Advances in Social Science, Education and Humanities Research, volume 200
3rd Annual International Seminar on Transformative Education and Educational Leadership (AISTEEL 2018)

The Effects of Visual Mapping and Science-Related Attitudes on Students" Problem Solving Skills

Muhammad Jamhari[1], Syarifuddin[2], Herbert Sipahutar[2]
[1]Student of Postgraduate Program of Biology Education, Universitas Negeri Medan, Indonesia
[2]Lecturer of Postgraduate Program of Biology Education, Universitas Negeri Medan, Indonesia
[2]Lecturer of Postgraduate Program of Biology Education, Universitas Negeri Medan, Indonesia
e-mail: jamiedarhany1@gmail.com

Abstract— **The aims of this study were to find out: (1) the effects of visual mapping on students' problem solving skills, (2) the effects of science-related attitudes on students' problem solving skills, and (3) the interactions between visual mapping and science-related attitudes on students' problem solving skills. This study was conducted at MAN 1 Tanjung Pura, with the samples of 141 students of XI-Science Program. This study was a quasi-experimental technique by using a pretest-posttest experimental group with 4x2 factorial design. The technique of data analysis was processed by the Two-Way ANOVA and followed by Duncan's Multiple Range Test with the aid of SPSS 22.00 on the significance level of 0.05. The results showed that: (1) there were the significant effects of visual mapping on students' problem solving skills (F=94.214; P=0.000), where the scores of students' problem solving skills taught by concept mapping (87.74±2.586) were significantly higher than taught by direct instruction (78.84±2.689), (2) there were the significant effects of science-related attitudes on students' problem solving skills (F=3.397; P=0.031), where the scores of high science-related attitudes on students' problem solving skills taught by visual mapping (85.68±4.312) were significantly higher than the scores of low science-related attitudes on students' problem solving skills taught by visual mapping (77.26±3.614), and (3) there were the interactions between visual mapping and science-related attitudes on students' problem solving skills (F=2.195; P=0.000), where the scores of students' problem solving skills taught by argument mapping with high science-related attitudes were significantly different than taught by direct instruction with high science-related attitudes (P=0.042<0.05) and low science-related attitudes (P=0.000<0.05).**

Keywords— visual mapping, science-related attitudes, problem solving skills

I. 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 [1]; [2]. 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.

For much of the 20th century, educators have devoted their attention to trying to define and teach problem solving skills. In the early 1900s, problem solving was viewed as a mechanical, systematic, and often abstract set of skills, such as those used to solve riddles or biological problems. These problems often have correct answers that are based on logical solutions with a single correct answer. Under the influence of cognitive learning theories, problem solving shifted to represent a complex mental activity consisting of a variety of cognitive skills and actions. Problem solving included higher order thinking skills such as visualization, association, abstraction, comprehension, manipulation, reasoning, analysis, synthesis, generalization, each needing to be managed and coordinated [3]. Problem solving also includes attitudinal as well as cognitive components [4].

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 concept mapping [5], mind mapping [6] and argument mapping [7]. All of these mapping techniques are called visual mapping [8]. When used as a part of instruction, these types of mapping techniques have been shown to increase students" achievement scores [9], enhance knowledge retention [10], support problem solving abilities [11] and increase students" attitude towards science [12].

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 [13]; [14]. 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.

In our society academic achievement is considered as a key criterion to judge one"s total potentialities and capacities. Hence, academic achievement has the same thing like problem solving ability and science-related attitude occupies a very important place in education as well as in the learning process. So in view of this a study was conducted to find out students" problem solving abilities and science-related attitudes in Biology, particularly for the topic of human locomotor system on the basis of constructive teaching method of visual mapping, such as concept mapping, mind mapping and argument mapping, respectively.

The researcher has conducted the preliminary studies and initial observation about the mean score that students have achieved for the topic of human locomotor system at MAN 1 Tanjung Pura. Most of the mean score that students have obtained were quite low. The school has applied the minimum accomplishment standard of 83.0 in the eleventh grade, in fact the students just obtained the score below 83.0 (see Table 1).

TABLE 1. The Mean Score of Students" Learning Accomplishment of the 11th Graders of Science Program at MAN 1 Tanjung Pura

No.	Grade	KKM	Mean Score
1.	XI-IPA 1	≥ 83	79.64
2.	XI-IPA 2	≥ 83	78.56
3.	XI-IPA 3	≥ 83	78.81
4.	XI-IPA 4	≥ 83	78.92
	Average		78.98

(Source: 11th Grade Students' Archives at MAN 1 Tanjung Pura, 2016)

In fact, students" problem solving skills and science-related attitudes were also declined because of students were not actively involved in learning activity [15]. 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 [16]; [17]; [18]; [19]. Most students considered science to be boring, a list of big words and facts, intimidating, and not relevant to their lives [19]. Negative attitudes towards the study of science are also fostered as students experience no connection between their study and their real lives [20].

