Analysis of High School Student's Mental Model on Virus: Representation of Students' Conceptions

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Abstract: In facing the challenges of the 21st century, mastery of concepts is needed by students. Mastery of a person's concept can be known by analyzing his mental model. This study aims to determine the mental model of high school students on virus concepts. The method used is descriptive method. Respondents in this study were 30 high school students in class X. Analysis of students' mental models was carried out using drawing-writing techniques, concept maps, interviews, and questionnaires. The drawing-writing technique was focused on knowing the students' mental models about the concept of virus structure and reproduction, while the concept map was used to analyze the entire concepts of the virus. The results showed that students' mental models were still low and students' understanding of viruses was not yet structured. Based on the results of the drawing-writing test, the majority of students' mental models on the concept of virus structure were at the D3W3 level. In the concept of non-enveloped virus reproduction, the majority of students are at the D5W5 level. In the concept of enveloped virus reproduction, the majority of students are at the D1W1 level. The results of the students' mental models analyzed by concept maps were at the developing and transitional levels. The results of the comparison of students' mental models with expert mental models show that students' mental models are not close to expert mental models. Students' mental models are generally incomplete and have no connection between one concept and another.

Keywords: Mental models; Drawing-writing; Concepts map; Virus.

Introduction

Science and technology in the 21st century is growing rapidly. This development will certainly require everyone to have qualified knowledge and skills in order to face the challenges of the times. According to the Partnership for 21st Century Skills (2019) the key subject of 21st century learning is mastery of major subjects, one of which is science. So, it is important for students to know the concepts that exist in science lessons. To find out the conception of knowledge that exists in a person can be known by analyzing the mental model (Jalmo & Suwandi, 2018; Hamdiyati et al., 2018a; Varela et al., 2018; Jee et al., 2015).

Mental models can be defined as understandings related to a concept or idea contained within the individual, where to express it requires a certain tool or technique (Hamdiyati et al., 2018a; Chang., 2007). Mental models can be measured using drawing-writing techniques (Hamdiyati et al., 2018a; Jalmo & Suwandi,

2018) and by using concept maps (Chang, 2007; Hamdiyati et al., 2018b).

Research on mental models has been carried out by Hamdiyati et al., (2017) on viral concept. The results showed that the majority of the mental model levels of prospective biology teachers were at the D3W3 level. Based on the results of this study, this study will also analyze mental models on virus concepts, but it is carried out on high school students. This is because the mental model of the virus in high school students is still unknown. Moreover, virus concepts are considered as one of the difficult school biology lessons (Fauzi & Mitalistiani, 2018; Hadiprayitno et al., 2019).

In the research of Hasibuan & Djulia (2017) the majority of students had difficulty in explaining virus replication and virus structure. Students' knowledge of the concept of a virus is very important to know, considering that the world is currently experiencing a Covid-19 pandemic caused by a virus. Therefore, a study entitled "Analysis of the Students' Mental Model on Virus Concepts".

Method

The method used in this research is descriptive method. The subjects in this research were 30 tenth grade student who had studied virus concepts. The school used in this research is one of the senior high schools in the city of Bandung. The instruments used are drawing-writing instruments, concept maps, questionnaires, and interviews. Mental model data with drawing-writing technique will be categorized into 5 levels (Table 1) while the concept map will be categorized into 4 levels (Table 2).

Table 1. Categories of Mental Models on the Drawing-Writing Test ((Hamdiyati et al., 2018a)

Level	Statement	Drawing	Writing
Level 1	There is no drawing/writing	D 1	W 1
Level 2	Wrong or irrelevant drawing/writing	D 2	W 2
Level 3	Partially correct drawing/writing	D 3	W 3
Level 4	The drawing/ writing had some mistakes	D 4	W 4
Level 5	Thoroughly correct and complete drawing/writing	D 5	W 5

Table 2. Categories of Mental Models through Concept maps (Hamdiyati et al., 2018b)

Level	Statement
Level 1 (emergent)	Less than 25% of the essential concepts are raised, the relationships between concepts are fully and correctly illustrated with the right connector, hierarchy and cross-links are also appropriate.
Level 2 (transitional)	Only 25-50% of the essential concepts are raised, the relationships between concepts are fully and correctly illustrated with the right connector, hierarchy and cross-linking are also appropriate.
Level 3 (close to extended)	Only 51-75% of the essential concepts are raised, the relationships between concepts are fully and correctly illustrated with the right connector, hierarchy and cross-links are also appropriate.
Level 4 (extended)	More than 75% essential concepts are raised, the relationships between concepts are fully and correctly illustrated with the right connector, hierarchy and crosslinks are also appropriate.

