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The Effect of Mind Mapping on the Tenth Graders' System Thinking on Trophic Structure Topic

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Abstract: Students' inability to understand the concept of science holistically has been identified in several studies on students' difficulty to understand the relationship between levels of organization of life. It is because of the reduced teaching and learning process in Biology in which the actual learning topics are taught separately without the attempt to connect the various topics. This study was aimed at reporting the thinking skills of high school students after being exposed to learning activities involving mind mapping note-taking on water cycle topics. It is a Quasi-Experimental study with a Nonequivalent Control Group Design and simple Random Sampling. The data were collected by means of essay test and questionnaire. For homogeneous and normally distributed data, the result of paired t-test showed a significant difference in the data (0.795). Furthermore, for not normally distributed data, they were analyzed using the Mann-Whitney test. The average of test results was 69.47 for the experimental class and 66.12 for the control class.

Keywords: Mind Mapping; System Thinking; Trophic Structure

Introduction

The inability of students to understand the concept of science holistically has been identified in several studies. One study conducted by Grotzer & Basca (2003) about the difficulty of students understanding the relationship between levels of organization of life showed that it has caused students' tendency to focus only on the behavior of certain species and ignore their interactions with other species in a community. Some other studies on students' and teachers' understanding of the circulatory system of the human body have shown their inability to link heart and lung function in the circulatory system (Bartoszeck et al., 2008; Özsevgeç, 2007; Pelaez et al., 2005; Fančovičová, & Prokop, 2019; Reiss & Tunnicliffe, 2001; Reiss et al., 2002).

One of the causes of the conditions is the reduced way of biology teaching and learning in which the actual learning topics are taught separately without connection among topics (Chatzikyriakidou et al., 2021; Prokop, P & Fančovičová, 2006). As a result of this, students are not able to integrate the relationship between each existing problem and topic (Tripto et al., 2013), so they have difficulty finding relationships between concepts and topics for the absence of a complete system understanding or popularly known as the misconception of fragmentation or fragmentation of knowledge (DiSessa, et al., 2004).

The ability required for connecting concepts and components in a holistic understanding is the systems thinking ability. These skills aim at integrating various types of scientific and social knowledge in a common system (Laszlo and Krippner, 1998). It pushes students to think about the existing systems in a topic of discussion and it has a close relationship with the specific discussion of content (Meilinda et al., 2018) which results in different systems with different instruments.

Some instruments have been developed to measure systems thinking including those developed by Meilinda et al., (2018) and Groundstroem, & Juhola (2021) on the topic of climate change, observations and interviews on the topic of cell biology (Verhoeff et al., 2008), as well as concept mapping on the concept of science in elementary schools (Brandstädter et al., 2012; Tripto et al., 2013; Verhoeff et al., 2008). Concept mapping can be one of the methods used to improve students' systems thinking skills (Brandstädter et al.,

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2012; Lich et al., 2017). Although there are many similarities between concept mapping and mind mapping, there are not many studies attempting to link mind mapping and systems thinking even though both are note-taking methods that can contain all important information and include relationships between material concepts and improve students' brain abilities in assimilating and relating facts (Cuthell & Preston, 2008; Silaban, 2011). With mind mapping, students are expected to think holistically which in turn will improve students' system thinking skills.

Based on the previous discussion, the purpose of this article is to report the thinking skills of high school students after being exposed to learning activities that involve taking notes using the mind mapping method on the topic of the water cycle.

Method

It is a quasi-experimental study with a nonequivalent control group design research design. The independent variable is the mind mapping method, while the dependent variable is systems thinking. In this design there are two research groups, the experimental group and the control group. The population in this study were all tenth graders of Mathematics and Natural Sciences Department at SMAN 10 Palembang. The samples used in this study were classes X MIA 1 as the experimental class and X MIA 5, as the control class. The research instrument used was a test based on the system thinking indicator developed by Meilinda et al. (2018) with four systems thinking skills: (a) Identifying system organizations; (b) Analyzing the behavior of the system; c) System modeling; d) predicting or retrofitting the system with sub-indicators of system thinking as shown in Table 1.