Based on the interviews conducted with a biology teacher of the eleventh grade at MAN 1 Tanjung Pura have been known that the topic of human locomotor system was considered to be one of the most difficult matters that students have faced, particularly bone tissue, skeletal system, muscular system and muscular tissue due to the unclear concepts. This case was in line with the conditions in other schools across Tanjung Pura suggested that human locomotor system was quite difficult to be understood well. Although traditional methods of lecturing and experimenting have not proven effective, additional visual mapping learning techniques were implemented to provide students with the opportunity to engage and discover concepts, draw conclusions and report findings with supporting information [7].

II. LITERATURE REVIEW

A problem is "a situation, quantitative or otherwise, that confronts an individual or group of individuals, that requires resolution, and for which the individual sees no apparent or obvious means or path to obtaining a solution" [21]. [21] also define problem solving as the means by which an individual uses previously acquired knowledge, skills, and understanding to satisfy the demands of an unfamiliar situation. The students must synthesize what they have learned, and apply it to a new and different situation. This definition is similar to the definition of the eighth element of problem solving, transfer: "when learning in one situation facilitates learning or performance in another situation" [22]. In the early 1900s, problem solving was viewed as a mechanical, systematic, and often abstract set of skills, such as those used to solve riddles or mathematical equations. These problems often have correct answers that are based on logical solutions with a single correct answer. Under the influence of cognitive learning theories, problem solving shifted to represent a complex mental activity consisting of a variety of cognitive skills and actions. Problem solving included higher order thinking skills such as visualization, association, abstraction, comprehension, manipulation, reasoning, analysis, synthesis, generalization, each needing to be managed and coordinated [3].

Attitude can be defined as "feelings, beliefs and values held about the enterprise of school science, school science and the impact of the science on society" [23]. In his study, [24] defined attitude as positive or negative feelings about a person, an object or an issue. [25] proposed six dimensions regarding „attitudes toward science" namely; the manifestation of favorable attitudes to science and scientists, acceptance of scientific inquiry as a way of thought, adaptation of scientific attitudes, enjoyment of science learning experiences, development of interest in science and science related activities, and the development of interest in pursuing a career in science. [24] emphasizes that science-related attitude is a very important factor in influencing human behavior. Attitude is affected by personal opinion, and these opinions can be formed through personal life experiences and education. Attitudes toward science involves the students‟ affective behaviors; *e.g.* example preference, acceptance, appreciation and commitment.

III. RESEARCH METHOD

3.1. Location and Time of the Study

This study has been conducted at MAN 1 Tanjung Pura, Jalan Pembangunan No. 5, Desa Pekubuan, Tanjung Pura Sub-district, Langkat Regency, North Sumatera, Postal Code 20853. This study has been employed from August to October 2017.

3.2. Population and Sample of the Study

The population of this study was the entire students of eleventh grade (XI) at MAN 1 Tanjung Pura, totally 141 students. The sample was consisting of 4 classes, XI-IPA 1 of 28 students, XI-IPA 2 of 39 students, XI-IPA 3 of 42 students and XI-IPA 4 of 32 students, respectively. The researcher withdrew the entire samples of this study using purposive sampling [26].

3.3. Type and Design of the Research

This research applied a *quasi-experimental technique*, by conducting experiments in the classroom available, but not changing the classroom situation and learning schedule. The design of this research has been using a *pretest-posttest experimental group design* with 4x2 factorial to find out the effects of learning techniques and science-related attitudes on students‟ critical thinking and problem solving skills and their interactions as well [27] (see Table 2).

TABLE 2**.** Pretest-Posttest Experimental Group Design

Science-Related Attitude (B)	Learning Techniques (A)			
	Concept Mapping (A1)	**Mind Mapping (A2)**	**Argument Mapping (A3)**	**Direct Instruction (A4)**
High Science-Related Attitude (B_1)	$\mathbf{A_1B_1}$	$\mathbf{A_2B_1}$	$\mathbf{A_3B_1}$	$\mathbf{A_4B_1}$
Low Science-Related Attitude (B_2)	$\mathbf{A_1B_2}$	$\mathbf{A_2B_2}$	$\mathbf{A_3B_2}$	$\mathbf{A_4B_2}$

(Source: Federer, 1977)

3.4. Instruments of Data Collection

The research instruments used in this study were students‟ critical thinking tests consisting of 10 essay test adapted from [28], based on *Illinois Critical Thinking Essay Test*, students‟ problem solving tests according to Polya and adapted by [29], and science-related attitude questionairres which have been developed by [30].

3.5. Technique of Data Analysis

According to [31], 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* on the significance value is greater than 0.05.

Data was created in tables and graphics or figures as well. An inferential analysis used to examine the research hypothesis by using *Two-Way ANOVA* (Two-Way Analysis of Variance) on the degree α = 0.05 as Duncan's Multiple Range Test (DMRT) for the post-hoc.

