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## THE EFFECTS OF VISUAL MAPPING AND SCIENCE-RELATED ATTITUDES ON STUDENTS' CRITICAL THINKING AND PROBLEM SOLVING SKILLS

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### ABSTRACT

The aims of this study were to find out: (1) the effects of visual mapping on students' critical thinking skills, (2) the effects of science-related attitudes on students' critical thinking skills, (3) the interactions between visual mapping and science-related attitudes on students' critical thinking skills, (4) the effects of visual mapping on students' problem solving skills, (5) the effects of science-related attitudes on students' problem solving skills, and (6) the interactions between visual mapping and science-related attitudes on students' problem solving skills. This study was conducted at MAN 1 Tanjung Pura, totally 141 students. It 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. The results showed that: (1) there were the significant effects of visual mapping on students' critical thinking skills ( $F=87.082$ ;  $P=0.000$ ), (2) there were the significant effects of science-related attitudes on students' critical thinking skills ( $F=2.493$ ;  $P=0.040$ ), (3) there were the interactions between visual mapping and science-related attitudes on students' critical thinking skills ( $F=2.037$ ;  $P=0.000$ ), (4) there were the significant effects of visual mapping on students' problem solving skills ( $F=94.214$ ;  $P=0.000$ ), (5) there were the significant effects of science-related attitudes on students' problem solving skills ( $F=3.397$ ;  $P=0.031$ ), and (6) there were the interactions between visual mapping and science-related attitudes on students' problem solving skills ( $F=2.195$ ;  $P=0.000$ ).

**Keywords:** Visual Mapping, Science-Related Attitudes, Critical Thinking Skills, Problem Solving Skills.

### INTRODUCTION

Education is the process of of the individual so as to prepare that developing the capacities and potentials 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.

There is widespread acceptance of the idea that critical thinking should be an important dimension of science education. Thus, National Academy of Sciences (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 [1].

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. Garofalo et al., (1985) stated that problem solving included higher order thinking skills such as visualization, association, abstraction, comprehension, reasoning, analysis, synthesis, generalization, each needing to be managed and coordinated [2]. According to Jonassen et al. (1996), motivation and attitudinal aspects such as effort, confidence, persistence and knowledge about self on science are important to the problem solving process [3].

The means of representing ideas in diagrams with node-link assemblies has been termed concept mapping (CM) (Novak et al., 1998) [4], mind mapping (MM) (Buzan et al., 1993) [5], and argument mapping (AM) (van Gelder, 2013) [6]. According to Davies (2010), all of these mapping techniques are called visual mapping (VM) [7]. When used as a part of instruction, these types of mapping techniques have been shown to develop critical thinking skills (Kinchin, 2001) [8], support problem solving abilities (Fiol et al., 1992) [9], and increase students'

attitude towards science (Akay et al., 2012) [10].

The objectives of the research were (1) to find out the effects of VM on students' critical thinking skills, (2) to find out the effects of science-related attitudes on students' critical thinking skills, (3) to find out the interactions between VM and science-related attitudes on students' critical thinking skills, (4) to find out the effects of VM on students' problem solving skills, (5) to find out the effects of science-related attitudes on students' problem solving skills, and (6) to find out the interactions between VM and science-related attitudes on students' problem solving skills.

The research findings are very important for researcher, to provide significant information about students' critical thinking skills, problem solving abilities and science-related attitudes through VM. For teachers and educators, this main study is very important to provide information about the utilization of VM that need to be carried out to improve and enhance students' critical thinking and problem solving skills and to provide some feedbacks for teachers, educators and

policy makers in term of enlarging knowledge and improvement on students' critical thinking and problem solving skills through VM.

## **RESEARCH METHOD**

This study was conducted at MAN 1 Tanjung Pura, North Sumatera from August to October 2017. The population was the entire eleventh graders totally 141 students 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 used purposive sampling and this study applied a quasi-experimental technique. The design of this research used a pretest-posttest experimental group design with 4x2 factorial to find out the effects of VM and science-related attitudes on students' critical thinking and problem solving skills and their interactions as well. The independent variable was VM (CM, MM and AM) and direct instruction (DI) method; science-related attitude acted as a moderator variable. Meanwhile, the dependent variables were students' critical thinking and problem solving skills.

