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CHANGES IN PROSPECTIVE BIOLOGY TEACHERS' MENTAL MODEL OF VIRUS THROUGH DRAWING-WRITING TEST: AN APPLICATION OF MENTAL MODEL-BASED MICROBIOLOGY COURSE

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ABSTRACT

The main goal of the present research was to analyze the prospective biology teachers' mental model about virus through the conduction of drawing-writing test on a modified model-based learning in a Microbiology course. The research method was quasi-experiment with pretest-posttest control group design. A total of eighty-one fifth-semester students separated into experiment and control group participated in the current study. The experiment class participated in a microbiology course-based mental model, in which the course program was developed by combining the constructivism learning stages and model-based learning framework featured with mental model, while the control class experienced course with conventional methods. A mental model test of drawing-writing of structure of viruses was employed as the main research instrument. The instrument also was featured with a rubric that is used to indicate the five levels of student's mental model. The main analysis was done through descriptive interpretation based on the frequency of higher levels of mental model showed by students in the different classes. Based on the results, there was no difference between students in experiment and control class in the pretest, which showed that most of the students in both class were concentrated in not higher than level D3 and W3 (partially correct drawing/writing). However, after an intervention, the experiment class showed a dramatically increase in the frequency of students mental model that belong to level D5/W5 (completely correct and complete drawing/writing), while the control group was found stagnant concentrated in the level D3/W3. The results are discussed with the connection to the advantages of Microbiology course-based mental model in student's conceptual change and the use of drawing-writing test in capturing changes in student's mental model about scientific concepts.

Keywords: mental models, drawing-writing test, virus, biology education program, microbiology course

INTRODUCTION

Microbes or microorganisms are known as the central part of microbiology course in the higher education level, both biology and biology education program. The importance of the study of microorganisms comes from the nature of microorganisms itself in which abundance in number, living in broad range of areas, and highly related to human's daily life (Tortora et al., 2009). To the extent, scientists have also considered that microbiology has a tight connection with other significant disciplines, such as modern biotechnology, genetic engineering and bioprocess, evolution, and molecular biology (Schaechter et al., 2004). By considering the issue of the nature of

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microorganisms and microbiology in which it is related to human's life and the development of other related-disciplines, biology education scholars contend that understanding microorganism is necessary for biology students (Kelwick et al., 2015) and even more crucial for prospective biology teachers, given they will deliver their understanding to the students. Prospective teachers with sufficient and scientific understanding about microorganisms can prevent them to teach alternative conceptions to students (Quilin & Thomas, 2015), as what Smith et al. (2008) stated that most of the misconceptions that in-service teachers have are originated from their undergraduate life.

In the past decade, many have been scrutinizing whether prospective biology teachers have sufficient understanding about microorganisms or not (e.g. Kurt, 2013). In addition, some even have been exploring whether prospective biology teachers, primary and secondary students and in-service teachers have misconceptions or alternative conceptions about microorganisms or not (e.g. Byrne, 2011; Jee et al., 2013). However, most of previous studies have found that prospective biology teachers, and in-service biology teachers still do not have sufficient knowledge of microorganisms and have misconceptions about microorganisms. The misconceptions or alternative conceptions found in the previous studies are due to the students' inability to connect a concept with another existing in their mind (Kurt et al., 2013). These conceptions and alternative misconceptions are undesirable in the learning process since learners will draw up wrong conclusions and will negatively affect the process their new knowledge construction. Buckley and Boulter (2000) suggested the use of mental-model in order to detect students' conceptions about scientific concepts and the interconnection between concepts within a scope of particular discipline. Thus, in the current study we attempt to use the concept of mental model in detecting prospective biology teacher's conceptions of microorganisms and the interconnection between concepts within microbiology scope.

Scholars have been defining the meaning of mental model. However, they have similarities in the key concept of the meaning of mental model. One noted definition of mental model was defined by Buckley and Boulter (2000). They define mental model as a depiction, personal ideas, or an individual's internal representation of a phenomenon, a collection of ideas or concepts. Buckley and Boulter (2000) added that mental model could give an indication of what one understands about a concept at a certain point and time, as well as their knowledge and belief in the concept. In addition, Norman (2014) described mental models as internal representations built by a person to provide a rational explanation of the phenomenon of experience. Coll (2009) argued that mental model is used to produce simpler concepts, providing support for simulation and visualization, also, provide explanations for scientific phenomena. However, Stains and Sevian (2014) revealed that knowing one's mental model is something that is difficult to do if it is not expressed in the form of concrete things. Therefore, Buckley and Boulter (2000) emphasized the necessity of expressed mental models through various means, through a drawing-writing test, for instance. Analyzing the expressed model can provide a perception of a person's conceptualization of events, phenomena, or concepts. Thus, information about one's knowledge about and understanding of the concept can be obtained.

