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The Effects of Visual Mapping and Science-Related Attitudes on Students' Critical Thinking Skills at Man 1 Tanjung Pura

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Abstract: *This study aimed to find out the effects of visual mapping and science-related attitudes and their interactions on students' critical thinking skills on the topic of human locomotor system at MAN 1 Tanjung Pura, Indonesia. This research applied a quasi-experimental technique, by using a pretest-posttest experimental group with factorial design. The population was the entire students of eleventh grade (XI), about 141 students, with the samples consisting of 4 classes of Science Program, namely XI-1 of 28 students taught by concept mapping (CM), XI-2 of 39 students taught by mind mapping (MM), XI-3 of 42 students taught by argument mapping (AM); those are classified as experimental group and XI-4 of 32 students taught by direct instruction (DI) as control group. The results showed that the means of critical thinking pre-tests based on CM, MM, AM, and DI were 67.36, 67.59, 67.67, and 67.53. Meanwhile the means of critical thinking post-tests were 86.54, 86.15, 86.83 and 78.03. Subsequently, the means of science-related attitudes were 72.79, 73.95, 72.40 and 70.91, respectively. From the results of the 2-Way ANOVA, it was concluded that there were significant effects of learning techniques (CM, MM, AM, and DI) on critical thinking skills in which the value of significance was 0.000 < 0.05. From the result of Levene's Test for critical thinking post-test, it was assumed that the data was homogenous, in which 0.798 > 0.05. Based on the results of Duncan's Multiple Range Test, it was obviously known that there were significant differences of critical thinking post-test scores between CM and DI, in which 86.54 > 78.03, between MM and DI, in which 86.15 > 78.03 and between AM and DI, in which 86.83 > 78.03. Furthermore, from the result of the 2-Way ANOVA, it was concluded that there were significant effects of science-related attitudes on critical thinking skills in which the value of significance was 0.040 < 0.05. From the result of the 2-Way ANOVA, it was concluded that there were interactions of learning techniques (CM, MM, AM, and DI) and science-related attitudes on critical thinking skills in which the value of significance was 0.000 < 0.05. Generally, it was concluded that concept mapping, mind mapping, and argument mapping as classified into visual mapping were more effective in enhancing critical thinking skills. Science-related attitudes could literally influence students' critical thinking skills and there were also interactions between visual mapping and science-related attitudes on students' critical thinking skills.*

Keywords: *Visual Mapping, Science-Related Attitudes, Critical Thinking Skills, Interaction*

1. Introduction

Education is the process of developing the capacities and potentials of the individual so as to prepare that individual to be successful in a specific society or culture. The world is becoming more and more competitive, quality of performance has been the key factor for personal progress. Parents desire that their children climb the ladder of performance to as high a level as possible. This desire for a high level of achievement puts a lot of pressure on students, teachers, schools and in general education system itself. School achievement may be affected by various factors like intelligence, study habits, and attitude of people towards school, different aspects of their personality, and socio-economic status.

An emphasis on understanding leads to one of the primary characteristics of the new science of learning: its focus on the processes of knowing (e.g., Piaget, 1978; Vygotsky, 1978). Humans are viewed as goal-directed agents who actively seek information. They come to formal education with a range of prior knowledge, skills, beliefs, and concepts that significantly influence what they notice about the environment and how they organize and interpret it. This, in turn, affects their abilities to remember, reason, solve problems, and acquire new knowledge.

There is widespread acceptance of the idea that critical thinking should be an important dimension of science education. Thus, for example, the *National Science Education Standards* (1996) as one of its goals has the promotion of science as inquiry. The work in the science education literature devoted to the fostering of critical thinking takes a number of different forms. Some of it focuses on particular aspects of critical thinking, for example identifying logical fallacies (Dreyfus & Jungwirth, 1980; Jungwirth & Dreyfus, 1990); formal reasoning (Garnett & Tobin, 1984; Lawson, 1982;1985; Obed, 1997); and scientific reasoning more broadly (Friedler *et al*., 1990). Most often it is directed to either the description and evaluation of projects and programmes aimed at fostering critical thinking (Moll & Allen, 1982; Novak & Detloff, 1989; Statkiewicz & Allen, 1983; Zohar & Tamir, 1993; Zoller, 1999) or the assessment of students' abilities to think critically (Dreyfus & Jungwirth, 1980; Garnett & Tobin, 1984).