First of all, pretests were made to measure students' critical thinking skills and problem solving abilities taught by CM, MM, AM, and DI, respectively. TOSRA questionnaires were also given to students in the end of session. The learning and teaching activities were employed to them taught by learning techniques. The procedure of learning activities of those learning techniques occurred as follows: (1) students were made in groups; (2) the learning materials were explained in accordance with the purpose of the learning activity; (3) a paper was given to them and asked them to write and create what was on their mind about the topics; (4) they were guided to make CM, MM and AM based on their comprehension; (5) the learning activities lasted for five meetings during 45 minutes per session; (6) they were given post-test at the end of sessions. Students who were treated by VM had been told previously, so that they understood what they had to do. The control group was not literally given a VM, however they were just directly instructed. Post-tests of students' critical thinking and problem solving skills were conducted and

TOSRA was also given to each experimental group very carefully.

There were 10 essay tests adapted from Finken et al. (1993), based on Illinois Critical Thinking Essay Test [11]. Students' problem solving skills were adapted by Peng (2004) [12]. The TOSRA questionnaires were conducted to students to acquire the science-related attitude about human locomotor system through VM as references that needs to be conducted. To simplify the measurement of science-related attitude can be used the dimension of attitude which have been developed by Fraser (1978) [13].

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. Data will be homogenous if the significance value is greater than 0.05. The data were subsequently created in tables of frequency distribution using Sturges rules and in histograms or diagrams. Data were created in tables and graphics or figures as well. An inferential analysis used to examine the research hypothesis by using Two-Way

ANOVA as Duncan's Multiple Range Test (DMRT) for the post-hoc.

## RESULTS AND DISCUSSION

The results from two-way ANOVA showed that VM influenced the scores of students' critical thinking skills ( $F=87.082$ ;  $P=0.000$ ). The scores of their critical thinking skills taught by AM ( $86.83\pm 2.478$ ) were significantly higher than the scores of their critical

thinking skills taught by DI ( $78.03\pm 2.658$ ). It means that the average score of their critical thinking skills taught by AM had a percentage of 11.95% was higher than the average score of their critical thinking skills taught by DI. However, there were no significant effects of their critical thinking skills taught by AM ( $86.83\pm 2.478$ ), CM ( $86.54\pm 2.701$ ) and MM ( $86.15\pm 2.710$ ) as well.

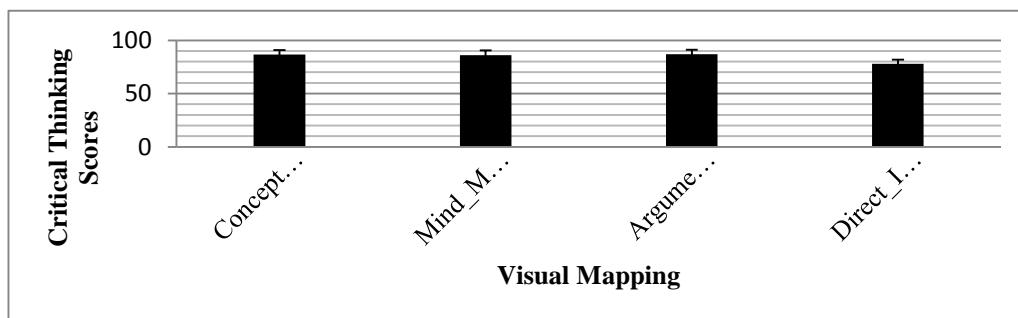


Figure 1. The Effects of VM on Students' Critical Thinking Skills for the Topic of Human Locomotor System ( $F=87.082$ ;  $P=0.000$ )

The results from two-way ANOVA showed that science-related attitudes influenced the scores of students' critical thinking skills ( $F=2.493$ ;  $P=0.040$ ). The scores of high science-related attitudes on their critical thinking skills taught by VM of  $85.00\pm 4.401$  ( $X\pm SD$ ) were significantly higher than the scores of low science-related attitudes taught by

VM of  $74.93\pm 3.254$  ( $X\pm SD$ ). It means that the average scores of their high science-related attitudes taught by VM had a percentage of 15.22% higher than the average scores of their low science-related attitudes taught by VM as well.

The results from two-way ANOVA showed that the interactions between VM and science-related attitudes influenced students' critical

thinking skills ( $F=2.037;P=0.000$ ). The interactions between VM and science-related attitudes taught by MM were significantly different than taught by DI. The results obtained for their high science-related attitudes were taught by CM of  $86.05\pm6.060$ , MM of  $87.46\pm5.254$ , and AM of  $86.67\pm5.058$ . The results obtained for their low

science-related attitudes were taught by CM of  $72.79\pm7.320$ , MM of  $73.95\pm6.589$ , and AM of  $72.40\pm6.556$  as well. Students who were taught by DI obtained high science-related attitudes of  $78.53\pm5.590$  and low science-related attitudes of  $70.91\pm 6.596$ .

