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THE RELATIONSHIP OF STUDENTS' THINKING LEVEL AND THE ABILITY TO DEVELOP PROPOSITION NETWORK REPRESENTATION OF HUMAN NERVOUS SYSTEM IN MODELING BASED LEARNING (MBL)

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ABSTRACT

The purpose of this research is to reveal the relationship of thinking level with the students' ability to form a representation of proposition network on the human nervous system concept using modeling based learning. This was quantitative research with 30 science class' students of grade XI from one private school in Bandung as the subject research, who learned using modeling-based learning (MbL). The instruments used to measure the thinking level were 19 numbers of multiple choices and 2 essays that were developed based on Marzano and Kendall's level thinking indicator. The result of this research shows that the thinking level of senior high school' students has reached L3 (analysis) with minimum standard mastery ≥70. The higher the expectation of students' thinking level, the lower the minimum standard mastery will be reached. The correlation result showS no significant relationship between thinking level and the students' ability to form a proposition network on the study of neuron structure and function (r= 0,075; p=0,692) with low concept complexity. The significant relationship between thinking level and the ability to form proposition representation is obtained during the study of the central nervous and peripheral nervous system (r= 0,506; p= 0,004) with higher concept complexity. It means the higher students' thinking level, the better their abilities to form a proposition network. MbL could be recommended for learning biology concept especially abstract concept like the human nervous system. This research concluded that students' thinking level reached level 3 (analysis) and MbL can facilitate a significant relationship between thinking level and the ability to form proposition networks if the concept taught has a higher complexity compared to the lower complexity concept.

Keywords: thinking level; proposition network representation; modeling based learning; human nervous system

INTRODUCTION

True learning brings someone to improve his thinking ability and get new knowledge so that learning is not about mastering the concept, but it is about the mastering and skill of a more specific knowledge learned which come from the result of the thinking process (Marzano & Kendall, 2007; Marzano & Heflebower, 2011). The thinking process is a significant factor to develop the mastery of knowledge so students can get meaningful knowledge as the result of their learning process. In connection with that, Marzano & Kendall (2007) developed this knowledge mastery domain into three domains, which are cognitive system,

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metacognitive system, and self-system. They also divided this knowledge mastery into six thinking level systems, which are: retrieval, comprehension, analysis, knowledge utilization, metacognitive system, and self-system. To improve the thinking level for each knowledge domain, a certain learning approach is needed so that during the learning process, students are able to integrate the three knowledge domains.

Studying Biology as a part of science learning is supposedly able to stimulate and improve students' thinking and reasoning abilities. But in reality, students experience difficulties in understanding the concepts in biology which are abstract, complex, and connected to one another. This generally causes misconceptions among students (Goff et al., 2017). The learning of the physiological processes of the human body at school is one of the concepts which is considered the most difficult one by the students. Their main difficulty is on understanding the abstract physiological concepts. The human nervous system is one of the abstract concept considered difficult to learn. Concept characteristic is complex because it links one element to another which is also connected to a complex chemical mechanism and that makes the students be in their formal stage of thinking. The causal mechanism, which becomes one of the principles used on the human nervous system concept, causes difficulty in understanding the concept (Lestari et al., 2016). The lack of innovation in learning strategy, the learning process which focuses only on the theory, and uses only textbooks as the learning source gives more difficulties to students in understanding this human nervous system concept (Lestari et al., 2016).

To overcome the difficulties in understanding those abstract concepts, some researches for biology education have suggested some teaching strategies using pictures, simulation using computers, and props model as parts of representations that can be used by teachers (Cavalho et al., 2018). Modeling based learning (MbL) is a learning approach where the students build their own scientific phenomenal models, and this approach is considered to give a positive contribution learning science by researchers (Louca & Zacharia, 2012). The models made by the students whether they are in the forms of 2 or 3 dimensional models are the forms of actualization to represent knowledge in their own ways. Through modeling and the models made, students are able to present the abstract concepts to be more real. When the students are able to represent the models correctly, then their understandings about the concepts and phenomenons of science are improved (Sunyono et al., 2015). Researchers also said that models come from MbL products are scaffoldings to support the learning process, curriculum concepts, additional tools in supporting the learning process of science, and is a representation from realities used by someone as a media to understand more about the phenomenon learned (Louca & Zakharia, 2012).