IV. RESULTS AND DISCUSSION

4.1. Results

The hypothetical tests for students‟ problem solving skills were conducted by the test of two-way ANOVA on the significance degree of 0.05 and followed by the post-hoc test of Duncan‟s Multiple Range Test (DMRT).

4.1.1. The Effects of Learning Techniques on Students‟ Problem Solving Skills

The result from two-way ANOVA showed that learning techniques influenced the scores of students‟ problem solving skills ($F = 94.214$; $P = 0.000$). The scores of students‟ problem solving skills taught by concept mapping (87.74±2.586) were significantly higher than the scores of students‟ problem solving skills taught by direct instruction (78.84±2.689). It means that the average scores of students‟ problem solving skills taught by concept mapping had a percentage of 14.38% were higher than the average scores of students‟ problem solving skills taught by direct instruction. However, there were no significant effects of students‟ critical thinking skills taught by concept mapping (87.74±2.586), mind mapping (86.64±1.940) and argument mapping (87.00±2.494) as well.

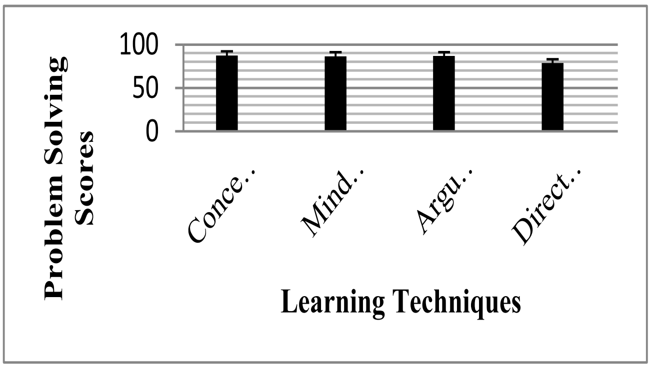

Fig 1. The Effects of Learning Techniques on Students‟ Problem Solving Skills for the Topic of Human Locomotor System ($F = 94.214$; $P = 0.000$). Different letters above the diagrams means significantly different.

4.1.2. The Effects of Science-Related Attitudes on Students" Problem Solving Skills

The result from two-way ANOVA showed that science-related attitudes influenced the scores of students" problem solving skills (F = 3.397; P = 0.031). The scores of high science-related attitudes on students" problem solving skills taught by learning techniques (concept mapping, mind mapping, argument mapping and direct instruction) of 85.68±4.312 (X±SD) were significantly higher than the scores of low science-related attitudes taught by learning techniques (concept mapping, mind mapping, argument mapping and direct instruction) of 77.26±3.614 (X±SD). It means that the average scores of students" high science-related attitudes taught by learning techniques had a percentage of 13.28% were higher than the average scores of students" low science-related attitudes taught by learning techniques as well.

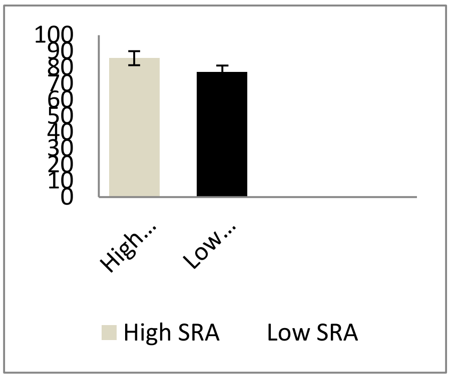

Fig 2. The Effects of Science-Related Attitudes on Students" Problem Solving Skills at MAN 1 Tanjung Pura (F = 3.397; P = 0.031). Different letters above the diagrams means significantly different.

4.1.3. Interactions Between Learning Techniques and Science-Related Attitudes on Students" Problem Solving Skills

The result from two-way ANOVA showed that the interactions between learning techniques and science-related attitudes influenced students" problem solving skills (F = 2.915; P = 0.000). The interactions between learning techniques and science-related attitudes taught by argument mapping were significantly different than taught by direct instruction. The results obtained for the scores of students" high science-related attitudes which were taught by concept mapping of 86.94±5.664, mind mapping of 87.29±4.493, and argument mapping of 88.19±4.726. The results obtained for the scores of students" low science-related attitudes taught by concept mapping were of 74.65±7.211, mind mapping of 75.81±6.328, and argument mapping of 77.38±6.415 as well. Students who were taught by direct instruction obtained the scores of high science-related attitudes of 79.00±5.652 and low science-related attitudes of 71.16±3.164.

Due to the hypotheses test, it showed that there were significant effects of learning techniques on students" problem solving skills, so it should be followed by Duncan"s Multiple Range Test (DMRT). The result of DMRT showed that students" problem solving skills taught by learning techniques with high and low science-related attitudes had significant differences. The scores of students" problem solving skills taught by argument mapping with high science-related attitudes were significantly different than the scores of students" problem solving skills taught by direct instruction with high science-related attitudes (P = 0.042<0.05) as well as taught by direct instruction with low science-related attitudes (P = 0.000<0.05). However, the scores of students" critical thinking skills taught by learning techniques (concept mapping, mind mapping and argument mapping) with high science-related attitudes were not significantly different than the scores of students" problem solving skills taught by learning techniques (concept mapping, mind mapping and argument mapping) with low science-related attitudes (P = 0.042>0.05).