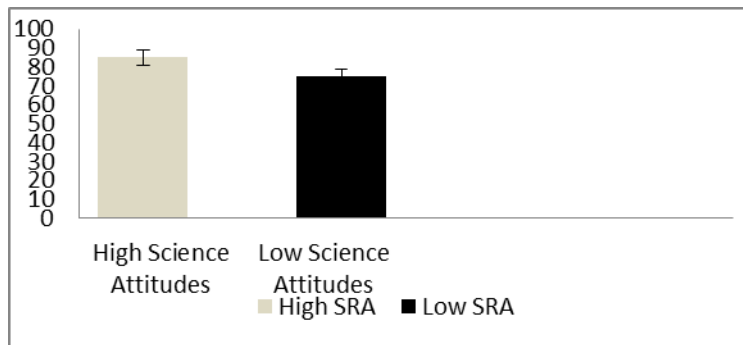


Figure 2. The Effects of Science-Related Attitudes on Students' Critical Thinking Skills for the Topic of Human Locomotor System ( $F= 2.493; P = 0.040$ ).

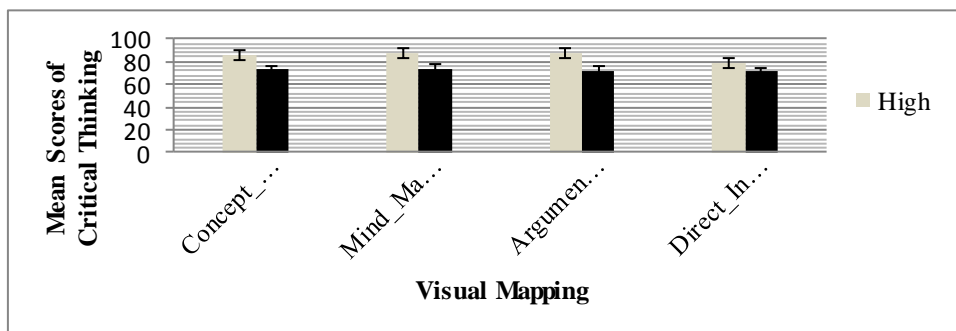


Figure 3. The Effects of VM and Science-Related Attitudes (High and Low) on Students' Critical Thinking Skills for the Topic of Human Locomotor System ( $F = 2.037; P = 0.000$ ).

The results of DMRT showed that the scores of students' critical thinking skills taught by VM with high and low science-related attitudes had

significant differences. The scores of their critical thinking skills taught by MM with high science-related attitudes were significantly different than the scores of their critical thinking skills taught by DI with high science-related attitudes ( $P=0.031 < 0.05$ ) as well as taught by DI with low science-related ( $P=0.000 < 0.05$ ). However, the scores of their critical thinking skills taught by VM with high science-related attitudes were not significantly different than the scores of their critical thinking skills taught by VM with low science-related attitudes ( $P=0.307 > 0.05$ ).

The results from two-way ANOVA showed that VM influenced

the scores of students' problem solving skills ( $F=94.214; P=0.000$ ). The scores of their problem solving skills taught by CM ( $87.74 \pm 2.586$ ) were significantly higher than the scores of their problem solving skills taught by DI ( $78.84 \pm 2.689$ ). It means that the average scores of their problem solving skills taught by CM had a percentage of 14.38% were higher than the average scores of their problem solving skills taught by DI. However, there were no significant effects of their critical thinking skills taught by CM ( $87.74 \pm 2.586$ ), MM ( $86.64 \pm 1.940$ ) and AM ( $87.00 \pm 2.494$ ) as well.