In regards to the discussion on the relationship between the expressed model, the mental model, and the person's perception of the phenomenon, it is an iterative relation. The expressed model can provide an insight into one's mental model, but along with the additional experience gained through both direct and indirect learning, the perception of a phenomenon will change, resulting in different outcomes of the mental model, and end up with a different expressed mental model (Byrne, 2011). The mental model is expressed through an individual interpretation which can be based on interaction with the environment, individual memory, individual learning diagram results, or information on the article (Saptono et al., 2017). Students will experience mental model changes gradually because of the influence of the obtained information. The mental models of students tend to be unstable, inconsistent, and ever-changing as more information is acquired or recalled (Khasanah et al., 2016). Research has shown that students' mental model of phenomena or scientific entities is limited by the students' assumptions about the entities and processes existing in the phenomenon or entity (Stains & Sevian, 2014).

Recalling back the discussion about the understanding of microorganisms, in which a part of it is the understanding of viruses, previous studies showed that mental model about viruses in non-expert groups (students and teachers) had a complex but scientifically incorrect mental model compared to expert groups (Jee et al., 2013). A study by Jee et al. (2013) on future Biology teachers in Turkey already found that they had some

knowledge about some microbial concepts, but there still existed misconceptions. They mostly wrote the definition of a virus to answer the question of virus concept, also, misconceptions were still there (Kurt, 2013, Kurt & Ekici, 2013). Several studies have shown that students often had an inaccurate concept of structure of a virus and function (Jones et al., 2013).

The previous studies show that drawing techniques are most often used to reveal participants' conceptual structures about microbial concepts. The drawing an illustration is one of the oldest methods to record the data. The same techniques were also employed in a research conducted by Dikmenli (2010) investigated biology student teachers' misconceptions of cell divisions using drawings and interviews. An analysis of drawings and interviews suggested that biology student teachers have a series of significant problems and misconceptions regarding cell division and structuring of concepts in a meaningful manner. The research results of Hamdiyati et al. (2017) on Biology students' early mental models show that the level of mental models through drawing and writing on the four concepts vary greatly. The highest level of the mental model through the drawing test (D5) was found in the concept of bacteria, while the highest level of the mental model through writing test (W3) was found in the concept of bacteria, viruses, and fungi. Therefore, it can be said that picture is the right tool to use in determining the image/ description, mental model, conceptualization, misconception, knowledge, and ideas of students (Oren & Ormanci, 2014).

New ideas are assimilated into an existing or accommodated scheme by creating a new one. This may lead to cognitive discrepancies if, for instance, new ideas are scientifically accurate but inconsistent with the schemes owned by students, while rejection of new ideas is also possible. When new ideas are accepted and linked to the existing ideas, learning processes will enlarge and improve the students' mental models, though this definitely takes time (Núnez-Oveido et al., 2008; Byrne, 2011).

Changes in the complexity of a person's mental model can be analyzed/facilitated through a particular learning model. In this study, the researchers modified a typical microbiology course by focusing it more on the mental model and using drawing-writing test assessment as one way to externalize an individual's mental model, so as to provide an overview of the mental model development before and after the course program on the virus subject. In addition, future Biology teachers must understand the basic concepts of Biology and have a great responsibility of their future students' understanding of the conceptual structure of biological concepts, including the concept of structure of a virus. Having appropriate microbiology lessons for the 21st-century curriculum will help students understand and appreciate the importance of microorganisms in everyday life so that they can make informed decisions now and then (Byrne, 2011).

Overall, the purpose this study was to determine the improvement of student's mental model through drawing-writing test in a modified Microbiology course. However, research on how to analyze the change mental models of the students about virus used specific learning strategies has never been done previously.

METHODS

The method of the present research adopted quasi-experiment method with pretest-posttest control group design. One class as the experiment class was the class using microbiology course-based mental model and on the other hand the control class used the conventional methods (discussion, lecture, and questions-answers). The sample in this research included 2 classes, 39 students of the experimental class and 42 students of the control class. Both classes consisted of 5th-semester students of Biology Education program at a public university in West Java, Indonesia. The data of both classes were collected before and after the students join the lectures. The subject of the virus was limited to viral structural materials. The students were asked to describe their imagination about the structure of the virus and explain the structure in writing through open-ended questions.