Science-related attitude is the most important outcome of science teaching. Though some people view the science-related attitude as the by-product of teaching science, yet a majority of the people consider it equally important as knowledge aspect. Science-related attitude is a very significant concern of the process of science education. To develop science-related attitude, the teachers should always remember that without a questioning mind and a spirit of enquiry, studies in science will only mean acceptance of dogma and will never lead to development of attitude towards science in the learner. The students should be made to practice and observe science so that they get the opportunity to feel and develop the components of science-related attitude in their minds.

The means of representing ideas in diagrams with node-link assemblies has been termed as concept mapping (Novak & Gowin, 1984), mind mapping (Buzan & Buzan, 1993) and argument mapping (van Gelder, 2013). All of these mapping techniques are called visual mapping (Davies, 2010). When used as a part of instruction, these types of mapping techniques have been shown to increase students' achievement scores (Horton *et al*., 1993), enhance knowledge retention (Nesbit & Adescope, 2006), develop critical thinking skills (Able & Freeze, 2006; Briscoe & LaMaster, 1991; Kinchin, 2001), and increase students' science-related attitudes (Akay, *et al*., 2012).

Educators are looking for new ways to make their teaching engaging, active, and student-centered can use visual mapping tools to achieve their teaching and learning goals. Teachers can visually engage students by making maps that complement or take the place of written information. They can also have their students participate in the tactile activity of making maps. Active learning occurs when "students are doing things and thinking about what they are doing" and meaningful learning happens when students integrate new information into what they already know (Stalheim-Smith, 1998; Novak *et al*., 2007). Visual mapping, which requires students to express their understanding of concepts in words and images and then draw and label links between those ideas, facilitates both learning processes.

The researcher has conducted the preliminary studies and initial observation about the score gains that students have achieved on the topics of human locomotor sysem at MAN 1 Tanjung Pura, Indonesia. Most of the score gains that students have obtained were quite low. The school has applied the minimum accomplishment standard of 83,0 in the eleventh grade, however the students just obtained the score below 83,0. So, most students failed in their own academic activities. In fact, students' critical thinking skills and science-related attitudes were also declined because of students were not actively involved in learning activity. The learning processes occured in schools were mostly based on a teacher-centered instruction. It was also stated that science education has, in many cases, become teacher centered, based on rote memorization, and focused on test scores (Heinze-Fry & Novak, 1990; Huai, 1997; Kinchin, 2001; Mason, 1992). Most students considered science to be boring, a list of big words and facts, intimidating, and not relevant to their lives (Mason, 1992). Negative attitudes towards the study of science, like Biology are also fostered as students experience no connection between their study and their real lives (Roth, 1994).

This study has been undertaken with the objectives to find out the effects of visual mapping and science-related attitudes and their interactions on students' critical thinking skills. This study was expected to be able to provide information about the effect of visual mapping and science-related attitudes and their interactions on students' critical thinking skills, particularly on the topics of human locomotor system. The results of this study were hoped to help educators making a right decision in teaching a meaningful and effective biology topics in the near future.

2. Research Method

2.1. Location, Time, Population and Sample of the Study

This study was conducted at MAN 1 Tanjung Pura, Jalan Pembangunan No. 5, Pekubuan, Tanjung Pura, Langkat Regency, North Sumatera, Indonesia. This study was held from August to October 2017. The population of this study was the entire students of eleventh grade (XI) about 141 students, with the samples consisting of 4 classes of Science Program, namely XI-1 of 28 students, XI-2 of 39 students, XI-3 of 42 students and XI-4 of 32 students, by purposive sampling (Cresswell & Plano Clark, 2011).

2.2. Research Variable and Design

The independent variable in this research was visual mapping techniques (concept mapping, mind mapping, argument mapping) and direct instruction, science-related attitude acts as a moderator variable and critical thinking skill acts as a dependent variable. This research applied a quasi-experimental technique, by using a pretest-posttest experimental group with factorial design. The researcher has considered that XI-1 was taught by concept mapping (CM), XI-2 was taught by mind mapping (MM), XI-3 was taught by argument mapping (AM); those are classified as experimental group and XI-4 was taught by direct instruction (DI) as control group.