Table 1. Systems Thinking Indicators and Sub-Indicators

Systems Thinking Indicators		Systems Thinking Sub-Indicators
Able to recognize the structure and role of components and sub-components in the system	1.1	Identify components, sub-components and their functions in
	1.2	Identify structural and functional relationships between system components at the same system level
	1.3	Map the concepts in the system at a specific level
Able to analyze the interaction of components and sub components in the system	2.1	Analyze the relationship between concepts at different levels
	2.2	Organize components and sub-components, processes and interactions that occur in them within the system framework
	2.3	Identify the feedback process that occurs between components and sub-components in the system
Able to analyze patterns/modeling in the system	3.1	Generalize the pattern formed by the system
	3.2	Design an interaction pattern of components that can be detected in a closed system
	3.3	Create/develop a model that describes the position of all components and sub-components in the system frame in 2D/3D
Able to predict/retrospect system behavior due to interactions within the system and outside the system	4.1	Predict/retrospect behavior that arises from the system as a result of interactions between components in the system
	4.2	Predict/retrospect the consequences that arise from an intervention to the system that causes the loss or increase
	4.3	Implement new patterns based on prediction and retrospective results

The data collection techniques used were tests and questionnaires. The resulted data were analyzed using t-test. Before testing the hypothesis, the normality, homogeneity, and n-gain tests were carried out. The forms of questions used in this research are as shown in Table 2.

Table 2. Examples of System Thinking Problems with Trophic Structure Topics

Systems Thinking Indicators	Items	Criteria of Answer	Score
Able to analyze the interaction of components in the system (Sub-Indicator of System thinking: Analyzing the relationship between concepts at different levels)	Water is an essential element for life on earth. The absence of water will be a big problem because it will disrupt the balance that occurs in the ecosystem. Water sources on earth vary from rivers, seas, lakes, and so on. The water cycle is a series or stages through which water passes from the earth to the atmosphere and back again to the earth. The processes that occur in the water cycle are evaporation, transpiration,	Global warming is a natural phenomenon where the temperature of the earth increases. This can be caused by air pollution such as CO2, greenhouse gases, use of CFCs and so on. When CO2 and many greenhouse gases are in the atmosphere, the temperature will increase which will cause an increase in evaporation into the atmosphere. When it is at a certain humidity point, there will be heavy rain accompanied by extreme weather:	4
		If the answer is correct and complete	3

Systems Thinking Indicators	Items	Criteria of Answer	Score
	condensation, and precipitation which eventually results in rain. Extreme weather can also increase the temperature in the atmosphere which can cause global warming. Surface runoff and groundwater can return water back to the ocean, thus completing the water cycle. The existence of green plants will greatly affect the sustainability of the water cycle. Based on the discourse above, analyze the relationship between global warming and evaporation that occurs in the tropics	If the answer is correct, but cannot connect global warming with evaporation that occurs in the tropics	
		If the answer is correct, but it is incomplete and cannot connect warming with evaporation that occurs in the tropics	2
		If you answer the question, but not correctly If you don't answer the question	1

Result and Discussion

The average pretest, posttest, and Gain scores from the test can be seen on Table 3. Table 3 shows the level of systems thinking in the experimental and control classes. In the experimental class, which was treated using mind mapping, the mean pretest score was 48.17 and the posttest was 69.47. In the control class, without the mind mapping treatment, the mean pretest score was 49.17 and the posttest was 66.12.

Table 3. The Mean of Pretest, Posttest, and Gain Score of System Thinking

Indicator	Experiment group			Control Group		
	Pretest	Posttest	Gain	Pretest	Posttest	Gain
I	59.70	76.30	16.60	55.50	62.50	6.90
II	33.20	61.00	28.00	36.80	68.00	31.00
III	61.00	67.00	6.00	60.00	66.00	6.00
IV	38.80	73.60	34.70	44.40	68.00	23.60
Total	48.17	69.47	21.32	49.17	66.12	16.87