The MbL application in learning science is able to improve the cognitive, social-concept, epistemological and metacognitive aspects, and is able to build spatial (Louca & Zacharia, 2012). Besides, MbL is also a media that plays a very important role in building students' scientific knowledge and thinking ability (Louca & Zacharia, 2012). MbL is an effective way to reach a good understanding of scientific concepts, in operational and also structural terms from knowledge domain, and to develop reasoning skill (Louca & Zacharia, 2012). Furthermore, according to Gilbert & Justi (2016), studying modeling and developing modeling skill applied in modeling based learning plays a big part in scientific literation, which are: (1) Modeling reduces learning burden for students;(2) Modeling is admitted as the main component in scientific behavior, validation and technology;(3) Modeling can increase thinking and communication skills;(4) Modeling develops personal values and makes students more aware to their society and surroundings.

Learning biology also uses lots of diagrams and visual representation forms. Nevertheless, connecting one part to another in diagrams needs texts to clarify the relationship patterns (Van Meter et al., 2017). The texts used to clarify the relationship patterns are known as propositional representation developed by cognitive psychological experts to learn meaningfulness, as someone only remembers the most meaningful thing from an object. Proposition as a representation concept has a role in the information processing model (describing any kind of information) which is often interpreted as relating to images. The empirical component which saves information based on experience can be explained in the form of proposition network. The forming of this proposition network can be shown through proposition network patterns. These patterns will measure students' ability in representing concepts into a whole and meaningful unity (Paivio, 2014). Among various forms of diagrams, mind map is mostly used in learning biology. Mind map as visual representation is useful to help students build the conceptual understanding and improve the learning result, and also used to visualize knowledge structures (Adodo, 2013; Long & Carlson, 2011). Based on the principles of the constructivism approach, the use of mind mapss can facilitate meaningful learning (Buzan, 2011). Diagrams in the forms of mind mapping completed with a proposition to show associative relationship among informations in it, enable students to create visual images in improving learning. Furthermore, it can be used to measure metacognitive ability which allows them to make connections and find conceptual relationship so the thinking scheme, unity and unanimity of knowledge are formed (Balim, 2013; Buzan, 2011).

Based on the problems, some research questions could be described as follow: (1) How about the thinking level of high school students in learning human nervous system concepts using modeling based learning?; (2) How is the relationship between students' thinking level and the ability to develop proposition network representation?. So the purpose of this research is to reveal the relationship of that thinking level with the students' ability to develop proposition network representation on the human nervous system concepts using modeling based learning.

METHODS

Research Method

This was quantitative research with 30 science class' students of grade XI from a private Senior High school in Bandung who learned the human nervous system as the research subjects. The learning process was done with the MbL approach for 4 meetings. The first meeting, students learned a concept about neuron's structures and functions from the handbook they usually use in biology class, and were asked to make 3D model designs in the form of images, and then individually asked to make their 3D designs in the forms of images into real 3D models as their home assignment and would be submitted a week after. In the second meeting that was held a week later, the students submitted the 3D models they had made and asked to make proposition network representation about neuron's structure and functions. On the third meeting, the students were asked to learn about central nervous system (CNS) and peripheral nervous system (PNS) from the handbook they usually use, after that they were asked to make the 3D model designs in images and then individually asked to turn their 3D model designs into real 3D models as a home assignment and would be submitted a week after. In the fourth meeting, the students submitted the 3D models they had made at home and were asked to make the proposition network representation about CNS and PNS.

Data Collection

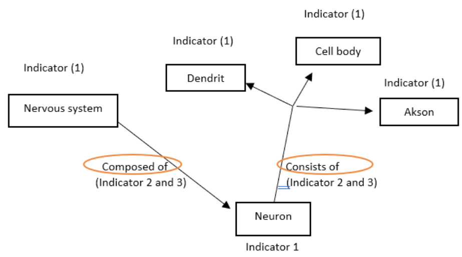
The data collection techniques were done as follows: the proposition network representation's data were taken twice at the second and fourth meetings, while the thinking level measurement's data were taken after the learning processes were finished. The students' thinking level was measured based on their abilities to do tests made and developed based on the new Marzano & Kendall's taxonomy indicators (2008) to measure students thinking level related to the human nervous system concept. The test consisted of 19 numbers of multiple choices to measure thinking level 1 to 4 and 1 essay for thinking level 5 and 1 essay for thinking level 6. Before it was tested to students, these questions had been validated by 3 experts and had been tested to 12 graders who had learned this concept. Those questions were made based on these guidelines as in Table 1.