2.3. Instruments and Data Analysis

The instruments were included the critical thinking test adapted from Finken and Ennis (1993), based on *Illinois Critical Thinking Essay Test,* and the science-related attitude was measured by TOSRA (Tests of Science-Related Attitudes) developed by Barry J. Fraser (1978). According to Connover (1999), the test of normality was applied by *Kolmogorov-Smirnov* Goodness-of-Fit Test, and homogeneity test was conducted by *Levene's Test for Equality Variance*. An inferential analysis used to examine the research hypothesis by applying *Two-Way ANOVA* on the degree $\alpha = 0.05$ as Duncan's Multiple Range Test (MRT) for the post-hoc. Data was processed by using SPSS Version 22.0.

3. Results

As seen in Table 1, at the beginning the pre-test means of CM, MM, AM and DI for critical thinking (CT) were 67.36, 67.59, 67.67 and 67.53. These results showed that the sample's present knowledge levels were very close to each other. There was not a statistical difference among the groups for the pre-tests of CM (0.905 > 0.05), MM (0.962 > 0.05) and AM (0.912 > 0.05). At the end of the treatment, the post-test scores were 86.54, 86.15, 86.83 and 78.03, respectively. It was obviously known that the means of CT post-tests for visual mapping (CM, MM, and AM) as experimental group were very close to each other compared with DI as control group. There was also a statistical difference among the groups for the post-tests of CM (0.000 < 0.05), MM (0.000 < 0.05) and AM (0.000 < 0.05). This means that CM, MM, and AM as classified into visual mapping were more effective in enhancing critical thinking skills.

Table1. *Means, Standard Deviation, Significance in Critical Thinking (CT)*

Tests	Techniques	Number of Students	Means	Std. Deviation	Sig.
Pre-test of CT	CM	28	67.36	6.105	0.905
	MM	39	67.59	5.098	0.962
	AM	42	67.67	5.239	0.912
	DI	32	67.53	5.187	
Post-test of CT	CM	28	86.54	2.701	0.000
	MM	39	86.15	2.710	0.000
	AM	42	86.83	2.478	0.000
	DI	32	78.03	2.658	

As seen in Table 2, the means of CM, MM, AM and DI for science-related attitudes were 72.79, 73.95, 72.40 and 70.91, respectively. These results showed that the sample's science-related attitudes levels were very close to each other. Furthermore, there was a statistical difference among the groups for the science-related attitudes of CM (0.040 > 0.05), MM (0.040 > 0.05) and AM (0.040 > 0.05), respectively.

Table2. *Means, Standard Deviation, Significance in Science-Related Attitudes*

Science-Related Attitudes	Techniques	Number of Students	Means	Std. Deviation	Sig.
	CM	28	72.79	7.320	0.040
	MM	39	73.95	6.589	0.040
	AM	42	72.40	6.556	0.040
	DI	32	70.91	6.596	

From the result of the test of 2 Way-ANOVA, it was concluded that there were significant effects of learning techniques (CM, MM, AM, and DI) on critical thinking skills in which the value of significance was 0.000 < 0.05, as presented in Table 3.

Table3. *The Effects of Learning Techniques on Critical Thinking Skills*

Tests of Between-Subjects Effects					
Dependent Variable: Posttest_CT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	1791.921[a]	4	447.980	64.524	.000
Intercept	107047.128	1	107047.128	15418.436	.000
Learning_Techniques	1777.909	3	592.636	85.360	**.000**
a. R Squared = ,655 (Adjusted R Squared = ,645)					

Then, to find out whether there were differences of critical thinking post-test scores among the learning techniques were applied by the Duncan's Multiple Range Test (MRT) for post-hoc. Based on the results of Duncan's Multiple Range Test, it was obviously known that:

- There was a significant difference of critical thinking post-test score between CM and DI, in which 86.54 > 78.03
- There was a significant difference of critical thinking post-test score between MM and DI, in which 86.15 > 78.03
- There was a significant difference of critical thinking post-test score between AM and DI, in which 86.83 > 78.03, all presented in Table 4.