Result and Discussion

The findings of the students' mental models analyzed by drawing-writing techniques are presented in the form of a frequency distribution table as in Table 3 and the results of students' mental models analyzed by concept maps are presented in Table 4.

Table 3. Frequency Distribution of Students' Mental Models through Drawing-Writing Test

Concept	Level	W1	W2	W3	W4	W5	Total	%
Virus Structure	D1	1	0	1	0	0	2	6.67
	D2	0	0	0	0	0	0	0.00
	D3	0	5	10	5	0	20	66.67
	D4	0	0	0	0	0	0	0.00
	D5	0	0	5	3	0	8	26.67
	Total	1	5	16	8	0	30	100.00
	%	3.33	16.67	53.33	26.67	0.00	100.00	
Non-Enveloped Virus Reproduction	D1	0	1	1	0	0	2	6.67
	D2	0	1	1	0	0	2	6.67
	D3	0	4	2	2	0	8	26.67
	D4	0	1	1	4	3	9	30.00
	D5	0	0	1	2	6	9	30.00
	Total	0	7	6	8	9	30	100.00
	%	0	23.33	20.00	26.67	30.00	100.00	
Enveloped Virus Reproduction	D1	18	3	1	0	0	22	73.33
	D2	0	1	1	0	1	3	10.00
	D3	0	1	2	1	0	4	13.33
	D4	0	0	0	0	0	0	0.00
	D5	0	0	0	0	1	1	3.33
	Total	18	5	4	1	2	30	100.00
	%	60.00	16.67	13.33	3.33	6.67	100.00	

Tabel 4. Students' Mental Model through Concept maps

Level	Jumlah Siswa	Persentase (%)
Level 1 (emergent)	29	96.67
Level 2 (transitional)	1	3.33
Level 3 (close to extended)	0	0
Level 4 (extended)	0	0

Based on the data in Table 3, it can be seen that the majority of students' mental models about the structure of the virus are at the D3W3 level (33.33%). The majority of students only described the structure of bacteriophage viruses (non-enveloped viruses). This shows that students' understanding of the structure of the virus is only partially correct. This is in line with the research of

Hamdiyati et al, (2017) that the majority of the mental model levels of prospective biology teacher students on the concept of virus structure are at the D3W3 level. The structure of the virus described by the majority of prospective biology students is a bacteriophage.

The highest level of students' mental model of the structure of the virus was at the D5W4 level (10.00%). This shows that students correctly know the image or shape of the virus (enveloped virus and non-enveloped virus) and also know the components that make up the virus, but students are less able to explain the components that make up the virus body correctly. An example of a student's mental model of the structure of a virus is presented in Figure 1.
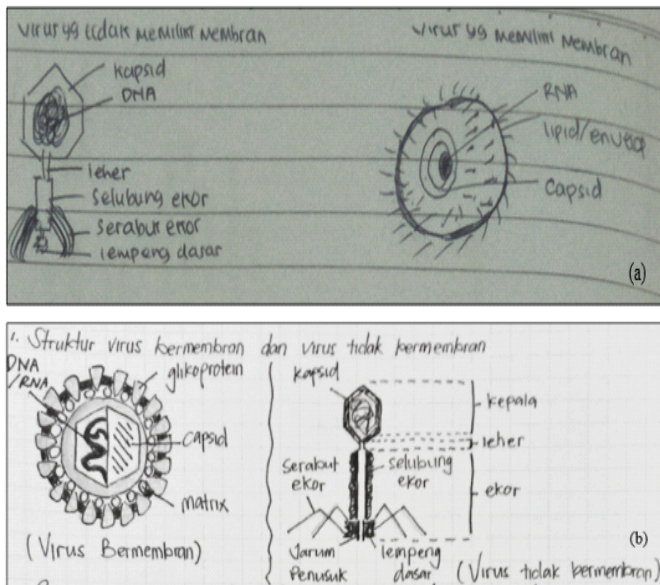
Figure 1. Students' Mental Model on the Concept of Virus Structure. (a) partially correct image/D3, (b) complete image/D5