In the experimental class, the students were divided into 13 small group consisting 2-3 students each. This modified microbiological learning has several stages (syntax). The course program was developed by combining the constructivism learning stages according to Duit et al. (2007) and model-based learning framework by Rea-Ramirez et al. (2008). The class was began with the exploration of students' preconceptions in order to find out how deep the students' knowledge about microorganism concepts is. Next, restructuring of the concept was conducted. At this stage, the students were led to achieve a target mental model or accomplish a higher level mental model through guided questions on student activity sheet. Following stage, the students were asked to apply the new acquired

concept into daily life situation. This modified microbiological learning ended up with reviewing and evaluating the new ideas whether they fit or not with the targeted mental model. Through these learning stages, the students can improve their mental model of the structure of a virus so as to achieve the target mental model according to the experts' mental models. The illustrations of the course are provided in Table 1. The mental model levels were drawn up from an implementation of drawing-writing test. Students' answers were categorized based on the indicators mentioned in the Table 2, also every indicator is assigned to the specific level of students' mental model. The results of the present study were represented in the form of tables and graphs. Besides, it is also described with some examples of students' answers representing each level of the mental model, both drawing and writing.

Table 1. The Syntaxes of Microbiology Course-Based Mental Model on Virus Topic (Excerpts of the 1st Sub-topic among 7 Sub-topics)

Lecture Stages	Lecturer's Activities	Students' Activities
Analyzing the learning sources	Providing suggestions of the microbiology textbooks used before the lecture begins.	Providing the textbooks as suggested by the lecture
	Providing learning media	
Assignment	Assigning the students to make concept maps (at home) before the lecture.	Providing the textbooks as suggested by the lecture
	Checking the maps created by the students via email.	
Learning Stages (Syntax) of Lectures		
Introduction	Preparing the students to be ready and interested in joining the lectures	Showing the readiness and interest in joining the lecture
	Explaining the objectives of the lectures	
Preconceptional exploration and Students' conception exploration of the 1st sub-topic (general structure of the virus)	Facilitating the students to explain the outline of the topic as they know	Stating initial knowledge about the topic (virus) classically.
	Guiding the student to decide essential concepts of the general structure of virus sub-topic	Stating essential concepts of the general structure of virus sub-topic classically.
Restructuring the concepts	Reminding the students to use basic source microbiology textbooks that have been specified in the lesson to restructure the concepts.	Using basic source microbiology textbooks that have been specified in the lesson to restructure the concepts.
	Asking referring questions to restructure the concepts.	Being able to restructure the concepts under the lecturer's guidance through the referring questions.
	Encouraging the students to achieve early mental model changes to M1, M2 ... Mn in accomplishing the target mental model.	Showing the changes of the early mental model to M1, M2...Mn in accomplishing the target mental model.
Applying new concepts	Encouraging the students to apply new ideas constructed to other contexts or real-life/everyday context through application questions.	Informing the examples of applications of new concepts constructed in real-life/daily life.
Reviewing and evaluating new ideas	Reviewing the target mental model according to the experts' mental model on the general structure of the virus	Listening to lecturer's explanation of the target mental model according to experts on the general structure of the virus

Table 2. Mental Model Categories for Drawing-Writing Test Results

Level	Statement	Drawing	Writing
Level 1	There is no drawing/writing	D1	W1
Level 2	Wrong or irrelevant drawing/ writing	D2	W2
Level 3	Partially correct drawing/writing	D3	W3
Level 4	The drawing/ writing had some mistakes	D4	W4
Level 5	Thoroughly correct and complete drawing/writing	D5	W5

(Modified from Yayla & Eyceyurt, 2011)

RESULTS AND DISCUSSION

The future Biology teachers' mental models of the structure of a virus through the application of mental model on microbiological learning and through the use of drawing-writing test assessment can be seen in Table 3 and Table 4. Figure 1 and 2 show the changes of drawing and writing levels based on pre and post-test result both in experimental and control groups. Figure 3 is an example of the structure of a virus drawing test results at level 2, 3, 4, and 5.

