%
True answer:		
There were changes in phospholipids saturation	8	20
False answer:		
Doubling occurs on phospholipid structure	2	5
Reduction in lipids liquid content	9	22.5
Evaporation occurs in part of phospholipids	10	25
Reduction in phospholipid amount	11	27.5
Number of students	40	100

Question 6:

You had a friend who was doing a diet. After an interval time his fat mass down to 3 kg. Where is your friend fat loss? Answer students were shown in Table 6.

Table 6. Students' reasoning about reduction of fat in diet program

Category	Number of students	%
True answer:		
Release in the form of CO_2 dan H_2O	5	12.5
False answer:		
Eliminated because of body heat	2	5
Tied proteins and form lipoproteins	8	20
Converted into fatty acids and released	17	42.5
Digested in stomach and released	8	20
Number of students	40	100

Connection between Concepts

Question 7:

A plant is growing in a pot in the sun. If that plant is placed in a dark place for a few days (its water needs was maintained), what will occur with plant biomass?

Variation student answers can be seen in Table 7.

Table 7. Students' reasoning about role of biomass in respiration

Category	Number of students	%
True answer:		
Reduced, because respiration occurs even though in a dark place	2	5
False answer:		
Increases, because in a dark place plant will grow lengthwise	24	60
Increases, because reaction occurs to produce glucose	8	20
Reduced, because water in plant will evaporate	1	2.5
Still, because in plant is not produce carbohydrates	5	12.5
Number of students	40	100

Question 8:

There is a scheme of the relationship between respiration and photosynthesis. What events are by the scheme?

Variations of student answers can be seen in Table 8.

Table 8. Students' perception related respiration and photosynthesis

Category	Number of students	%
True answer:		
Oxygen as a photosynthesis result takes to burn glucose in the mitochondria	15	37.5
False answer:		
CO_2 as respiration results needed in photosynthesis to burn glucose	10	25
CO_2 released from the chloroplasts through respiration	9	22.5
CO_2 is produced in photosynthesis metabolism	4	10
Oxygen and CO_2 are needed for respiration and photosynthesis	2	5
Number of students	40	100

Question 9:

Research conducted to investigate the role of an organism cell organelles. Observation result related changes in solute substance as below.

Glucose	Unchanged
CO2	Increases
O2	Unchanged
ATP	Increases

Based on the finding, what metabolic processes these organelles play a role?

Variation of students' answer can be seen in Table 9.

Table 9. Students' conception in cellular respiration

Category	Number of students	%
True answer:		
Krebs cycle	13	32.5
False answer:		
Light reaction	7	17.5
Calvin cycle	5	12.5
Glycolysis	10	25
Oxidative phosphorylation	5	12.5
Number of students	40	100

Future teacher students' misconceptions were found is a representation of ability to grasp and understand essential concepts of cell biology. Diagnostic test results represent several categories of misconceptions possessed by students. Variations in student answers may be caused by limitations of different capabilities, in addition to a different learning experience as well. Besnard, et al. (2004) argues that the dynamic mental system strongly influences the comprehension ability as critical for responding to stimuli coming.

The results of the interview can provide a more realistic description of students understanding differences. Interview conducted on several students who purposively selected because they relate to the characteristics of student answers. Here are excerpts of interview results. It was performed to identify misconceptions students through question number 1 on cell biology basic concepts.

Lecturer: "What's your answer for number 1 question?"
Student 1: "I answered that plasma membrane of mitochondria, endoplasmic reticulum, and the ribosome."
Lecturer: "Why?"
Student 1: "Because of plasma membrane found in mitochondria, ER, and the ribosome."
Lecturer: "What about your answer (student 2)?"
Student 2: "I answered on Golgi complex, ribosomes, and nucleus."
Lecturer: "Actually, what is ribosome? Is it one of cell organelles?"
Students 1.2: (speechless and thinking)
Lecturer: "What about your answer (3 students)?"
Student 3: "I think the answer is chloroplast, centrosome, and ER.
Lecturer: "According to you, what is centrosome? Do centrosome surrounded by a plasma membrane? "
Student 3: (speechless).

Based on the interview we can identify one of the mental models of students, such as students tend to use intuition to make decisions in answering test questions. Students are not able to give the right arguments about ribosome and centrosome structure but still choose the incorrect answer. The results of the interview also provide information that we found students who do not understand the basic concepts even though they have learned for one semester. It has also been identified in some items about basic concepts, such as questions number 2, 3, and 4.