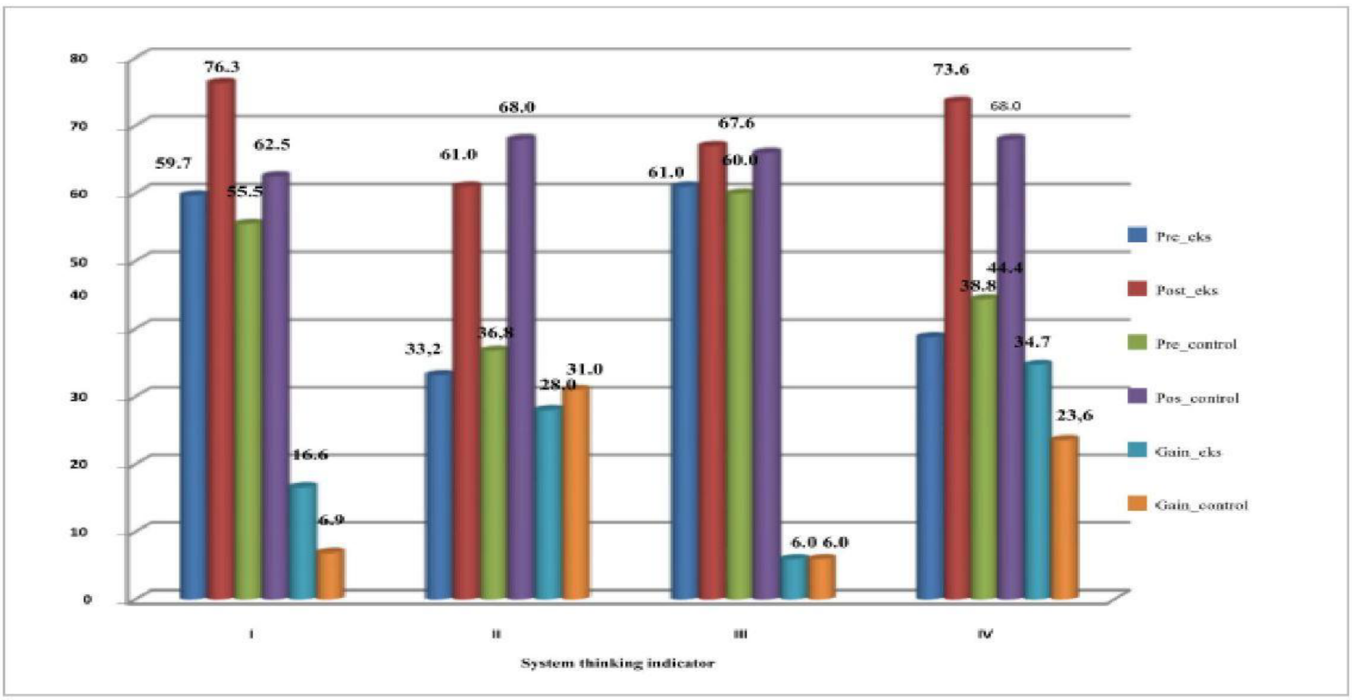

Figure 1. Gain Percentage of Thinking System

After pretest-posttest and gain scores were known, the value of n-gain from the data can be determined. The n-gain men and categories on concept mastery can be seen in Table 4.

Table 4. Mean and Category of N-Gain for Experimental and Control Classes

System Thinking Indicator	Experiment		Control	
	N-Gain	category	N-Gain	Category
I	0.20	Low	0.10	Low
II	0.30	Fair	0.40	Fair
III	0.11	Low	0.13	Low
IV	0.50	Fair	0.30	Fair

In the experimental class, indicators I and III were of "low" category and indicators II and IV "fair" category. In the control class, indicators I and III were of "low" category and indicators II and IV "fair" category. ".

Hypothesis testing was carried out using the independent sample t-test and the Mann-Whitney test for not normal data distribution per system thinking indicator to see the asymptotic value of Significance (2-tailed). Data analysis test results per indicator can be seen in Table 5.

Based on Table 5, it is found that for indicator I using the Mann-Whitney test, the result was 0.017 which means that Ha is accepted. For indicator II by using the t-test the result was 0.116 which means that H0 is accepted. Furthermore, for indicator III using the t-test, the result was 0.683 which means that H0 is accepted. For indicator IV using the t-test, the result was 0.373 which means that H0 is accepted. From indicators I, II, III, and IV, only indicator I has a significant effect. This can be interpreted that mind-mapping has a significant influence on students' system thinking skills for indicator I: the structure and function of each component of the system.

Table 5. Hypothesis Test Results Per Indicator

Indicators	Sig.(2-tailed)	Information
I	0.017	significant effect
II	0.116	No significant effect
III	0.683	No significant effect
IV	0.373	No significant effect

In the experimental class X MIA 1 system thinking skills on the resulted data show that indicator I has a significant effect, while indicators II, III, and IV have no significant effect. In indicator I, the experimental class was given treatment using mind mapping and the final project was making mind mapping so that students are expected to be able to detect concepts that need to be included in mind mapping. Although not yet able to understand and relate the concepts made, mind mapping has a significant effect on indicators being able to recognize the structure and role of components and sub-components in the system.

Significant effects of mind mapping on indicator I thinking systems but not on other indicators might be due to the more emphasis students put on structure and roles but not on mechanisms, and interactions within the system (Perkins & Grotzer, 2000). This is also in accordance with the research conducted by Boersma et al. (2011) that concluded in concept mapping, students tend to focus on the structure; and in research of Evagorou et al. (2009) in which it was found out that students tend to think about things directly related to events, and ignore indirect relationships (Evagorou et al., 2009).