According to Table 3, the pretest results on the highest level of the experimental class' mental model level were at D2 / W2 and D3 / W3, respectively 10 people each. The highest level achieved in the experimental group was only at D3 / W4, while the lowest level was at D1 / W1. In the control group, the highest mental model level was found in D3 / W2 (13 people). The highest level accomplished in the control group was only at D4 / W3, while the lowest level was at D2 / W1. Based on the pre-test results, it can be said that the prior knowledge about the structure of a virus of the control class was better than experimental class. It is important for a teacher to know his/ her students' prior knowledge to determine the best learning strategy. This is in accordance with the statement of Kurnaz & Emen (2013) that early knowledge of students important to be used as consideration in preparing learnings.

Table 4 shows the final test results of the experimental class on the mental model level. There were 10 students achieved D5/W5 and it was recorded as the highest. Meanwhile, the lowest level was at D2 / W2. In the control class, the students' mental model levels were found at D3 / W3 (19 students). The highest level achieved in the control group was D5 / W4 (1 student), while the lowest level was at D2 / W1 (1 student). These results indicated that the implementation of the mental model application in microbiological learning could improve the prospective Biology teachers' mental model levels. The increasing of the mental model levels was due to the assistance was given by the lecturer facilitated by the Students Activity Sheets at each stage/syntax of the lecture, resulting in the reconstruction of the students' knowledge-based their prior knowledge. The increasing levels of the students' mental models indicated improving mastery concepts of the students about structure of a virus. It can be inferred from the results that the future Biology teachers had different abilities in constructing and applying the mental models they have to complement or improve their initial mental models in order to achieve the targeted mental models. The target mental models were consensus mental models and in accordance with the opinions of the experts. This is in line with previous studies,such as study conducted by Albaiti et al. (2016), Coll (2009), and Khasanah et al. (2016), in which explain that the ability to construct and use mental models can influence the conceptualization of learners.

Table 3. Prospective Biology Teacher' Mental Models of Virus Structure (Pretest)

	Experimental					Control				
Level	**W1**	**W2**	**W3**	**W4**	**W5**	**W1**	**W2**	**W3**	**W4**	**W5**
D1	4	0	0	0	0	0	0	0	0	0
D2	2	10	3	0	0	1	12	5	0	0
D3	2	7	10	1	0	0	12	11	0	0
D4	0	0	0	0	0	0	0	1	0	0
D5	0	0	0	0	0	0	0	0	0	0

D = Drawing, W = Writing

Table 4. Prospective Biology Teachers' Mental Models of Virus Structure (Posttest)

	Experimental					Control				
Level	**W1**	**W2**	**W3**	**W4**	**W5**	**W1**	**W2**	**W3**	**W4**	**W5**
D1	0	0	0	0	0	0	0	0	0	0
D2	0	3	0	0	0	0	1	1	0	0
D3	0	1	2	5	0	0	14	19	2	0
D4	1	0	3	3	5	0	1	2	0	0
D5	0	0	0	6	10	0	0	1	1	0

D = Drawing, W = Writing

The tendency to increase the level of the mental model through drawing and writing in both groups is clearly seen in Figure 1 and 2. Figure 1 shows prospective Biology teachers' drawing skill. The mental model level of the students through drawing in both study groups tended to increase at the post-test. At the pre-test, there was no one of the experimental class students reached level 5 (completely correct and complete drawing/writing). However, there were 16 prospective Biology teacher who reached the D5 mental model level at the post-test. On the other side, the post-test results show there were only 2 prospective Biology teacher who accomplished D5 mental model level in the control class.

Figure 2 informs the writing skill of the prospective Biology teachers. The mental model level of the students through writing in both study groups tended to increase at the post-test. At the pre-test, there was no one of the experimental class students reached level 5, the same thing happened in the control class. The post-test results were 15 prospective Biology teacher accomplishing D5 mental model level, while there was no single student achieving D5 at the post-test in the control class.

Based on Figures 1 and 2, the pre-test results generally did not differ significantly between the two experimental groups. Paying attention to each level, the experimental class had more D1 and W1 than the control class at the pre-test. However, the post-test results show that the experimental class had a higher mental model level, nearly hit the target. This suggested that the application of mental model on microbiological learning may lead to changes in the learners' mental models through disconfirmation mode, modification mode, confirmation mode, and addition mode. This is in line with Buckley & Boulter (2000) who revealed that the early mental model information of his research results was the model evolution where the existing prior knowledge along with new information formed a new mental model through model-reinforcement, model-elaboration & revision, or model-rejection.