Table 1. Thinking Level's Guidelines Based on the New Marzano & Kendall Taxonomy Indicators (2008)

Thinking level (degree of difficulty)	Thinking Process
Level 6 – Self System	Examining Efficacy
Level 5 – Metacognitive System	Specifying Goals
Level 4 – Knowledge Utilization	Investigating Decision making
Level 3 - Analysis	Specifying Matching
Level 2 - Comprehension	Symbolizing Integrating
Level 1 - Retrieval	Recalling Recognition

The result data from the representation of the proposition network was assessed using the assessment instrument rubric which was developed and adapted based on the information processing standards from Marzano et al. (1993) and Fatiha et al. (2017) as seen in Table 2 and had been validated before by the experts.

Table 2. The Guidelines for the Task Sheet's Instrument of Proposition Network Representation

No	Rated Aspects	Indicators	Example
1	Identification of information elements	The amount of important and correct information elements in the diagrams	
2	Interpretation and infomaation synthesis	The proposition's position accuracy from information elements in proposition network	
3	The information relevance analysis	The accuracy in using proposition phrases in explaining the relationships among information elements	

The score results from proposition network representation were then categorized using a formula adapted from Arikunto (2012) as it is seen in Table 3.

Table 3. Results' Categories for Proposition Network Representation

Scores convention	Category
80-100	Very Good
60-79	Good
40-59	Fair
20-39	Poor
0-19	Very Poor

Data Analysis

The data analysis for the thinking level was held by categorizing the result tests into six thinking levels (L1-L6) based on each level's minimum standard mastery. If a student can get the minimum score of 70 for a certain level, then he is said to have reached the intended thinking level. The relationship between thinking level and the student's ability to form proposition network representation is analyzed using Pearson Product Moment correlation tests on the SPSS version 23 program.

RESULTS AND DISCUSSION

Thinking Level

Based on the test results to measure the students' thinking levels, data showed that the average scores are decreasing as the thinking level gets higher. These test results also show that based on the level's minimum standard mastery (≥70), on average, the students have already been able to reach level 3 (analysis). The percentage of students who achieve the standard mastery on each thinking level is shown in Figure 1 as follows.

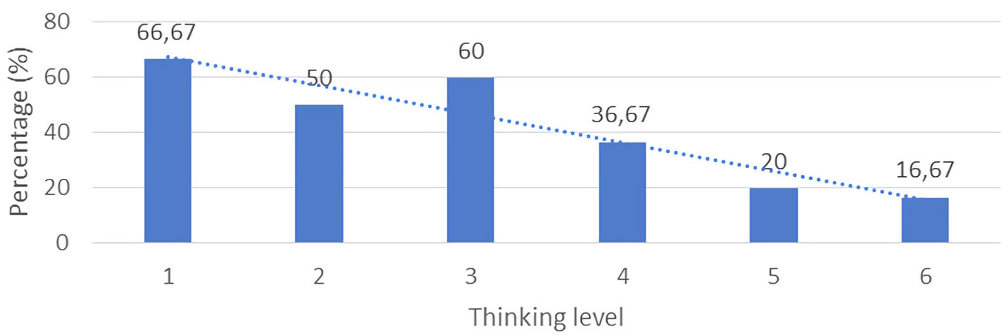


Figure 1. Students' Percentage Who Achieve the Score above 70 on Each Thinking Level

The diagram in Figure 1 shows that the higher the expected thinking level is, the smaller the average scores are achieved, as well as the percentage on students who are able to complete the questions given on each level is also decreasing along with the increased thinking level.

The questions used for the test to measure the thinking level were arranged in such a way that the higher the thinking level is, the more difficult the questions were arranged and would need a more complex way of the thinking process. The questions provided to measure level 5 (metacognitive system) were made to measure how the students were able to set goals and how they were capable to set strategy to accomplish their learning goals. Meanwhile, the questions provided to measure level 6 (self-system thinking) were made to see the students' self-confidence for studying using modeling based learning to improve their understanding and knowledge of the human nervous system concept. According to Krell & Kruger (2017), if someone has a good metacognitive (L5) and self-system (L6) skills, then he will be able to master the knowledge and thoughts of the previous level. This is in line with Marzano and Kendall's opinions, that only students with higher thinking levels can complete tests with more complex cognitive process demands and scope with the knowledge and thinking process in the previous thinking levels.

