Biology Students’ Initial Mental Model about Microorganism

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Abstract: The purpose of this study was to identify biology students’ initial mental model about microorganism. This research used descriptive method with 32 sixth semester biology students at Biology Education Department-Universitas Pendidikan Indonesia as its respondents. Data was taken at the beginning of the 6th semester before respondents endure microbiology course. Instrument used to assess mental model was drawing-writing test in which it contains concepts such as structure of bacteria, archaea, virus, and fungi. Students were asked to describe their imagination about the structure of microorganisms and subsequently asked to explain the structure of microorganisms in writing through open-ended questions. Students’ response was then compared to scientists or experts’ mental models as the targeted mental model. Student mental models were categorized into five levels (levels 1-5), namely “there is no drawing/writing,” “wrong or irrelevant drawing/writing of question,” “partially correct drawing/writing,” “the drawing/writing that has some deficiencies,” and “completely correct and complete drawing/writing.” Results showed that the level of mental models through drawing or writing about the four concepts were varied. The highest level of mental models through drawing (D5) was found in the concept of bacteria, while the highest level of mental models through writing (W3) was found in the concept of bacteria, virus, and fungi. Mental model levels most commonly found in each concept through drawing-writing tests (D/ W) were bacteria (D2/ W2), Archaea (D1/ W1 and D2/ W2), virus (D3/ W3), and fungi (D2/ W1). From these results it is advisable to improve lectures and assessment strategy to enhance or complement students’ mental models about microorganisms.

Keywords: Mental model, biology students, microorganism, drawing-writing test.

1 Introduction

Microorganism plays a pivotal role for life on earth. Physically and chemically, microorganisms as one of the subjects in microbiology have a central role in biosphere [1]. Two important themes in microbiology are understand microorganism characteristics and function as well as applying these understanding for the benefit of human and earth [2]. Increasing use of microorganisms in health, food, and other industry, as well as in environment and certain aspects of biotechnology make students’ knowledge about this science aspect is essential. Genetic engineering and cell culture are closely associated with microbiology because microorganism (especially plasmid) is a tool to insert genes from one organism to another. Therefore, good understanding of microbiology concepts is vital for thoroughly understands these phenomenons.

Research on learners’ understanding and knowledge about scientific phenomenons has been done previously and some research has also delved on how learners conceptualize a biological phenomenon, but learners’ ideas about microbiology concepts is still understated in the
literature [3]. Results from several studies showed that all participants at each education level have different misconceptions about microbes [3,4]. The participants have alternative views about microbes’ size and morphology, associate microorganisms with horrible animals and assume that the shape of microorganisms is like that of small animals. The formation of misconceptions or alternative conceptions is undesirable in learning process, because students will draw the wrong conclusions, and it will negatively affect the process of constructing new knowledge. Learners’ conception about microbiology and interconnection between concepts can be fully detected by exploring their mental models.

Mental model is a depiction, personal idea, or internal representation of an individual about a phenomenon, a collection of ideas or concepts. Mental model provides an indication of the ideas believed by someone at a particular time, although it is not considered as a static entity. Through the interview and drawing-writing techniques, non-expert groups (students and teachers) already have a complex mental model, but it is not scientifically correct yet. Meanwhile, group of experts discussed more topics [5]. Through free word association test, drawing-writing techniques, and semantic differences attitude scale, Biology education students already have knowledge about some concepts of microorganism but there are concepts that they have not yet mastered, and misconceptions are still occurred. Through free word association test and drawing-writing techniques, biology education students mainly wrote about the definition of a virus and there are still misconceptions about virus [6].

Mental model as a dynamic representation that is never complete, continuously grow and develop along with the increase of information [3]. Mental models are generative because it can lead the student to new information, and they can subsequently use it to predict and explain [7]. Therefore, a teacher or lecturers need to know the initial level of students’ mental models before learning process begins in order to create more effective and meaningful learning.

The purpose of this study was to identify students’ mental models about the concept of microorganism’s (bacteria, archaea, viruses, and fungi) structure. The main goal of exploring mental model is to improve the quality of learning based on the description of students’ conception and the internal representation. This study was based on constructivism framework in which learners’ ideas about a concept, phenomenon, or event are usually obtained from previous experience both in everyday life as well as in formal occasions.