Table4. *Duncan's Multiple Range Test*

Posttest_CT			
Duncan[a,,b]			
Learning_Techniques	**N**	**Subset for alpha = 0.05**	
		1	**2**
Direct_Instruction	32	78.03	
Mind_Mapping	39		86.15
Concept_Mapping	28		86.54
Argument_Mapping	42		86.83
Sig.		1.000	.317

Furthermore, from the result of the test of 2-Way ANOVA, it was concluded that there were significant effects of science-related attitudes on critical thinking skills in which the value of significance was 0.040 < 0.05, as presented in Table 5.

Table5. *The Effects of Science-Related Attitudes on Critical Thinking Skills*

Tests of Between-Subjects Effects					
Dependent Variable:Posttest_CT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	1791.921[a]	4	447.980	64.524	.000
Intercept	107047.128	1	107047.128	15418.436	.000
Science_Attitudes	2.622	1	2.622	.378	**.040**

From the result of the test of 2 Way-ANOVA, it was concluded that there were interactions of learning techniques and science-related attitudes on critical thinking skills in which the value of significance was 0.000 < 0.05, as presented in Table 6.

Table6. *The Interactions of Learning Techniques and Science-Related Attitudes on Critical Thinking Skills*

Tests of Between-Subjects Effects					
Dependent Variable:Posttest_CT					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	1599.031[a]	4	399.758	47.812	.000
Intercept	107547.476	1	107547.476	12862.828	.000
Learning_Techniques * Science_Attitudes	1599.031	4	399.758	47.812	**.000**

3.1. Discussion

3.1.1. The Effects of Visual Mapping on Students' Critical Thinking Skills

Based on the results of 2-Way ANOVA from the statistical testing aforementioned above, it was clearly known that the value of significance was 0.000 < 0.05. It was concluded that there were significant effects of visual mapping (CM, MM, and AM) on students' critical thinking skills.

There is empirical support for the use of visual mapping tools in enhancing, retaining and improving knowledge and critical thinking. Evidence from the cognitive sciences shows that visual displays do enhance learning (Vekiri, 2002; Winn, 1991). Visual mapping allows the separate encoding of information in memory in visual and well as propositional form, a phenomenon called "conjoint retention" or "dual coding" (Kulhavy, Lee, & Caterino, 1985; Paivio, 1971, 1983; Schwartz, 1988). In the former hypothesis, representations are encoded as separate intact units; in the latter, visual representations are synchronously organised and processed simultaneously and verbal representations are hierarchically organised and serially processed (Vekiri, 2002).

Farrand *et al*., (2002) conducted a study on the usage of mind mapping to enhance performance in a fact-recall test by students. As an additional variable they asked students to self-rate their motivation and critical thinking skill. In the study, a control group used their preferred study technique (keywords, re-reading the text or underlining keywords). The experimental group was instructed to use mind mapping. Both groups were immediately tested with a 15-question factual test. They were also tested a week after the initial exposure. In general, students allowed to use their own study techniques were more motivated than those told to use mind mapping and their critical thinking were raised simultaneously. However, the mind mappers had better performance than non-mappers on the immediate recall test (13% more) and in the long-term recall test (24% more) when results were adjusted for motivation and critical thinking skill.

There is also evidence that concept mapping enhances free recall and critical thinking ability by college students when the material is presented in a concept map versus ordinary text (Hall, 1996). This is especially true of propositions at the top of the mapping, i.e., super ordinate concepts (Hall, 1999). In general, these studies seem to indicate that concept mapping may enhance learning, recall and most especially with students with lower abilities. They also suggest that learners should achieve a significant level of mastery in the construction of concept maps to reap their full benefits. Finally, they indicate that concept maps can be evaluated and graded reliably. The main advantage of concept mapping is precisely its relational aim. As outlined above, concept maps enable relational links to be made between relevant concepts. In the educational context, it is claimed that meaningful learning best takes place by linking new concepts to existing knowledge (Craik & Lockhart, 1972; Maas & Leauby, 2005). Concept maps enable the elements of learning to relate to how cognitive knowledge is developed structurally by the learner (Maas & Leauby, 2005). In this way, representations are stored longer in memory. In summary, the evidence indicates that concept mapping are potentially useful techniques that can enhance learning, recall and critical thinking skill.