Proposition Network Representation

In this research, the students were asked to create two kinds of proposition network representation in the forms of mind mapping. They were proposition network representation for the neuron's structures and functions, also the Central Nervous System (CNS) and Peripheral Nervous System (PNS). The average score achieved by the students for the neuron's structures and functions proposition network was 47,62 and included to be in the Fair category. The percentage categories of the students' achievements in forming these proposition networks are shown in Figure 2.

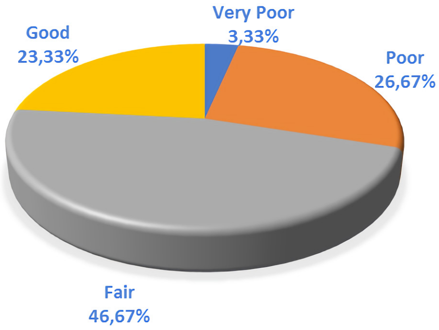


Figure 2. The Skill of Forming Proposition Network for Neuron's Structures and Functions

Based on Figure 2 above, the data show that most students are able to create the expected proposition network since 70% of students were able to reach the Fair and Good categories, and only 30% of students were in Poor and Very Poor categories.

The results of the average score for the second proposition about CNS and PNS was 43,86 and included to be in the Fair category. The percentage categories of the students' achievements in forming proposition networks of CNS and PNS are shown in Figure 3.

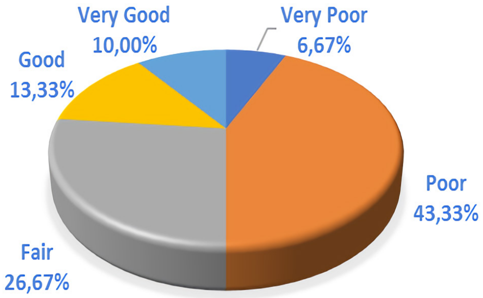


Figure 3. The Skill of Forming Proposition Network for CNS and PNS

The diagram in Figure 3 shows that half of the students are able to form the expected proposition network since 50% of students were able to achieve Fair, Good and Very Good categories, while the other 50% of students were not able to form a proposition network for CNS and PNS well or even worse.

The students' ability in forming a proposition network looks a bit different for the two concepts. The concepts' complexity seems to be the factor that differs from the results achieved from the two proposition network diagrams (Won et al., 2014). The neuron's structures and functions concept has a lower complexity so it has fewer information elements and proposition compared to the CNS and PNS concepts. It is also less difficult and easier to understand and make the proposition network for this concept so the result achieved is better than the proposition networks for CNS and PNS which has a higher complexity. Even though there are some students who are capable to reach the Very Good category in forming CNS and PNS proposition networks, generally, the average score is decreasing and the total percentage for students who achieved Fair, Good, and Very Good categories are also decreasing.

The Relationship between Thinking Level and the Ability of Forming Proposition Network Representation

The results for the students who have not reached the minimum standard mastery level and those who have are related to the students' ability in representing the neuron's proposition network are shown by Figure 4 as follows.

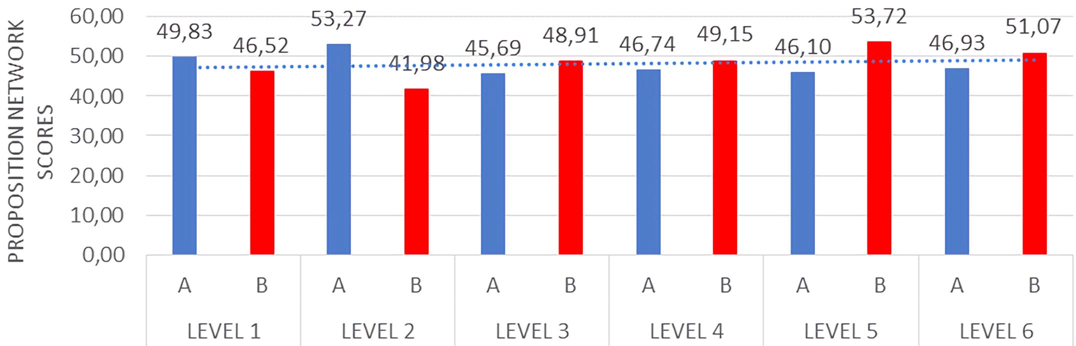


Figure 4. Thinking Level's Standard Mastery and the Average Score of Proposition Network for Neuron's Structures and Functions. (Note: A= students who have not achieved the standard mastery learning, B= students who have achieved the standard mastery learning)