In the concept of non-enveloped virus reproduction, the majority of students' mental models are at the D5W5 level (20.00%). This means that students' pictures and explanations about the concept of non-enveloped virus reproduction are complete (explaining the stages of the lytic cycle and also the lysogenic cycle). However, there were some students who only explained the reproduction of non-enveloped viruses through the lytic cycle only. This shows that students' understanding of the reproduction of non-enveloped viruses is still partial (included in the level 3 mental model). Because apart from going through the lytic cycle, non-enveloped virus reproduction can also reproduce by the lysogenic cycle. An example of a student's mental model of the reproduction of a non-enveloped virus is presented in Figure 2.
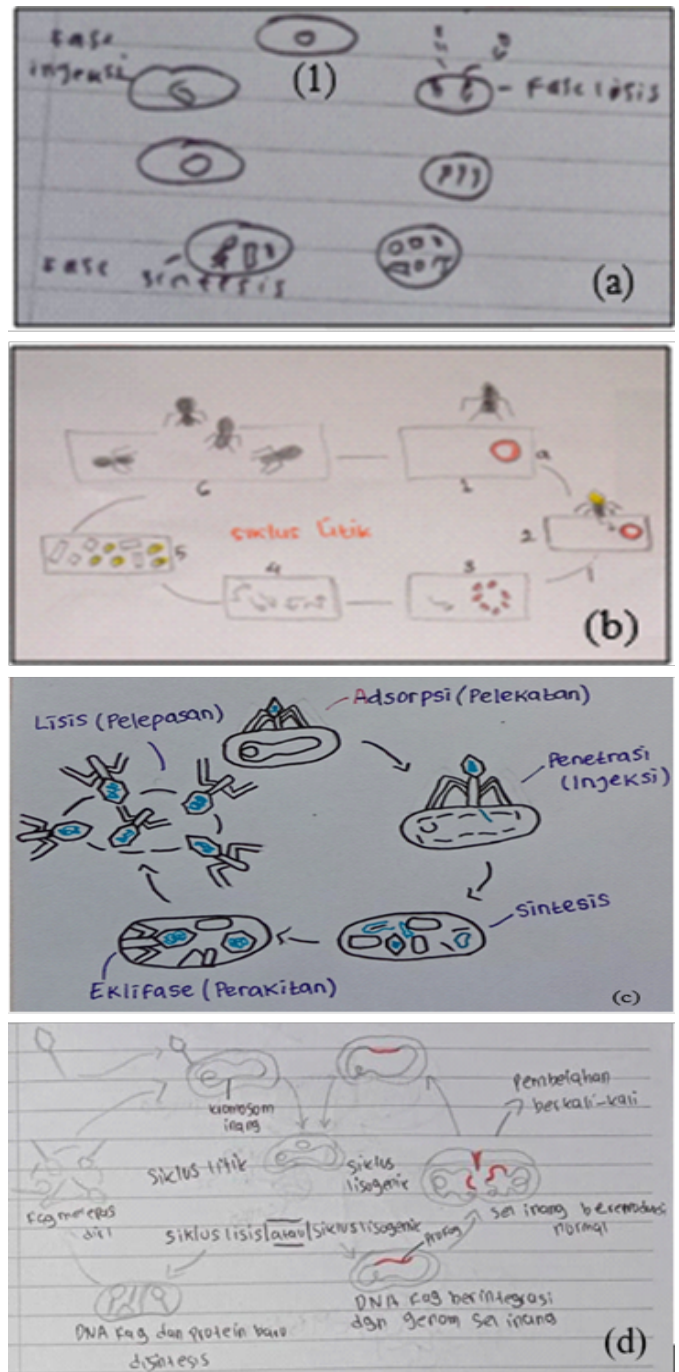
Figure 2. Student's Mental Model on the Concept of Non-Enveloped Virus Reproduction (a) irrelevant image/D2, (b) partially correct image/D3, (c) image has several errors/D4 (d) complete image/D5

The lytic cycle and the lysogenic cycle are related. Viruses that reproduce by the lysogenic cycle can change their reproductive cycle from the lysogenic cycle to the lytic cycle. This can occur if the virus genome is induced out of the bacterial chromosome. So that the picture of the lytic cycle and the lysogenic cycle is generally described as unified. However, some students describe the two cycles separately. This shows that students do not understand the relationship between the lysogenic cycle

and the lytic cycle. After conducting interviews with students who know the process or stages of the lytic and lysogenic cycle, as many as 20.00% of students know the relationship between the lytic cycle and the lysogenic cycle and 10.00% of students do not know the relationship between the two cycles.