Based on the mind mapping made by the students, it was found that students had difficulty making a mind mapping that showed a system, this happened for two reasons: 1) students were not specifically instructed to make a system-oriented mind map; and 2) Mind mapping in the experimental class was only given in the form of an assignment to take notes after listening to the teacher's explanation and searching from various sources. The system is a conceptual trap that can be used to understand events or phenomena in the surrounding environment as well as within the scope of science; and to practice this requires a paradigm shift from partial ones such as in the form of causality to being holistic system-based (Ulrich & Reynolds, 2010). Taking notes even one that attempts to interrelate between concepts is not enough to change students' thinking to system paradigms. The following is an example of mind mapping made by experimental class students on the topic of the water cycle.

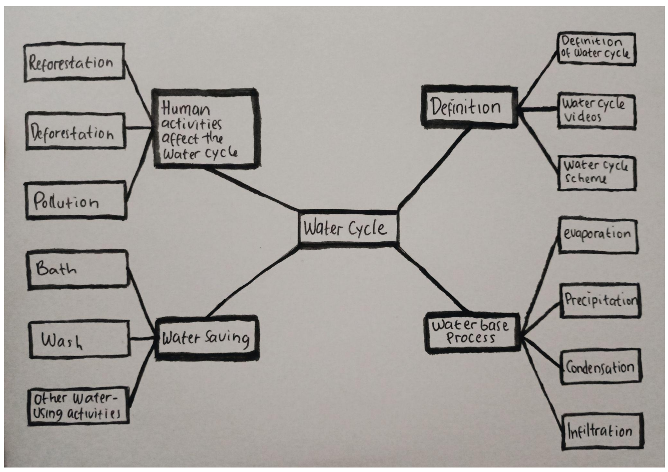

Figure 2. Mind Mapping Made by Students about the Water Cycle

Based on Figure 2 mind mapping about the water cycle, students divide the water cycle into two main points, context and content. In the context of the water cycle, students discuss how human activities affect the water cycle, while in the content of the water cycle, the meaning and terms in the water cycle are discussed. The same thing was found in the research of Sträng & berg-

Bengtsson (2010), whereas when we talk about the water cycle, human activities are not separate activities but the activities they do affect the water cycle.

Another point from figure 2 is that the depth of the material presented is not extensive, and the relationship between the concepts made is very simple. The keywords or concepts that are made tend to be in the form of words or phrases and sometimes some concepts are made in the form of sentences which are actually avoided in mind mapping. Because mind mapping should only use keywords that are able to represent the message conveyed and also make it easier to remember since the brain only remembers the keywords (Swadarna, 2013). Furthermore, it can also be seen students formed a simple pattern. Starting with the main topic in the middle, then proceed by making sub-theme branches that have smaller lines, but the lines made are the same as the main topic. This becomes less observed by students, even though the lines/branches should indicate the increasingly complex mind mapping. Students tend to be only able to make the structure of the system and are more inclined to have difficulty making patterns that link between these structures. This is in accordance with Tripto et al. (2013) that students' concept maps are able to reflect the role of students' domain knowledge in understanding dynamic systems which emphasize more on the structural components of the system and tend to be able to describe the first two levels of systems thinking but have difficulty understanding patterns and interactions within them.

Based on the results, high school students tend to think logically where the reasoning or thinking phase inclines to be linear and there has not been much research on formal operations. Meanwhile, the system skills are more complex. The difficulty of achieving systems thinking skills in students is what renders the results of hypothesis testing insignificant. This is in accordance with Meilinda et al. (2019) that students' systems thinking skills do not reach 50% of the total score because to understand the system, post-formal operations, which are outside of formal reasoning operations, are needed.

Conclusion

Based on the results of hypothesis testing, the value of sig. (2-tailed) on the paired sample test is 0.795 which means H0 is accepted. It indicates that the mind mapping has no significant effect on the system thinking of the tenth graders on the topic of trophic structure. The insignificant effect is described qualitatively which shows the influence of mind mapping on systems thinking. This is because mind mapping can indeed improve the structure and function as in the I indicator of systems thinking. Based on the conclusion, some suggestions can be put forward such as the number of samples is small, it is expected that further research will have a larger number of samples, the research is better to be carried out offline, and more instruments, such as modules and workbooks, as an addition to mind mapping, might yield better data.

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