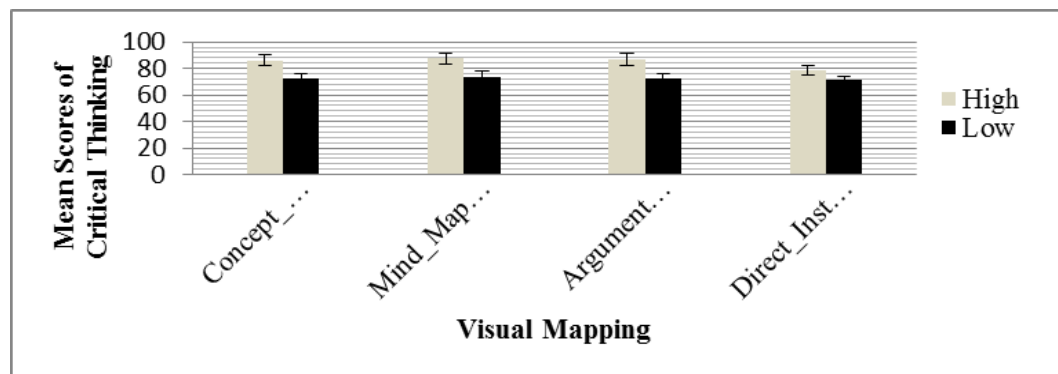


Figure 4. The Effects of VM on Students' Problem Solving Skills for the Topic of Human Locomotor System ( $F = 94.214; P = 0.000$ ).

The results 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 their problem solving skills taught by VM of  $85.68 \pm 4.312$  ( $X \pm SD$ ) were

significantly higher than the scores of low science-related attitudes taught by VM of  $77.26 \pm 3.614$  ( $X \pm SD$ ). It means that the average scores of their high science-related attitudes taught by VM

had a percentage of 13.28% were higher than the average scores of their low science-related attitudes taught by VM as well.

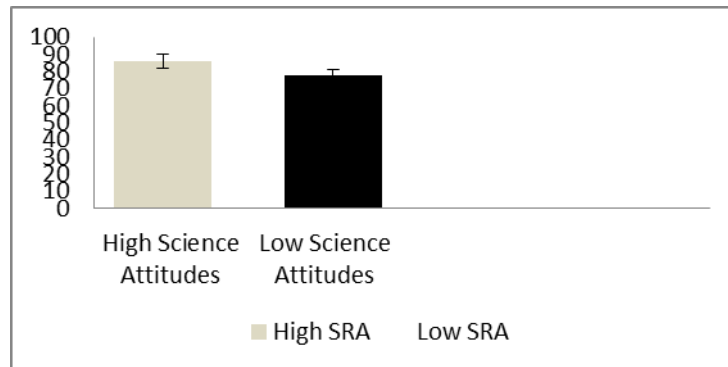


Figure 5. The Effects of Science-Related Attitudes on Students' Problem Solving Skills for the Topic of Human Locomotor System ( $F = 3.397$ ;  $P = 0.031$ ).

The results from two-way ANOVA showed that the interactions between VM and science-related attitudes influenced students' problem solving skills ( $F=2.915$ ;  $P=0.000$ ). The interactions between VM and science-related attitudes taught by AM were significantly different than taught by DI. The results obtained for the scores of their high science-related attitudes which were taught by CM of  $86.94 \pm 5.664$ , MM of  $87.29 \pm 4.493$ , and AM of  $88.19 \pm 4.726$ . The results obtained for the scores of their low science-related attitudes taught by CM

were of  $74.65 \pm 7.211$ , MM of  $75.81 \pm 6.328$ , and AM of  $77.38 \pm 6.415$  as well. Students who were taught by DI obtained the scores of high science-related attitudes of  $79.00 \pm 5.652$  and low science-related attitudes of  $71.16 \pm 3.164$ .

The results of DMRT showed that students' problem solving skills taught by VM with high and low science-related attitudes had significant differences. The scores of their problem solving skills taught by AM with high science-related attitudes were significantly different than the scores



of their problem solving skills taught by DI with high science-related attitudes ( $P=0.042 < 0.05$ ) as well as taught by DI with low science-related attitudes ( $P=0.000 < 0.05$ ).