2 Research Methods

This research used descriptive method. Respondents for this study were 32 sixth semester students in Biology Education Department at Universitas Pendidikan Indonesia (UPI). Data was taken at the beginning of 6th semester before students endure microbiology course. Students’ mental model was probed by using drawing-writing test in which it contains several microorganism concepts such as structure of bacteria, archaea, virus, and fungi.

| Level  | Statement                                    | Drawing | Writing |
|--------|---------------------------------------------|---------|---------|
| Level 1| There is no drawing/writing                 | D1      | W1      |
| Level 2| Wrong or irrelevant drawing/writing of question | D2      | W2      |
| Level 3| Partially correct drawing/writing           | D3      | W3      |
| Level 4| The drawing/writing that has some deficiencies | D4      | W4      |
| Level 5| Completely correct and complete drawing/writing | D5      | W5      |

Adapted from Yayla and Eyceyurt [8].
Students were asked to describe their imagination about the structure of microorganisms, and they subsequently asked to explain the structure of microorganisms in writing through open-ended questions. Students’ answer was then compared with scientists’ mental model as the targeted mental model. Student mental models are categorized into five levels [8]. Five levels of mental models for each concept (structure of bacteria, archaea, virus, and fungi) are illustrated in Table 1.

3 Results and Discussion

Student mental model on microorganism structure (bacteria, archaea, virus, and fungi) through drawing and writing tests are depicted in Table 2 and 3. Students’ mental models through drawing test (D) show a higher level than writing test (W) except in structure of a virus concept. Student learning experiences during junior high school as well as in prerequisite courses for microbiology always used pictures to explain about microorganism. It appears that through an image, a mental model about microorganisms is easily represented. Image could represent a model expressed by a student about a particular phenomenon that exist in the public domain [3]. Moreover, in terms of time, drawing is much easier to use. Drawing techniques are also very good tools in collecting data from various perspectives. Furthermore, data in a form of image is also easier to internalized [3]. Figure 1-4 shows students’ mental model about microorganisms found during this study. Figure 1 illustrates students’ mental models about bacteria were at D2 to D5 level. Figure 2 depicts student mental models about Archaea were at D2 and D3 level. Figure 3 illustrates student mental models about virus at D2 and D3 level. Figure 4 depicts students’ mental models about fungi at D2, D3, and D4 level. Students’ mental models about microorganisms (writing test) are illustrated in Table 4.

| Bacteria | Archaea |
|----------|---------|
| W1       | W2      | W3       | W4 | W5 | W1 | W2 | W3 | W4 | W5 |
| D1 -     | 1       | -        | -  | -  | 11 | 1  | -  | -  | -  |
| D2 2     | 11      | -        | -  | -  | 4  | 11 | -  | -  | -  |
| D3 4     | 7       | 4        | -  | -  | 4  | 1  | -  | -  | -  |
| D4 -     | -       | 2        | -  | -  | -  | -  | -  | -  | -  |
| D5 -     | -       | 1        | -  | -  | -  | -  | -  | -  | -  |

D = Drawing, W = Writing

| Virus | Fungi |
|-------|-------|
| W1    | W2    | W3 | W4 | W5 | W1 | W2 | W3 | W4 | W5 |
| D1 1  | -     | 1  | -  | -  | 2  | -  | -  | -  | -  |
| D2 -  | 1     | 2  | -  | -  | 9  | 7  | 1  | -  | -  |
| D3 3  | 4     | 20 | -  | -  | 1  | 8  | 3  | -  | -  |
| D4 -  | -     | -  | -  | -  | -  | 1  | -  | -  | -  |
| D5 -  | -     | -  | -  | -  | -  | -  | -  | -  | -  |

Based on Table 2 and Table 3, one student reached D5 mental model for structure of bacteria concept, one student achieved D4 mental model for fungi concept, although from four concepts
about microorganism structure, mental models were mostly at D3 (partially correct drawing) level. It means that for drawing test, only one student achieved the targeted mental model (in line with experts or scientist's mental model) while mental models for writing were still in D3 level. Compatibility between drawing and writing level were found in structure of a virus mental model (D3/ W3, 20 respondents). This result suggested that good image representation does not reflect equally good verbal representations.