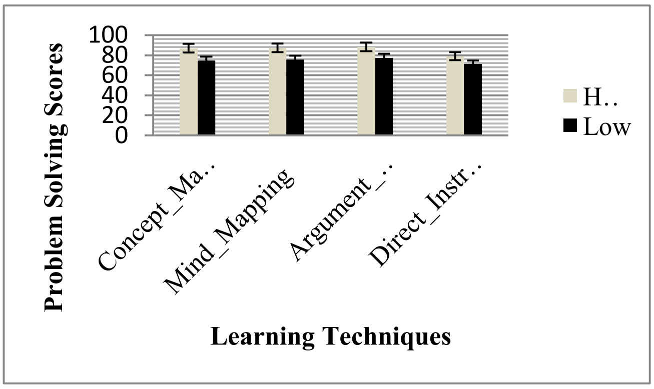

Fig3. The Effects of Learning Techniques and Science-Related Attitudes (High and Low) on Students" Problem Solving Skills at MAN 1 Tanjungpura (F = 2.915; P = 0.000). Different letters above the diagrams means significantly different.

4.2. Discussion

4.2.1. The Effects of Learning Techniques on Students" Problem Solving Skills

The result from two-way ANOVA showed that that learning techniques influenced the scores of students" problem solving skills (F = 94.214; P = 0.000). The scores of students" problem solving skills taught by concept mapping (87.74±2.586) were significantly higher than students" problem solving skills taught by direct instruction (78.84±2.689).

There is empirical support for the use of concept mapping (visual mapping tools) in enhancing, retaining and improving knowledge and problem solving. The potential of concept mapping to provide an effective and efficient support for ill-structured problem solving has been reported in a number of studies [32]; [33]; [34]. Most of the studies define concept mapping as a knowledge *representation* technique [35]; [36]; [37]; [38]; [39]; [40]. This definition reflects only one of the characteristics of concept mapping as problem solving tool. Concept mapping as a knowledge *representation* technique is a concise and intuitive way of externalizing the mental models of the problem solver as technique proposes a simple graphical format, which combines both visual and verbal coding. Concept mapping as a knowledge *reflection* technique, effectively supports self-appraisal on problem solving process and results. It also involves perception, that amplifies memory and thinking as creating more space for cognitive resources. Concept mapping as a knowledge *creation* technique, has a potential for an effective and efficient combination of different ideas and construction of alternative solutions.

[41] reported a study of secondary school students in Venezuela where students trained in concept mapping outperformed students without concept mapping training in tests measuring problem-solving skills. In another study by [42], high school students in the United States showed significant advantages in achievement and problem solving tests when using concept mapping throughout a course as opposed to using single-shot concept mapping at the end of the course. However, even students using concept mapping at the end of the course had significantly better achievement and problem solving skill than those who did not use concept mapping at all.

[43] trained a group of students in concept mapping. They practiced their skills with the help of a mediator during case presentation sessions. A control group of students followed the traditional case discussion sessions. All students took multiple-choice examinations and problem-solving exams. The students were receiving concept mapping training performed significantly better than the traditional students in the problem-based exam but not in the multiple-choice exams. This was particularly true for lower-achieving students. [44] trained students in concept mapping techniques and immediately after asked them to develop a concept map on the topic of seizures. The students completed three one-hour education sessions on the same topic and were asked to develop a concept map again. Using their rubric, they found that the second maps had significantly better quality. However, the mapping scores were not significantly correlated to students‟ in-training board exams. [45] performed a meta-analysis of experimental studies and found that student concept mapping had the greatest effect on enhancing the correcting problem solving skills and correcting misconceptions.

In summary, the evidence indicates that visual mapping are potentially useful techniques that can increase students‟ problem solving skill.

4.2.2. The Effects of Science-Related Attitudes on Students‟ Problem Solving Skills

Science-related attitudes had the significant effects on students‟ problem solving skills. Science-related attitude was categorized into two main parts, high and low science-related attitude. In this case, high science-related attitudes taught by visual mapping (learning techniques) were better than low science-related attitudes by learning techniques as well. Problem solving competence could be developed by solving non-routine problems. Students rarely solve non-routine problem in their classroom [46] ; [47], this due or to the fact that these kind of problems are rarely given on national tests [48] or students are not confident in their problem solving competence [46]. For a successful problem solving, students need to be motivated, as there is a correlation between students‟ science-related attitude and their scientific results [49]. Students‟ motivation is strongly related with their beliefs about the utility of science in their future life [50], and with the interest level of solving the concrete problem. Teachers‟ science-related attitude influences students‟ attitude and problem solving skill [51]; [50].