Each stage (syntax) of the modified model-based microbiological learning facilitated the changes of the students' mental model. The exploration of the students' initial ideas was done during the preconception exploration stage. This is important as the information for lecturers to lead the students hit the target mental models. Lecturers should be ready to facilitate the dynamics of the students' mental model changes either in the low, medium, or high. This is supported by Hamid's (2016) opinion that teachers should be explorative of the students' basic ideas of a concept so that their ideas can be used as a starting point to lead them to the experts' ideas. The mental model is dynamic and sustainable, means that the mental model can be modified if there is new information inserted into the old mental model. This indicates mental model's nature of dynamic and sustainable (Wiji et al., 2014). Implementation of the modified Microbiology course on the subject of bacteria shows a change of mental model level from transitional to close to extended and extended (Hamdiyati et al., 2018).

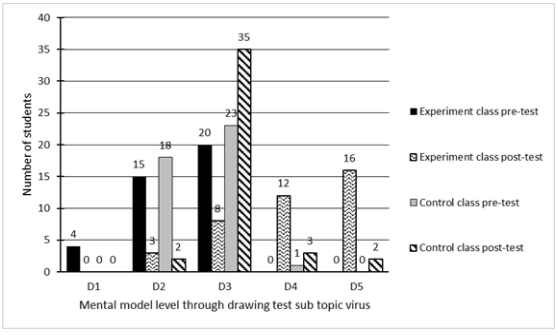

Figure 1. The Mental Model Levels of Prospective Biology Teachers on Structure of a Virus Through Drawing Tests in the Experimental and Control Classes (Pre and Post-Test).

Figure 3 tells some examples of the students' drawing results at the mental model level 2, 3, 4, and 5. The level 2 drawing test results show that the students only drew a sphere and an image resembling inappropriate bacteriophage. The level 3 drawing test results indicate that the students only described the bacteriophage virus by giving the incomplete description of parts of the structure of a virus and misconceptions were still there. The level 4 drawing test results show that the students drew two structures of the naked virus and enveloped virus equipped with more complete descriptions of the image, but the description of the enveloped virus was less precise. The level 5 drawing test results indicate that the future Biology teachers drew the complete structure of the virus, there was a naked virus and a membrane virus. At the pre-test, the prospective teacher students both in the control and the experimental class drew bacteriophage structure of a virus only. This was due to their learning experiences in studying the virus during high school, in which only discussing bacteriophages. High school textbooks discuss the life cycle of bacteriophage as an example of a naked virus. Some high school textbooks also tell about the enveloped virus and describe the life cycle of the HIV virus.

The prospective Biology teachers seemed to have no difficulty in drawing the virus. This was because they are used to draw biological objects in the previous course (in semester 5) before joining the Microbiology course. Drawing is a common learning activity that is always be done by students in science/biology lesson since primary high school. Drawing mostly used to record observation data such as organism's cells, tissues, organs, and organism/ microorganism specimens. Images can represent a model expressed by a person about a particular phenomenon existing in the public domain, including the ability to write the virus structure and shows the level of a person's mental model (Leutner et al. 2009; Zhang, 2008; Yayla & Eyceyurt, 2011). These results are different from the results of research on Biology teacher candidates in Turkey. Most of the prospective teachers have difficulties in describing animal and plant cells (Celiker, 2015). Nevertheless, the research result of Ormanci & Ören (2011) that 80% of the pre-service science and technology teachers stated that they would like to employ the drawing method during their in-service career.

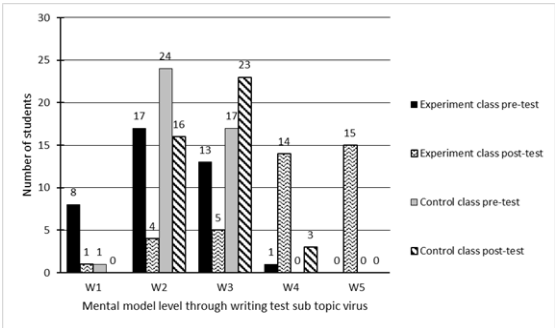

Figure 2. The Mental Model Levels of Prospective Biology Teachers on Structure of a Virus through Writing Tests in the Experimental and Control Classes (Pre and Post-Test).