Students fail to understand their experiences caused essential concept. Lack of ability to understand main text ideas and less of using reasoning abilities were main factors in the construction of intuitive mental models. Construct a mental error model of specific content is caused by a partial representation and limited scope of phenomena understanding, and it will be a misconception (Besnard, et al., 2004; Strickland, et al., 2010; Wijaya, et al., 2016).

Another finding from interview provides information that we found students' misconceptions. Students can understand the basic concepts, but they are not able to apply concepts they have been mastered. Most students fail to apply concept on other conditions. Here are interview excerpts to question number 7.

Lecturer: "What is your answer about the role of biomass in respiration?"
Student 4: "I chose, it will grow because of etiolation process."
Student 5: "I also said to be generated increased because of the starch."
Student 6: "I answered not increasing and not decreasing."
Lecturer: "Please, try to be rethought, in dark conditions without light, plants perform respiration or not? If you do respiration, what does it mean? "
Student 4,5,6: "There was demolition biomass."

Those interview results indicated that students could find events of photosynthesis and respiration in plants. However, not all students can apply their understanding phenomenon represented. Student 4 has understood about etiolation phenomenon can occur in dark conditions, but she is not able to apply respiration process was occurs. Five students failed to understand that photosynthesis requires light energy. Six students understand the phenomenon of light energy needed for photosynthesis, but they are not able to apply that respiration is also performed in dark conditions.

Based on question number 5, 6, 7 and 8 on exposure results, it can be identified by students' misconceptions. They are only able to recognize the concept of the content, but they are not able to apply it. Respectively, based on their answers to questions describe that students are not able to apply the concept of respiration and photosynthesis in certain conditions.

The ability of concept application requires higher order thinking, like reasoning and to think systemically. Assaraf & Orion (2005) asserts that development of systemic thinking is needed to support high-level capabilities, such as applying, analyzing, and arguing. It implies the importance of exercise to develop the ability to think at the

high level for students to understand and be able to apply concepts they have learned.

The result of the interview focused on identification of other misconceptions. There is one category provides information that students have understood the basic concepts, but they are not able to associate the concept with other relevant concepts. Nonetheless, we found some students who successfully managed an understanding associated with essential concepts of cell biology. Here are excerpts of the interview to question number 9.

Lecturer: "How do you answer the question number 9?"

Students 7: "The oxygen of photosynthesis takes to burn glucose in mitochondria."

Students 8: "The same answer."

Lecturer: "Give me an argument for your answer?"

Students 8: "Diagram shows that there is a relationship between photosynthesis and cellular respiration processes. In photosynthesis generated oxygen which can be used for formation of energy through respiration".

Students 7: "The same answer, Sir. In photosynthesis generated oxygen. Oxygen can be used in cellular respiration process ".

Micro mental model students are also identified through question number 10, which is to question the relationship between glycolysis, Krebs cycle, and oxidative phosphorylation in cellular respiration, as well as the light reactions and the Calvin cycle in photosynthesis. Students can construct understanding relationships precisely.

The phenomenon of this study provides information; student teachers misconceptions are affected by experience and ability. Student misconceptions can be divided into three categories: basic concepts, application of concepts, and relationships between concepts. The understanding can be reconstructed through a cognitive conflict in the learning process. Duit & Treagust (2003) provides an alternative model of conceptual change to reconstruct understanding. Conceptual change model allows students perform cognitive conflict. Furthermore, students can reconstruct their understanding.

The results of diagnostic tests on basic concept show that most students can understand plasma membrane concept and provide the right answers. However, some other still have difficulty to understand the concept of plasma membrane existence. As in Question 1, we found only 12.5 % of students who answered correctly, and the others have misconceptions. Students' argumentation by interview describes that there are students who understand that ribosome is an organelle with a membrane. There are also students who thought that microtubules have a membrane, and vacuole did not have a membrane.

The same thing happened to simple diffusion concept across of plasma membrane. We found that 67.5 % of students can understand diffusion concept. However, we found students have the perception that simple diffusion across of membrane occurs caused by protein assistance or higher concentration of cell fluid. In the interview process, we found that student misconceptions were caused by fail students' perceptions of simple diffusion concept. Perception of students was troubled by different of processes in simple diffusion, facilitated diffusion, and osmosis.