In the students' answers about the reproduction of non-enveloped viruses, several errors were found. First, there are students who describe the lysogenic cycle without being preceded by the adsorption stage. This is in accordance with the statement of Köse (2008) that drawing can diagnose students' misconceptions about abstract concepts. Then the second mistake is that they describe and explain the lysogenic cycle will end with the lysis stage. This is certainly a misunderstanding, because the lysogenic cycle does not have a lysis stage. After being confirmed again, students still assumed that the lysogenic cycle would end with the lysis stage. This can be said to be a wrong concept, because the characteristic of the wrong concept is that students have a high level of confidence in the answers that have been given (Winarni, 2014).

In writing answers from the lysogenic cycle, it was also found that one student (respondent F) was wrong in understanding the explanation of the stages of the lysogenic cycle. The lysogenic cycle of respondent F is pictured in Figure 3. The following is an explanation of respondent F to the stages of the lysogenic cycle.
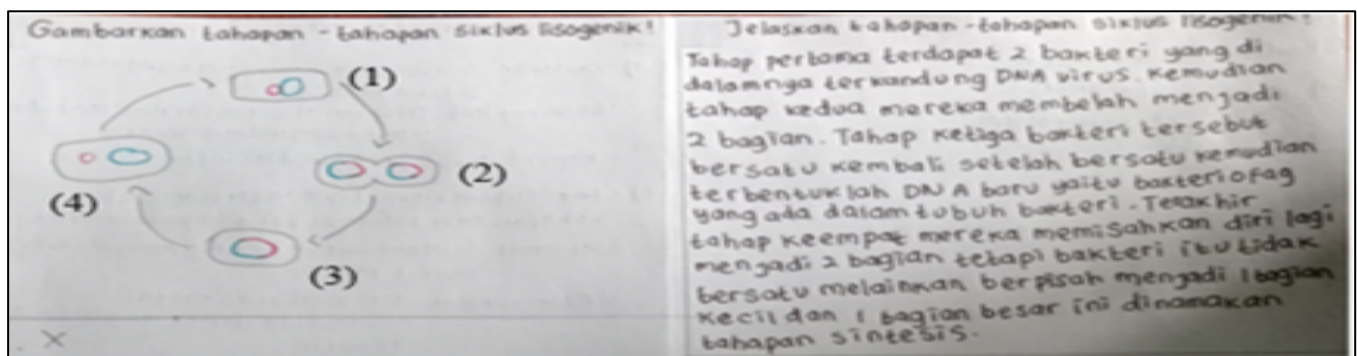

Figure 3. Errors in the Lysogenic Cycle Explanation

Researcher   :"Please explain again the explanation of the stages of the lysogenic cycle!"

Respondent F :"First, there are two bacteria that contain viral DNA (in the figure shown by number 1). Then the bacteria divide into two parts. After dividing, the bacteria reunite and form new DNA called bacteriophages (stage 3 in the figure). After the formation of new DNA, namely bacteriophages, the bacteria separate themselves again into two parts. The two parts consist of one small part (red circle) and one large part (blue circle). This stage is called the synthesis stage. The synthesis stage is the stage of bacteria separating themselves into two parts (between one bacterium and another)."

Researcher   :"May I know which viral DNA is it?"

Respondent F :"Viral DNA shown at stage 3."

Researcher   :"So the third stage with the blue and pink circles is viral DNA? What is the blue and pink circle in the first stage?"

Respondent F :"The blue and pink circles in the third stage are viral DNA, while the blue and pink circles in stage 1 indicate the presence of two bacteria."