Examples of prospective Biology teachers' mental models on structure of a virus through writing tests can be seen in Table 4. The level 5 of writing can be achieved by the students if they are able to write the virus structure. Students should explain the structure of naked and enveloped virus, including the core material presented in the virus. In the pre-test, many students explained bacteriophage only. After the new treatment was given, there was a change in the students' mental model about the structure of the virus, including naked and enveloped virus. This indicates that the application of mental model on microbiological learning provided meaningful learning. The students obtained new information and synergized the old knowledge relevant to the new information in constructing a new mental model. Jia (2010) stated in forming a correct model, the students should be given opportunities to test the model.

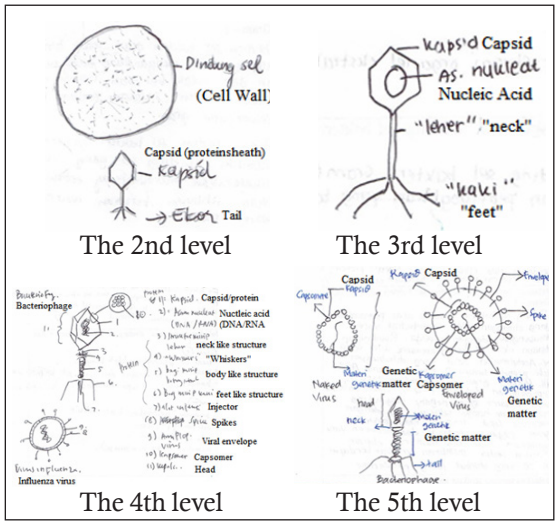

Figure 3. The Examples of Drawing Test Results on Structure of a Virus at Level 2, 3, 4, and 5.

The identification of prospective Biology teachers' mental models through drawing-writing test can provide information about ideas of the students. The results of the pre-test through drawing-writing served the initial information on how deep the students the knowledge. In Biology, drawing skill is not a something new that the students must have. However, combining the writing and writing skill to explain an idea is rarely found. Integrating the drawing-writing instruments to see the students' mental models for generating ideas is in line with Oren & Ormanci's (2014) and Nugraha (2018). Stains & Sevian (2014) also employed the drawing-writing instrument to find out the mental model of diffusion concept. Images with explanations will dig the students' deeper ideas about a concept. Interpretation of images and interviews also provides effective results in biology course (Dikmenli, 2010).

Table 5. The Examples of Prospective Biology Teachers' Mental Models on Virus Structure through Writing Test.

Mental Model Levels	Writing
W2	Viruses contains only genetic material without cells. The virus penetrates with its tail fibers.
W3	Viruses have a capsid acting as a protective nucleic acid composed of proteins. The nucleic acid in the virus can be either RNA or DNA. Having a neck-like structure serves as a conduit for the discharge of nucleic acids and a leg-like structure serves as a place of attachment to the host.
W4	Viruses consist of 2 main parts; capsid and nucleic acid (RNA or DNA). Capsid consists of structural proteins (capsomers). Some viruses have envelopes. Bacteriophages have neck-like and leg-like structures.
W5	Viruses are composed of genetic material (RNA / DNA) and proteins. Capsid is a sheath of protein that protects the viral genetic material. The capsid is composed of capsomers. There are 2 types of viruses; naked virus and enveloped virus. Bacteriophages have head -like structures containing genetic material.

Based on the above explanation, we know how important the integration between drawing skill as visual ability and writing skill as verbal ability is. Then how both verbal and visual information are integrated? Mayer (2009 in Quilin & Thomas, 2015) proposed his cognitive theory of multimedia learning stating that a student create his/her mental model in working memory by performing three cognitive tasks which are as follows: 1) selecting verbal and visual information from the material presented (sensory processing) and from prior knowledge (long-term memory); 2) organizing verbal and visual information; and 3) integrating those elements into the mental model. The importance of the drawing-writing test is reinforced by the opinion of Kurt et al. (2013) who explained that this test is very effective in generating natural and quality data about students' opinions, understanding, and posture about certain concepts.

CONCLUSION

The results show that the students in the experimental class had better improvements on their mental model level through drawing-writing test after joining the Microbiology course-based mental model on virus structure concept, compared to the students in the control group. The highest mental model level of the experimental class after the treatment was D5 / W5. There was a level 1 of writing and a level 4 of drawing (D4/ W1) found in the experimental class. No one of the students in the control class reached D5 / W5 level. The results of this study indicated that the drawing-writing tests were effective to see changes in the prospective Biology teachers' prior mental model toward the target mental model. The drawing-writing skills on the structure of viruses are the expressions of the prospective Biology teachers' mental models of the concepts.

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