In order to be able to solve non-routine problems, students should have a reasonable level of problem solving competency. This competency is "an individual‟s capacity to use cognitive processes to confront and resolve real, cross-disciplinary situations where the solution path is not immediately obvious and where the literacy domains or curricula areas that might be applicable are not within a single domain of mathematics, science or reading" [52]. Science problem solving needs application of multiple skills [53]. Beliefs towards science are also important for a successful problem solving [54]. To measure the cognitive processes essential for problem solving, it is better to avoid the need of domain specific knowledge and strategies [55], and try to evaluate logical reasoning skills, which are important for a successful science learning [56].

In summary, the evidence indicates that science-related attitude is a potential aspect that can increase student‟s problem solving skill.

4.2.3. The Interactions Between Learning Techniques and Science-Related Attitudes on Students‟ Problem Solving Skills

The result from the hypothetical testing previously showed that the interactions between learning techniques and science-related attitudes influenced students‟ problem solving skills. The interactions between learning techniques and science-related attitudes taught by argument mapping were significantly different than taught by direct instruction.

In order to solve problems, students need to think critically, scientifically-mannered and formulate coherent evidence-based arguments. An evidence-based argument is an argument where the conclusion is reasonable given the assumptions, and the assumptions should be self evident or supported by evidence. Students at all levels have been found to be lacking in the ability to think critically, to have attitudes scientifically and to create evidence-based arguments. For these reasons more research needs to be done related to identifying and implementing effective and efficient instructional strategies that facilitate the development of argumentation skills to solve problems and have attitudes scientifically.

Argument mapping as a visual mapping tool has been found to be an effective technique for developing problem-solving skills. However, given the characteristics of argument mapping such as the use of ill-structured problems and minimal guidance from the teacher, some students still struggle to solve problems, and they do not necessarily provide sound reasons or arguments for their solutions [57]; [58]; [59]. Research findings have been mixed regarding the effectiveness of argument mapping on the development of problem solving skills [60]; [61], the ability to create arguments [62]; [58], and learner motivation [63]. Therefore, in order for learners to develop the skills needed to create sound arguments to solve problems, some form of learner support is needed. Learner support in the form of scaffolding has been found to be effective in facilitating the ability to create evidence-based arguments. Several types of scaffolding in particular, such as question prompts, expert modeling and argumentation, have been found to be effective when used in argument mapping for the development of problem-solving skills and improving learner science-related attitudes. In addition to the mixed findings in the literature regarding the effectiveness of argument mapping, another rationale for this study includes understanding the effects of instructional strategies such as problem-based learning when used with argument mapping on a skill that has been deemed important for success in the 21st century.

According to [64], that an attitude is a tendency to think, feel, and act positively or negatively toward objects in our environment. Attitude organizes thoughts, emotions and behaviors towards a psychological object. Some attitudes are based on people‟s own experiences, knowledge and skills, and some are gained from other sources [65]. It can be concluded in words of [66] that attitudes are learned, not inherited. The attitudes toward science change with exposure to science, but that the direction of change may be related to the quality of that exposure, the learning environment, and learning technique [66]. It can be said that a negative attitude towards a certain subject makes problem solving skills and learning or future-learning difficult. As conceived by [67], "A positive attitude toward science leads to a positive commitment to science that influences student‟s problem solving ability and lifelong interest and learning in science". But once the attitudes are formed they are long lasting and difficult to change [68].

Problem solving tasks related to the content learned are provided in order to establish a context for the learners to engage metacognitive processes. Problem solving, one of the unique human capabilities, is categorized as a learning outcome, in which the learners are able to select and use rules to find a solution in a novel situation [69]. What learners acquires during the process of problem solving is a synthesis of other rules and concepts. [70] states that metacognitive processes in problem solving include assessing the requirements of the problem, constructing a solution plan, selecting an appropriate solution strategy, monitoring progress toward the goal, and modifying the solution plan. Thus, if visual mapping has facilitated meaningful learning for the learners to transfer their metacognitive skills from one situation to another, the learners should be consciously aware of themselves as an active problem solver participating in these metacognitive processes in problem solving. Therefore, in order to verify such transfer, the learners are asked to introspect their own thinking after they participate in a problem solving task. It could be concluded that there are interactions of visual mapping and science-related attitudes on students‟ problem solving skills.

V. CONCLUSION

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

1. There were significant effects of learning techniques on students‟ problem solving skills at MAN 1 Tanjung Pura (F = 94.214; P = 0.000).
2. There were significant effects of science-related attitudes on students‟ problem solving skills at MAN 1 Tanjung Pura (F = 3.397; P = 0.031).
3. There were interactions between learning techniques and science-related attitudes on students‟ problem solving skills at MAN 1 Tanjung Pura (F = 2.915; P = 0.000).