The figure above shows that the students who can not reach the minimum standard mastery for thinking level L1 have a better average score on proposition network (49,83) compared to those who are able to reach L1's standard mastery (46,52). This also happens for L2, the students who can not reach L2's minimum standard mastery have a higher average score (53,27) than the students who reach L2's standard mastery (41,98). Along with the increased thinking level, it seems that the average score for proposition networks made by the students who can not pass the standard mastery is lower than those who pass the standard mastery for their thinking level. The students who do not pass L3's standard mastery achieve the average score of 45,69 for proposition network while those who pass L3's standard mastery achieve the average score of 48,91. Students who do not pass L4's standard mastery get the average score of 46,74 for the proposition network and those who pass L4's standard mastery get the average score of 49,15. Students who do not pass L5 standard mastery for proposition network achieve the average score of 46,10 while those who pass L5's standard mastery achieve the average score of 53,72. Students who do not pass L6's standard mastery for proposition network have an average score of 46,93 and those who pass L6's standard mastery get the average score of 51,07.

After the Pearson Product Moment correlation test had been held, the correlation coefficient value 0.075 was obtained with significance value 0,692. It means, there is no correlation between students' thinking level and their ability in forming proposition network representation for neuron's structures and functions.

The result received for the students' skill in representing the proposition network for Central Nervous System (CNS) and Peripheral Nervous System (PNS) is shown in Figure 5 as follows.

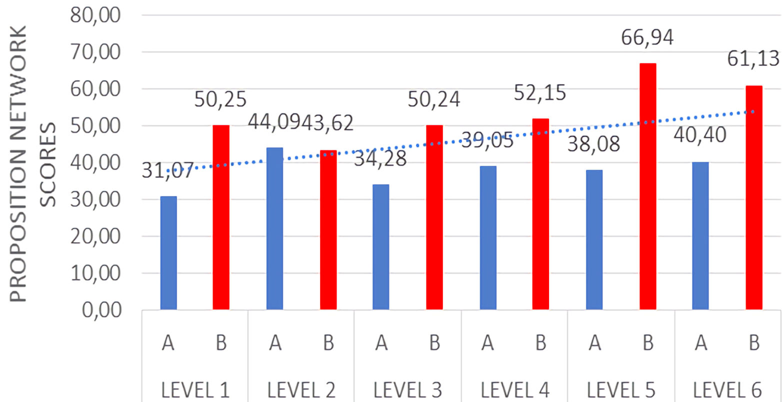


Figure 5. Thinking Level's Standard Mastery and the Average Score of Proposition Network for CNS and PNS (Note: A= students who have not achieved the standard mastery learning, B= students who have achieved the standard mastery learning)

The result of proposition networks for CNS and PNS in Figure 5 shows a tendency of increasing results in line with the students' thinking levels. This is reinforced by a Pearson correlation analysis using the SPSS version 23 program. A correlation of 0,506 is obtained between thinking level and student's ability to form CNS and PNS proposition network with significance level 0,004. The correlation coefficient result of 0,506 shows a quite strong relationship level with significance level 0,004 also shows a significant result (Sudjana, 2013). So it means that student's thinking level significantly has a quite strong relationship with the ability in forming proposition network for CNS and PNS.

Based on the data obtained from this research, it is seen that there are differences in results from the relationship of thinking level and the student's ability in forming proposition network representation for neuron's structures and functions concept and CNS and PNS concepts. These statistical analysis results show that there is no relationship between thinking level and student's ability in representing neuron's structures and functions concept in the form of proposition network, it means either student with higher or lower thinking level tend to have the same abilities in forming their proposition networks. Meanwhile, differences seem really clear when the students are asked to build a proposition network for CNS and PNS concepts. The students who can complete higher thinking levels have the ability to represent this concept better than those students who can only complete lower thinking levels. The concept's complexity seems to also influence the students' ability to form this proposition network representation. The neuron's structures and functions concept is simpler compared to CNS and PNS concepts. For a simpler concept, thinking level does not affect the student's ability to represent the concept, as for the more complex one, it needs a better and more complex thinking process so that the thinking level achievement would affect the student's proposition network result. This proves that there is a significant relationship between students' thinking level and their ability to form a proposition network for a more complex concept, such as this CNS and PNS concepts.