From the interview, it can be seen that respondent F interprets bacterial chromosomes and viral nucleic acids in the bacteria's body as individual bacteria. Respondent F misinterpreted that two bacteria can unite and from the two bacteria that unite they can form viral DNA. In addition, Respondent F also misinterpreted that viral DNA was called a bacteriophage.
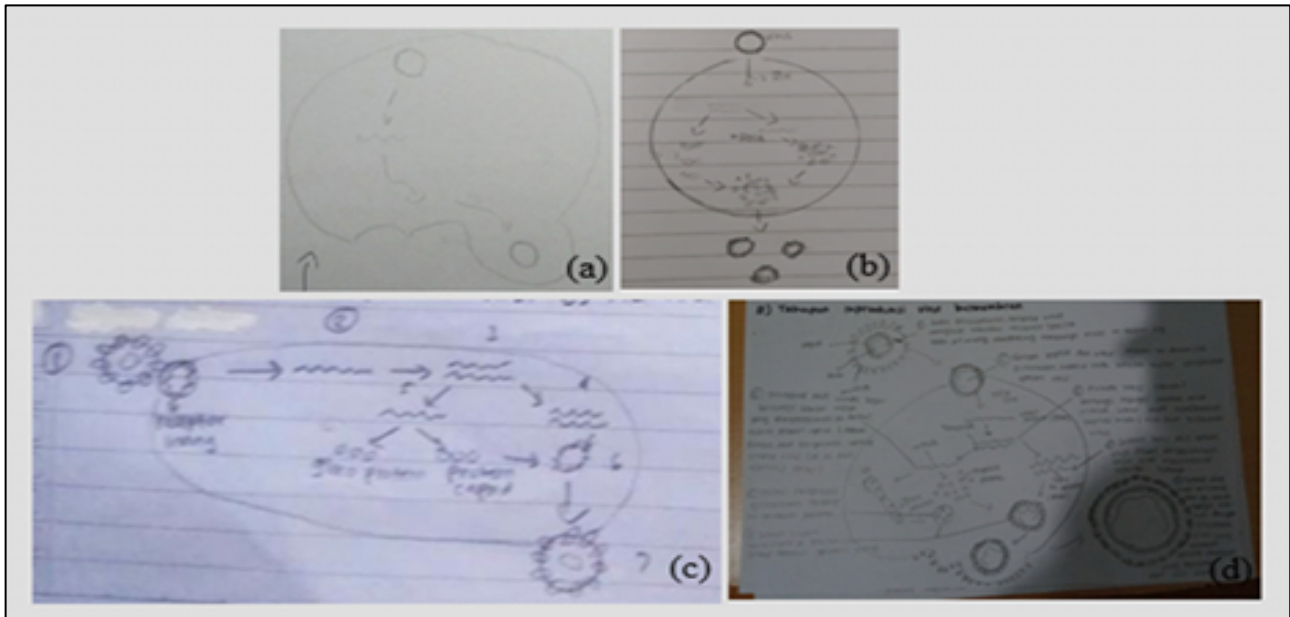
In the students' mental model of enveloped virus replication, the majority of students were at the D1W1 level (60.00%). The highest mental model level is at the D5W5 level (3.33%). An example of a student's mental model of the reproduction of a enveloped virus is presented in Figure 4.

Students' understanding of enveloped viruses is still very lacking. One of the factors is that the source of their reference book does not discuss the reproduction of enveloped viruses. Based on the results of interviews with students, the majority of students stated that the concept of enveloped virus reproduction is very difficult to understand than the concept of lytic and lysogenic cycles.

Based on the data presented in Table 3, it can be seen that the majority of students' mental models on the concept of virus structure and reproduction of non-enveloped viruses (lytic and lysogenic cycles) have a drawing level that is higher than the writing level. In the concept of enveloped virus reproduction, the students' writing level is higher than the drawing level. This is because the concept of reproduction of enveloped viruses is more abstract than the concept of lytic and lysogenic cycles for class X high school students. Based on research conducted by Rennie & Jarvis (1995) in

explaining more abstract aspects, children will use words to represent them rather than using pictures. Then writing is more suitable for doing something that requires deep understanding (Boscolo & Mason, 2001). If analyzed as a whole from all the concepts studied, it can be seen that the students' drawing level is higher than the writing level. This shows that the majority of students are better able to express their thoughts through pictures than to explain them through writing. This can happen because it is influenced by the student's learning experience.