The results of the study implied that visual mapping is one of the other learning techniques which focuses on student-centered instruction. A variety of educational mapping aids have been developed that enable the visual display of information, concepts and relations between ideas. These mapping aids take a variety of names including, such as concept mapping, mind mapping and argument mapping. The potential of these mapping aids for educational purposes is only now starting to be realised.

ACKNOWLEDGMENTS

I would like to thank to Prof. William Martin Davies, Ph.D from the University of Melbourne, Australia who have shared his experiences and given me a bunch of relevant journals to support and strengthen my research, the one who have motivated me to do a lot of valuable and meaningful works, inspired me to complete my research and who have one way or another, contributed to the success of this research.

REFERENCES

[1] Piaget, J. 1978. *Success and Understanding*. London: Routledge & Kegan Paul.

[2] Vygotsky, L.S. 1978. *Mind In Society*: *The Development of Higher Psychological Processes.* Cambridge: Harvard University Press.

[3] Garofalo, J., F. Lester. 1985. Metacognition, Cognitive Monitoring, and Mathematical Performance. *Journal for Research in Mathematics Education*, *16*(3): 163-176.

[4] Jonassen, D., M. Tessmer. 1996. An Outcomes-based Taxonomy for the Design, Evaluation, and Research on Instructional Systems. *Training Research Journal, 8*(2): 67-84.

[5] Novak, J.D., D.B. Gowin. 1984. *Learning How to Learn*. Cambridge University Press: Cambridge.

[6] Buzan, T., B. Buzan. 1993. *The Mind Map Book: How to Use Radiant Thinking to Maximize Your Brain's Untapped Potential*. New York: Plume.

[7] van Gelder, T.J. 2013. Argument Mapping. In *Encyclopedia of the Mind*, edited by H. Pashler. Thousand Oaks, CA: Sage.

[8] Davies, W.M. 2010. *Concept Mapping, Mind Mapping and Argument Mapping: What are the Differences and Do They Matter?* Available from: http://www.tlu.fbe.unimelb.edu.au/teaching_staff/seminar_series/documents/Sem1CMMMAM.pdf. Accessed August 30, 2017.

[9] Horton, P.B., A.A. McConney., M. Gallo., A.L. Woods., G.J. Senn., D. Hamelin. 1993. An Investigation of the Effectiveness of Concept Mapping as an Instructional Tool. *Science Education, 77*(1): 95-111.

[10] Nesbit, J.C., O.O. Adescope. 2006. Learning with Concept and Knowledge Maps: A Meta-analysis. *Review of Educational Research, 76*(3): 413-448.

[11] Fiol, C.M., A.S. Huff. 1992. Maps for Managers: Where are we? Where do we go from here? *Journal of Management Studies*, *29*(3): 267–285.

[12] Akay, O.S. 2012. The Effect of Concept Maps on The Academic Success and Attitudes of 11th Graders while Teaching Urinary System. *International Online Journal of Primary Education*, *1*(1): 62-76.

[13] Stalheim-Smith, A. 1998. *Focusing on Active, Meaningful Learning*. Idea Paper 34. Manhattan, KS: Kansas State University, Center for Faculty Evaluation and Development.

[14] Novak, J.D., A.J. Canas. 2007. Theoretical Origins of Concept Maps, How to Construct Them and Uses in Education. *Journal of Reflecting Education, 3*(1): 29-42.

[15] Liu, M., J.J. Lee., C. Linn. 2010. The Effect of Science-Technology-Society Teaching on Students‟ Attitudes Toward Science, Problem Solving and Certain Aspects of Creative and Critical Thinking Abilities. *International Journal of Science Education*, *29*(11): 1315-1327.

[16] Heinze-Fry, J.A., J.D. Novak. 1990. Concept Mapping Brings Long-term Movement Toward Meaningful Learning. *Science Education, 74*(4): 461-472.

[17] Huai, H. 1997. Concept Mapping in Learning Biology: Theoretical Review on Cognitive and Learning Styles. *Journal of Interactive Learning Research, 8*(3/4): 325-340.

[18] Kinchin, I.M. 2001. If concept mapping is so helpful to learning biology, why aren‟t we all doing it? *International Journal of Science Education, 23*(12): 1257-1269.

[19] Mason, C.L. 1992. Concept Mapping: A Tool to Develop Reflective Science Instruction. *Science Education, 76*(1): 51-63.

[20] Roth, W.M. 1994. Science Discourse Through Collaborative Concept Mapping: New Perspectives for the Teacher. *International Journal of Science Education, 16*(4): 437-455.

[21] Krulik, S., J.A. Rudnick. 1980. *Problem Solving: A Handbook for Teachers,* (2nd eds.). Boston: Allyn & Bacon.

[22] Ormrod, J. 1999. *Human Learning* (3rd eds.). Upper Saddle River, New Jersey: Prentice Hall.