The student's thinking-level achievement is also related to their reasoning skill and emotion. Thinking ability does not only refer to thinking processes but also psychological processes that influence learning behavior (Lee, 2018). Students who are able to complete or reach the stage of thinking level for the metacognitive system (L5) and self-system thinking (L6) is not only able to think from the cognitive aspect but also able to manage themselves. They have self-control and are able to set their goals and learning strategies. Moreover, students who are able to reach L6 have an awareness to be involved in the learning process and the assignments given. Students who have reached L5 and L6 have strong confidence so that they have wills, eagerness, self-awareness, struggling power, and always try to look for sources to support their assignments in studying so their motivation in learning is also high (Heong et al., 2011). This is probably the important factor so students who are in thinking level L5 and L6 are able to learn from their mistakes and are motivated to have self-improvements so that the results they get on making the second proposition network about CNS and PNS are a lot better than students in a lower thinking level (L1-L4) even though the learning concept has a higher complexity. Student's ability to form a proposition among information elements that show their ability to form a causal relationship is not determined only by their cognitive thinking skills but also by their metacognitive and self-system skills that they have.

The research's results show that student's ability to make diagrams is influenced by their early knowledge about the concept learned, thinking level, the experience got from exercises of making diagrams, and concept's characteristics (Bergey et al., 2015; Cheng & Gilbert, 2015; Kragten et al., 2014; Nichols, 2017; Olander et al., 2017). This is in line with the findings obtained from this research. Students with higher thinking levels are able to form a mind-mapping diagram representation, together with its proposition network well. Besides, an increase in the average scores of proposition network for CNS and PNS structures and functions happens because the students who have already reached a higher thinking level have a will to learn and self-improvement from their mistakes so that they are able to make the second proposition networks on CNS and PNS better though the concept is more complex.

Besides the previous factors mentioned above, the learning approach using modeling based learning which has been done by the teacher is also one of the potential factors that causes a higher thinking level student (L5 and L6) to undergo improvements in forming their proposition network. When they made their first proposition networks on neuron's structures and functions, their understanding was not developed yet because that was the first time they made a model, but when they had to learn the second time using the MbL approach, their understanding is having a progress and it is shown with the increase of their average scores on their second proposition network that they have made for CNS and PNS. According to experts, learning activity using MbL approach where the students themselves make their own visual representation is believed by the experts as a good media to improve scientific knowledge, thinking knowledge, give contribution for cognitive, metacognitive, social concept and epistemological aspects in learning science (Jong et al., 2015; Louca et al., 2011; Peel et al., 2019). MbL can hone student's skills to represent something abstract to be real in their own way so that the student's understanding of scientific phenomena will increase (Heijes et al., 2017; Hidayat et al., 2019). For students with higher thinking levels (L5 and L6), learning and practicing to represent their knowledge about the nervous system in the form of modeling also develop their understanding of the nervous system, since they know the study's goal so they are fully involved in the learning process. This is what students with lower thinking levels do not have (L1-L4).

The MbL approach used for the process of the nervous system's learning in this research does not give a significant relationship between thinking level and the ability to form a proposition network for low complexity concepts. It may happen because the neuron's structures and functions concept (low complexity) is less contextual in students' daily life compared to CNS and PNS concepts (high complexity). The research from Jansen et al. (2019) shows that modeling is closely related to the exercise conducted and the facts seen by students in everyday events. Students in their daily life can understand the brain and spinal cord more easily because they can see images, a human torso model, or even the real objects even though they are not a human brain or spinal cord. So even though CNS and PNS concepts have a high complexity but it is contextually felt more by students. Meanwhile, a neuron is an object which cannot directly be seen, abstract and hard to imagine the process carried out by neuron, so the context cannot be felt by students in everyday life even though the complexity is low. The difficulty in this neuron' modeling becomes one of the factors of students' lack of understanding in building proposition networks, either for low or high thinking level students. However, further research for implementation of MbL needs to be conducted to confirm whether the problem is as mentioned above.

CONCLUSION

Thinking level of Senior High School's students have reached level 3 (analysis) and in line with the increased thinking level, the percentage of students who are able to reach it is decreasing. Students' thinking level is not significantly related to their ability to build proposition networks on low complexity concepts. The significant relationship between thinking level and students' ability to form a proposition network happened when students learned the nervous system concept with higher complexity. In conclusion, MbL can facilitate a significant relationship between thinking level and the ability to form proposition networks if the concept taught has a higher complexity compared to the lower complexity concept.

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