Figure 4. Student's Mental Model regarding Reproduction of Enveloped Viruses (a) irrelevant image/D2, (b) partially correct image/D3, (c) image has several errors/D4 (d) complete image/D5

Based on the research results contained in Table 4.3, it can be seen that the students' mental models are at the developing and transitional levels, with the majority of students being at the developing level. In the study of Hamdiyati et.al (2018c) the mental model level of biology teacher prospective students on virus concepts was also at the developing and transitional level at the time of the pretest, but the majority of the mental model level of biology teacher prospective students was at the transitional level.

The factor that causes the level of students' mental models to be at the developing level is because the concept maps that students make are still very simple. The concepts they list are not deep. This is because the learning process they have done is not comprehensive. The learning they have done is more focused on the characteristics of the Corona virus, the incubation period of the Corona virus, and efforts to prevent the corona virus. Based on the analysis of students' concept maps, the concepts that often appear on students' concept maps are the concepts of structure, reproduction, and the role of viruses. In the concept of virus structure, only a few students included the structure of viruses that have a membrane or envelope. Generally they only write that the structure of the virus consists of a head, neck, and tail.

On the concept of reproduction, they only wrote the concept of reproduction of viruses that do not have membranes (lytic and lysogenic cycles). Some students also only included the concepts of the lytic cycle and the lysogenic cycle without mentioning the concepts in the reproductive stages of the lytic cycle (adsorption, penetration, synthesis, assembly and lysis) and the lysogenic cycle (adsorption, penetration, merging, and cleavage). This is in line with research conducted by Hasibuan & Djulia (2016), that the majority of students (57.89%) in explaining virus reproduction only included the concept of the lytic cycle with the lysogenic cycle, without further elaborating on each stage of the cycle. In the concept of the role of the virus, the majority of students have been able to list the beneficial and detrimental roles. Students have also been able to give examples of the beneficial and detrimental roles of viruses.

Another factor that causes the majority of students to be at a developing level is because the propositions they make are not correct. Students are less able to make the right conjunctions in connecting one concept to another. Another reason is that almost all students cannot make cross-links to the concepts they have written down. In the research of Hasibuan & Djulia (2016) there are also 18.94% students who have not been able to use connecting words correctly and the cause of the low average value of students' concept maps is because students have not been able to connect the relationship between one concept to another concept. The absence of cross-links in the majority of students'

concept maps shows that students' understanding of virus concept is still very low. The existence of cross-links on the concept map can explain a person's cognitive structure. The more students are able to relate one concept to another, then the student has a complex cognitive structure (Kempa & Nicholls, 1983).

The complexity of students' concept maps at the emergent level is slightly different from the transitional level. In the emergent level mental model, the concepts put forward by students are still limited and there are still many concepts that are not quite right. Another characteristic of the emerging level is that it does not yet have a structured understanding. This can be seen from the mistake of placing a general concept with a specific concept. In addition, at the emergent level, students have not been able to relate one concept to another and have not been able to provide examples of the concepts given. The characteristics of mental models at the transitional level are more or less the same as those at the emergent level. The difference is from the number of concepts that are raised, where the transitional level has a number of concepts that are actually more than the level that appears. At the transitional level, cross-links have begun to appear between one concept and another, but the cross-links still have errors.

Based on the results of research taken with drawing-writing techniques and concept maps, it can be seen that the levels of students' mental models are different. Differences in the level of students' mental models are caused by differences in students' learning experiences. Based on the results of the questionnaire, it can be seen that the learning resources of students are different. All students learn from the virus concepts given by the teacher, but there are differences in other learning resources apart from the virus concepts provided by the teacher. There are 26.70% of students whose learning resources come from books, 53.3% from videos about viruses on Youtube, 46.7% from websites, and 23.30% from learning applications. The information that students get will help build their mental models (Michael, 2004). Mental models combine diverse knowledge from various sources (Buckley & Boulter, 2000). This is in line with the opinion of Jones et.al (2011), which says that mental models are internal representations built by each individual based on experience, perception, and understanding of something.