[23] Osborne, J., S. Simon., S. Collins. 2003. Attitudes Toward Science: A Review of Literature and its Implication. *International Journal of Science Education, 25*(9): 1.049-1.079.

[24] Newhouse, N. 1990. Implication of Attitudes and Behavior Research for Environmental Conservation. *The Journal of Environmental Education, 22*(1): 26-32.

[25] Klopfer, L.E. 1976. A Structure for the Affective Domain in the Relation to Science Education. *Science Education, 60*(2): 299-312.

[26] Cresswell, J.W., V.L. Plano Clark. 2011. *Designing and Conducting Mixed Methods Research*. Los Angeles: Sage Publications.

[27] Federer, W.T. 1977. *Bibliography on Experiment and Treatment Design*. Published for the International Statistical Institute by Oliver and Boyd, Edinburgh: Scotlandia.

[28] Finken., R.H. Ennis. 1993. *Illinois Critical Thinking Essay Test*. Illinois Critical Thinking Project. Department of Educational Policy Studies University of Illinois.

[29] Peng, C.N. 2004. *Successful Problem-Based Learning for Primary and Secondary Classrooms*. Singapore: Federal Publications.

[30] Fraser, B.J. 1978. *Test of Science-Related Attitudes (TOSRA) Handbook*. The Australian Council for Educational Research Limited, Radford House, Frederick Street, Hawthorn, Victoria 3122.

[31] Connover, 1999. Practical Nonparametric Statistics, (3rd eds.). Hoboken, New Jersey: Wiley.

[32] Novak, J.D. 1998. *Learning, Creating, and Using Knowledge: Concept Maps as Facilitative Tools in Schools and Corporations,* (1st eds.). New Jersey: Lawrence Erlbaum Associates, Inc.

[33] Jonassen, D.H. 2004. *Learning to Solve Problems. An Instructional Design Guide*. Pffeifer, San Francisco: California.

[34] Stoyanov, S., P. Kommers. 2006. WWW-intensive Concept Mapping for Metacognition in Solving Ill-structured Problems, *International Journal of Continuing Engineering Education and Lifelong Learning*, *16*(3): 297–316.

[35] Gulmans, J. 2004. Mapping for the Constructivistic Acquisition of Concepts? In P. Kommers (eds), *Cognitive Support for Learning*. Amsterdam: IOS Press.

[36] Huai, H., P. Kommers. 2004. Cognitive Styles and Concept Mapping. In P. Kommers (eds.), *Cognitive Support for Learning*. Amsterdam: IOS Press.

[37] Jonassen, D.H., T.C. Reeves., N. Hong., D. Harvey., K. Peters. 1998. Concept Mapping as Cognitive Learning and Assessment Tools. *Journal of Interactive Learning Research*, *8*(3-4): 289-308.

[38] Kennedy, D., T. McNaught. 1998. Use of Concept Mapping in the Design of Learning Tools for Interactive Multimedia. *Journal of Interactive Learning Researc*h, *8*(3): 389-406.

[39] Reimann, P. 1999. The Role of External Representations in Distributed Problem-Solving. *Journal of Learning and Instructio*n, *9*(3): 411-418.

[40] Sherry, L., M. Trigg. 1996. Epistemic Forms and Epistemic Games. *Educational Technology, 3*6(3): 38-44.

[41] Bascones, J., J.D. Novak. 1985. Alternative Instructional Systems and the Development of Problem-Solving Skills in Physics. *Eur. J. Sci. Educ*., *7*(3): 253-61.

[42] Pankratius, W.J. 1990. Building an Organized Knowledge Base: Concept Mapping and Achievement in Secondary School Physics. *J. Res Sci Teach*., *27*(4): 315-33.

[43] Gonzalez, H.L., A. Pardo-Palencia., L.A. Umana LA., L. Galindo. 2008. Mediated Learning Experience and Concept Maps: A Pedagogical Tool for Achieving Meaningful Learning in Medical Physiology Students. *Adv. Physiol. Educ*., *32*(1): 312-316.

[44] West, D., J.R. Pomeroy., J. Park., E. Gerstenberger., J. Sandoval. 2000. Critical Thinking in Graduate Medical Education. *Journ. Am Med Assoc. 284*(9): 256-271.

[45] Guzetti B.J., T.E. Snyder., V. Glass. 1993. Promoting Conceptual Change in Science: A Comparative Meta-analysis of Instructional Interventions from Reading Education and Science Education. *Read Res Q. 28*(2): 117-55.

[46] Silver, E.A., H. Ghousseini., D. Gosen., C. Charalambous., B.T.F. Strawhun. 2005. Moving from Rhetoric to Praxis: Issues Faced by Teachers in Having Students Consider Multiple Solutions for Problems in the Mathematics Classroom. *Journal of Mathematical Behavior*, *24*(2): 287-301.