Another finding shows that only 22.5 % of students can understand the concept of energy producing. Students are confident that energy producing occurs in respiration metabolism. Most of the other students have varying perceptions. We found students who think right that glucose molecule is converted into energy and O_2. But, we found another false answer that glucose molecules will react with ATP to form energy, glucose molecules transform ATP into energy and H_2O, and the potential energy of glucose will be changed into O_2.

Based on these findings we can take a premise that mental models of students about basic concepts of Cell Biology can be divided into two categories, i.e. students who have capabilities on basic concepts, and students who have misconceptions about basic concepts. Data show that we still found students who have not been able to understand basic concepts well.

The results of diagnostic tests on applying concept suggest that there are students who master on basic concepts and be able to apply concepts in new situations. Nonetheless, we found that students master on basic concepts but are not able to apply the concept in other situations. Only 15 % of students can master basic concepts and apply concepts in the problem of Question 4. They cannot apply their osmosis concept across of plasma membrane on a diagram or picture. When we asked about osmosis definition, students were able to answer correctly. But, when we asked the question on diagrams or pictures, students fail to apply the concept.

In Question 6, we asked about concept application of cellular respiration which occurs in the diet program. Only 12.5 % of students can

apply respiration concept. The other 77.5 % of students failed to apply respiration concept in the diet program. Interview results indicated that students who fail to apply the concept, they understand that respiration in mitochondria releases CO_2 and H_2O. However, they fail when we faced them with dietary issues related to cellular respiration concept.

Based on diagnostic tests results of concept application, we identified three categories of student mental models. First, the macro mental model represents the ability of basic concepts. Second, the micro mental model represents the ability to apply the concept. Third, intuitive or misconceptions mental model represents of inability to apply the concept.

Results of diagnostic tests of student ability to relate to concepts, we got information that there are students who appropriately able to associate with concepts. However, only 37.5% of students have exactly ability to connect respiration and photosynthesis concept in Question 8. The other students have varying abilities. Argumentation interviews described that students could understand respiration and photosynthesis concept, but they failed in linking these concepts. There are also student misconceptions about these concepts. Our data obtained, the same thing happened to Question 9.

We have identified kind of mental models about student ability to connect between concepts. There are three kinds of student mental models. First, the macro mental model represents of student mastery of basic concepts. Second, the micro mental model represents of student capabilities of concepts link, and intuitive or misconceptions as representing the failure of students understand.

A mental model is an internal representation of object, idea or process that allows cognitive abilities give a reason, an explanation, or predict phenomena for problem resolution (Janssen, et al., 2009; Wang & Borrow, 2011; Jansoon, et al., 2009; Johnson-Laird, 2013). A mental model is expressed through individual interpretation. Interpretation can be based on interactions with the environment, individual memory, learning outcomes of individual diagrams, or information on the article.

Lecturers or teachers should be paying attention to students' mental model before they give opportunities their students learn more. Some research results indicated that implementation of science learning in higher education is more concerned about comprehensive content (Wilson, et al., 2006; Bao, et al., 2009; Jansoon, et al., 2009). Fencl(2010) describes that teachers of colleges tend to provide extensive material to students in learning. The breadth of science content is required in science learning to understand natural phenomena, but these conditions are not enough to ensure that students will understand the entire content. Higher thinking should be a crucial goal in science. Some researchers assumed that conditional reasoning is a critical component of logical and deductive thinking that teachers could improve it in the learning process so that students could make some inferences (Markovits&Barrouillet, 2002; García-Madruga, et al., 2002; Santamaría et al., 2013). For meaningful learning, teachers may apply conceptual change scheme to improve students' mental model (Duit&Treagust, 2003; Michael, 2004, Mohammed, et al., 2010; Hegarty, et al., 2013; Albaiti, et al., 2016).

CONCLUSION

Student teachers' mental model about Cell Biology essential concepts can be divided into three categories. First, macro-mental models that represent students are only able to understand basic concepts but are not able to associate with concepts. Second, micro-mental models that represent students can understand basic concepts and connect between concepts. Third, intuitive-mental models or misconceptions that represent students are not able to understand basic concepts.

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