Students' learning experience will determine students' mastery of concepts. Mastery of students' concepts is closely related to the learning model carried out. In a study conducted by Hamdiyati et.al (2018a) it showed that the experimental class (getting a mental model-based microbiology lecture program developed by combining constructivism learning steps) had a better level of mental model than the control class. Based on the results of interviews with students regarding the virus learning process that has been carried out, it is known

that students get virus concepts through lecture (conventional) and assignment methods. The concepts delivered by the teacher is not in-depth because the time available is very limited. Therefore, the teacher gave a power point file. Most of the material in the power point only contains pictures related to virus concept, not accompanied by an explanation of the pictures. Then for assignments given by teachers to students, they focus more on prevention efforts against the Corona virus. In this assignment, students were asked to describe the Corona virus accompanied by writing the names of the parts, writing down the characteristics of the Corona virus, and also efforts to prevent the Corona virus. Giving assignments to students to draw the Corona virus does not seem to be a meaningful study. This is because based on the results of the study, the majority of students did not describe enveloped viruses. At least if students do the assignment seriously, students can describe the enveloped virus in this study.

From the explanation of the learning process that has been carried out by students with the teacher, it is not surprising that the results of students' mental models are still very low and the results of students' mental models with drawing tests are higher than writing tests. According to Brown (1993), in order for students to be able to write or explain something, students must be involved in many learning experiences. Students are less able to represent their knowledge in written form because their learning experience is very limited. Based on the results of the questionnaire given to students, the majority of students rarely review the concepts that has been studied with the teacher. The total time for self-study of students while studying virus concepts is 50% of students taking 1-2 hours for independent study and 37.50% of students taking less than 1 hour. The intensity of student learning is directly proportional to the level of the student's mental model.

All the instruments used in this study were consistent. In the concept map of students who have a low level of drawing-writing, the resulting concept map also has a low level. Students who cannot show the components of the virus and are also unable to explain these components in the result of the concept map do not explain further about the concept of the structure of the virus that is listed. The concept of virus reproduction is the same. Students who can't explain the reproduction of the resulting virus in the concept map only include the concept of the virus without being explained in more detail the concepts regarding the process of reproduction. After further confirmation through interviews, the students did not really understand the concepts of the structure and reproduction of viruses. So that the concept map made only includes the concept of viral structure, virus reproduction, lytic cycle, and the concept of the lysogenic cycle. So that the results of the drawing-writing test are in line with the results of

concept maps, interviews and questionnaires. Students who have a good level of mental modeling have relatively more learning experiences than students with low levels.

Overall, by looking at all the instruments used in this study, students' mental models on virus concepts are still very low. The majority of students' mental models still do not approach the mental models of experts. This is because the students' pictures and explanations are incomplete when compared to the expert mental model whose answers are complete (D5W5). This student's mental model is categorized into a beginner mental model. This is based on the criteria for differences between the beginner and expert mental models according to Michael (2004), who says that the beginner mental model is incomplete (there are important elements missing) while the expert mental model is more or less complete (there are all elements). The most visible difference between the student's mental model and the expert's mental model is the cross-linked component. The majority of students' concept maps do not have cross-links, while the mental models of experts will have many and correct cross-links when compared to students' mental models. Because according to Michael (2004) mental models of experts have knowledge that is interrelated with another knowledge, both externally and internally.

Conclusion

The mental model of students on viral concepts is still very low. Students' understanding of the virus concepts is still low and students' understanding is still not structured. The concepts written by students are still very limited and have not been able to relate one concept to another. This shows that the cognitive structure of students is not complex.

The results showed that the mental models of students who were analyzed by drawing-writing techniques on the concept of the structure of the virus, the majority of students were at the D3W3 level. This shows that students' understanding is still partially correct. In the concept of non-enveloped virus reproduction, the majority of students are at the D5W5 level, which means that the concepts presented by students are complete. In the concept of enveloped viral reproduction, the majority of students are at the D1W1 level, this shows that students do not know the concept of enveloped virus reproduction. The results of students' mental models analyzed using concept maps were at the emergent and transitional levels. The characteristics of the emergent level are that they do not have a structured understanding, the concepts put forward are limited and there are still inappropriate concepts found, they have not been able to relate one concept to another and have not been able to provide examples of the concepts given.

The characteristics of the mental model at the transitional level are more or less the same as the emergent level. The difference is that the transitional level has a higher number of correct concepts than the emergent level. At the transitional level, cross-links have begun to appear between one concept and another, but the cross-links still have errors. The results of the comparison of students' mental models with expert mental models show that students' mental models are not close to expert mental models. Students' mental models are generally incomplete and have no connection between one concept and another.

The recommendation from this study for further research is that it would be better if the learning model used when teaching virus was also investigated. This is because the mental model is closely related to the learning process carried out.

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