The highest mental model level from writing test (W) is found at W3 level for structure of bacteria, virus, and fungi concept, while mental models for structure of Archaea were still at W2 level. These results indicated that verbal representation is harder to store in long-term memory compared when it is in a form of image.

Based on Table 2 and Table 3, the levels of student mental models for structure of bacteria and fungi concepts were higher. This was because students have been studying these concepts since junior high school. In high school, those concepts were discussed in an even more comprehensive manner as a form of compliance to the curriculum implemented in Indonesia. In college, students are getting the information about the structure of bacteria in general biology and cell biology courses. The structure of fungi has been studied in more detail in Botany Cryptogame course, while archaea and virus were studied in 10th grade [9]. None of the students could describe or write characteristics of archaea cell walls, because they did not obtain this information in high school. In prerequisite courses (general biology and cell biology), they also did not get information about archaea. Similar case were also found for virus concept.

Figure 1. Students mental model about bacteria structure, (a) irrelevant drawing/D2, (b) partially correct drawing/D3, (c) drawing that has some deficiencies/D4, and (d) completely correct and complete drawing/D5.

Figure 2. Students mental model about archaea structure, (a) irrelevant drawing/D2 and (b) partially correct drawing/D3.
Figure 3. Students mental model about virus structure, (a) irrelevant drawing/D2, and (b) partially correct drawing/D3.

Figure 4. Students mental model about fungi structure, (a) irrelevant drawing/D2, (b) partially correct drawing/D3, and (c) drawing that has some deficiencies/D4.

All of the students choose to describe bacteriophage virus structure. Similarly, most students choose to depict Basidiomycetes fungi (56%) while the remaining students choose to illustrate molds. There was not even one student decided to describe yeast. Students’ initial mental model about microorganisms is strongly influenced by the process of inserting new information into existing schemas. Initial mental model was resulted from mental model evolution in which prior knowledge converges with new information to form new mental models. This mental model-building process can be through a model-reinforcement, elaboration and revision model, or model-rejection [10]. Drawing-writing is an efficient technique to reveal student's learning. This technique is an important technique because it enables researchers to collect data about learners’ mind, understanding, perspectives and attitudes [4].

Table 4. Students mental model about microorganism structure through writing test.

| Microorganism | Writing |
|---------------|---------|
| Bacteria      | Bacteria is a unicellular organism with peptidoglycan cell wall (W2). Bacteria is microorganism with peptidoglycan cell wall, do not have |
core membrane, and has a circular DNA (W3).

Archaea
Archaea has similar characteristics with bacteria (W2).

Virus
Virus consisted of capsid (W2).
Virus has DNA/RNA protected by capsid (W3).

Fungi
Fungi has a cap forming-hypha structure and do not have chloroplast (W2).
Fungi is a eukaryotic organism, do not have chloroplast, consisted of hypha, and this hypha formed a structure called mycelium (W3).

New ideas are assimilated or accommodated into the existing scheme by creating a new scheme. This may cause cognitive dissonance if new ideas are scientifically accurate but are not consistent with the scheme that learners have, in which rejection of new ideas may also occur. When new ideas are accepted and connected with existing ideas, learning occurs by increasing and improving learners’ mental models, although this is of course will take time [3]. Based on research results, it is advisable to develop a strategy to correct or improve student mental models about microorganism so that learners’ mental models will be in compliance with targeted mental model. Course’s strategy development also needs to be supplemented with appropriate assessment to encompass students’ mental model.

4 Conclusion
Results showed that the level of mental models through drawing or writing about four microorganism concepts were varied. The highest level of mental models through drawing test (D5) was found in the concept of bacteria, while the highest level of mental models through writing test (W3) was found in the concept of bacteria, viruses, and fungi. Mental model level most commonly found in each concept through drawing-writing test (D/W) were bacteria (D2/W2), Archaea (D1/W1 and D2/ W2), virus (D3/ W3), and fungi (D2/ W1). From these results it is advisable to improve lectures and assessment strategy to enhance or complement students’ mental models about microorganisms.

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