[47] Leikin, R., A. Levav-Waynberg. 2007. Exploring Mathematics Teacher Knowledge to Explain the Gap Between Theory-based Recommendations and School Practice in the Use of Connecting Tasks. *Educational Studies in Mathematics*, *66*(3): 349-371.

[48] Marchis, I. 2009. Comparative Analysis of the Mathematics Problems Given at International Tests and at the Romanian National Tests, *Acta Didactica Napocensia*, *2*(2): 141-148.

[49] Nicolaidou, M., G. Philippou. 2003. *Attitude Towards Mathematics, Self-efficacy and Achievement in Problem-solving*. Proceedings of the 3rd Conference of the European Society for Research in Mathematics Education.

[50] Marchis, I. 2011. Factors that Influence Secondary School Students" Attitude to Mathematics, The 2nd International Conference on Education and Educational Psychology 2011, *Procedia-Social and Behavioral Sciences*, *29(2)*: 786-793.

[51] Ford, M.I. 1994. Teachers' Beliefs About Mathematical Problem Solving in the Elementary School. *School Science and Mathematics*, *94*(6): 314-322.

[52] OECD. 2003. *The PISA 2003 Assessment Framework: Mathematics, Reading, Science and Problem Solving Knowledge and Skills*. PISA: OECD Publishing.

[53] de Corte, E., L. Verschaffel., P. Op"t Eynde. 2000. *Self-regulation: A Characteristic and a Goal of Mathematics Education*. In M. Boekaerts, P.R. Pintrich & M. Zeidner (eds.). *Handbook of Self-Regulation*, Academic Press, Orlando: Florida.

[54] Schoenfeld, A. 1985. *Mathematical Problem Solving*. New York: Academic Press.

[55] OECD. 2013. *PISA 2015 Field Trial Collaborative Problem Solving Framework.* Presented at the 33rd PISA Governing Board Meeting in Talinn: Estonia.

[56] Nunes, T., P. Bryant., D. Evans., B. Bell., S. Gardner., A. Gardner., J. Carraher. 2007. The Contribution of Logical Reasoning to the Learning of Mathematics in Primary School, *British Journal of Developmental Psychology*, *25*(1): 147–166.

[57] Andriessen, J. 2006. The Cambridge Handbook of Learning Sciences. In R.K. Sawyer (eds.), Arguing to Learn. New York, NY: Cambridge University Press.

[58] Krajcik, J., P. Blumenfeld., R. Marx., K. Bass., J. Fredricks., E. Soloway. 1998. Inquiry in Project-based Science Classrooms. *Journal of the Learning Sciences, 7*(3&4): 313-351.

[59] Reiser, B.J. 2004. Scaffolding Complex Learning: The Mechanisms of Structuring and Problematizing Student Work. *Journal of the Learning Sciences, 13*(2): 273-304.

[60] Albanese, M.A., S. Mitchell. 1993. Problem-based Learning: A Review of Literature on Its Outcomes and Implementation Issues, *Academic Medicine, 68*(3): 52-81.

[61] Hmelo-Silver, C. 2004. Problem-based Learning: What and How do Students Learn? *Educational Psychology Review, 16*(3), 235-266.

[62] Cho, K., D.H. Jonassen. 2002. The Effects of Argumentation Scaffolds on Argumentation and Problem Solving. *Educational Technology Research and Development*, *50*(3): 5-22.

[63] Ge, X., S.M. Land. 2003. Scaffolding Students" Problem-Solving Processes in an Ill-structured Task Using Question Prompts and Peer Interactions. *Educational Technology Research and Development*, *51*(1): 21-38.

[64] Salta, K., C. Tzougraki. 2004. Attitudes Towards Chemistry Among 11th Grade Students in High Schools in Greece. *Science Education, 88*(2): 535-547.

[65] Erdemir, N. 2009. Determining Students" Attitude Towards Physics Through Problem-Solving Strategy. *Asia-Pacific Forum on Science Learning & Teaching*, *10*(2): 5-12.

[66] Craker, D.E. 2006. Attitudes Toward Science of Students Enrolled in Introductory Level Science Courses at UW-La Crosse. *UW-L Journal of Undergraduate Research IX*, 1-6, from www.uwlax.edu/urc/JUR-online/html/2007.htm

[67] Nurulazam. A., Rohandi., A. Jusoh. 2010. Instructional Congruence to Improve Malaysian Students" Attitudes & Interests Toward Science in Low Performing Secondary Schools. *European Journal of Social Sciences, 13*(1): 27-34.

[68] Ajzen, I., M. Fishbein. 1980. *Understanding Attitudes and Predicting Social Behavior*. Englewood Cliffs, New Jersey: Prentice Hall.

[69] Gagne, R.M. 1966. *Conditions of Learning*. New York: Holt, Rinehart and Winston.

[70] Mayer, R.E., M.C. Wittrock. 1996. *Problem-Solving Transfer*. In D.C. Berliner & R.C. Calfee (eds.), *Handbook of Educational Psychology*. New York, NY: MacMillan.