Dwyer *et al.* (2010) have argued that argument mapping decrease the cognitive burden by combining the text (reading) and structure of the argument. They hypothesized that argument mapping would significantly increase comprehension and memorization of an argument compared to a pure text reading that will create the critical thinking occurs. In an experiment, they presented written (text only) arguments compared to arguments maps to groups of university students. Students' reasoning ability was initially assessed with the Differential Aptitude Test. Six experimental groups were tested using a multifactorial design with two levels of complexity (arguments with 30 propositions and 50 propositions) and three conditions (text only, black-and-white maps, and color maps). Subjects were tested for comprehension by being asked whether a subset of the propositions supported or denied the main argument claim.Each subject also received a fill-in-blank memory test. The results indicated that there was no difference in the comprehension level across all experimental groups. However memory performance was better for the smaller (30 proposition) complexity in the text-only, black-and-white map and the color map conditions. Also, both the black-and-white and color map conditions were superior to the text-only condition. In short, argument mapping produced better recall and critical thinking than text-only arguments. It is possible that longer presentations by subjects experienced in argument mapping techniques may lead to better comprehension and critical thinking skill.

3.1.2. The Effects of Science-Related Attitudes on Students' Critical Thinking Skills

Based on the results of 2-Way ANOVA aforementioned above, it was obviously known that there were significant effects of science-related attitudes on critical thinking skills in which the value of significance was $0.040 < 0.05$.

As from the findings of the study it can be elucidated that there is a difference between students on the variables of science-related attitudes and critical thinking skills. For the present study the representative sample of students are showing a high mean score of students on both the variables; science-related attitude and critical thinking skill, means that students are having significantly higher science-related attitude, open-mindedness, curiosity, judgement based on verified facts, ready to test and verify conclusion, faith in cause and effect relationship, be ready to reconsider their judgement, be free from superstitions and false beliefs, honest in recording, collecting and reporting scientific data, being critical in observations.

The present study had revealed many interesting findings students showing more scientific temper and critical thinking. Having science-related attitude is not only the needs skepticism but also humility. There would be no branch of new knowledge discovered without this science-related attitude. Critical thinking should be improved in students. It is a process of examining the offered evidence and reasoning, and forming reasonable judgments about the facts. Without the critical thinking ability, we would be misled to our high sight bias and overconfidence of our judgments. Science education often includes in its aims the development of critical-mindedness. This is usually regarded as one of a range of scientific attitudes. It is argued that critical-mindedness depends on appropriate cognitive and affective inputs as well as critical thinking ability, and that consequently critical-mindedness is context dependent.

3.1.3. The Interactions of Visual Mapping and Science-Related Attitudes on Students' Critical Thinking Skills

Based on the results of two-way ANOVA aforementioned above, it was clearly known that there were interactions of visual mapping (CM, MM, and AM) and science-related attitudes on critical thinking skills in which the value of significance was $0.000 < 0.05$.

Almost all researchers agreed that for science education, one of the critical problems is the negative attitude towards science (Ramsden, 1998), so to overcome this problem, study of science-related attitude and science learning should be conducted. The importance and role of science-related attitude can be recognized from the researches' findings showing positive relationship of science-related attitude on critical thinking skill, and students with more positive attitude towards science has sustainable learning and enhances their critical thinking abilities, and also want to continue with those subjects they enjoy (Pell & Jarvis, 2001). These researchers provided revealing insight regarding attitude towards science and most of them have reported positive attitude of students towards science and critical thinking (Osborne, Simon, & Collins, 2003). Visual mapping could also improve students' critical thinking skills and was expected to enhance their attitudes on science as well. It could be concluded that there are interactions of visual mapping and science-related attitudes on students' critical thinking skills.

4. Conclusion

Based on the results of the study and data analysis aforementioned above, it was obviously concluded that:

- There are significant effects of learning techniques (CM, MM, AM, and DI) on students' critical thinking skills on the topic of human locomotor system at MAN 1 Tanjung Pura ($P = 0.000 < 0.05$).
- There are significant effects of science-related attitudes on students' critical thinking skills on the topic of human locomotor system at MAN 1 Tanjung Pura ($P = 0.040 < 0.05$).
- There are interactions between learning techniques (CM, MM, AM, and DI) and science-related attitudes on students' critical thinking skills on the topic of human locomotor system at MAN 1 Tanjung Pura ($P = 0.000 < 0.05$).

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