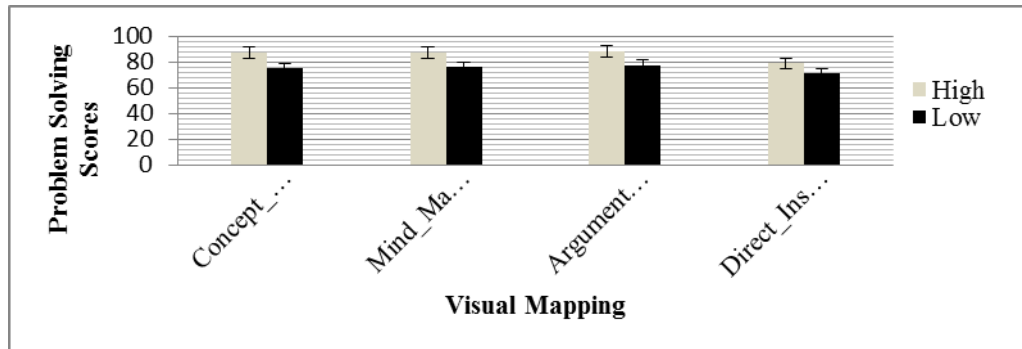


Figure 6. The Effects of VM and Science-Related Attitudes (High and Low) on Students' Problem Solving Skills for the Topic of Human Locomotor System ( $F = 2.915$ ;  $P = 0.000$ ).

However, the scores of their critical thinking skills taught by VM with high science-related attitudes were not significantly different than the scores of their problem solving skills taught by VM with low science-related attitudes ( $P=0.042 > 0.05$ ).

### The Effects of VM on Students' Critical Thinking Skills

The results from two-way ANOVA showed that VM influenced the scores of students' critical thinking skills ( $F= 87.082$ ;  $P=0.000$ ). The scores of their critical thinking skills taught by AM ( $86.83 \pm 2.478$ ) were significantly higher than the

scores of their critical thinking skills taught by DI ( $78.03 \pm 2.658$ ). It means that there is empirical support for the use of AM as VM tools in enhancing, retaining and improving knowledge and critical thinking. According to Vekiri (2002), evidence from the cognitive sciences shows that visual displays do enhance learning [14]. In line with the study, Schwartz (1988) states that AM allows the separate encoding of information in memory in visual and well as propositional form, a phenomenon called "conjoint retention" or "dual coding" [15]. Finally, Vekiri (2002) suggests that 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 [14].

### **The Effects of Science-Related Attitudes on Students' Critical Thinking Skills**

Science-related attitudes had the significant effects on students' critical thinking 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 VM were better than low science-related attitudes by VM as well. As from the findings of the study, Akilli (2008) stated that it can be elucidated that there is a difference between students on the variables of science-related attitudes and critical thinking skills [16]. 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, collecting and reporting scientific data, being critical in observations. Geban (1996) suggested that there is a positive and significant relationship between the science-related attitude and critical thinking of students signifying if there is increase in the magnitude of the variable science-related attitude there will be an increase in the magnitude of critical thinking skill [17].

### **The Interactions Between VM and Science-Related Attitudes on Students' Critical Thinking Skills**

The results from the hypothetical testing previously showed that the interactions between VM and science-related attitudes influenced students' critical thinking skills. The interactions between VM and science-related attitudes taught by MM were significantly higher than taught by DI. However, the scores of students' critical thinking skills taught by VM with high science-related attitudes were not significantly different than the scores of students' critical thinking skills taught by VM with low science-related attitudes.

According to Ramsden (1998), almost all researchers agreed that for science education, one of the critical problems is the negative attitude towards science, so to overcome this problem, study of science-related attitude and science learning should be conducted [18]. Besides, Pell et al. (2001) suggests that 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 [19].

### **The Effects of VM on Students' Problem Solving Skills**

The results from two-way ANOVA showed that VM influenced the scores of students' problem solving skills ( $F=94.214$ ;  $P=0.000$ ). The scores of students' problem solving skills taught by CM ( $87.74 \pm 2.586$ ) were significantly higher than students' problem solving skills taught by DI ( $78.84 \pm 2.689$ ). It means that there is empirical support for the use of CM tools in enhancing,

retaining and improving knowledge and problem solving. From the study of Stoyanov (2006), the potential of CM to provide an effective and efficient support for ill-structured problem solving has been reported in a number of studies [20].

### **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 VM were better than low science-related attitudes by VM as well. Nicolaidou et al. (2003) states that problem solving competence could be developed by solving non-routine problems. For a successful problem solving, pupils need to be motivated, as there is a correlation between students' science-related attitude and their scientific results [21].

### **The Interactions Between VM and Science-Related Attitudes on Students' Problem Solving Skills**

The results from the hypothetical testing previously showed that the interactions between VM and science-related attitudes influenced students' problem solving skills. The interactions between VM and science-related attitudes taught by AM were significantly different than taught by DI. According to Andriessen (2006), 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 [22].

### **CONCLUSION**

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

concluded that: (1) there were significant effects of VM on students' critical thinking skills for the topic of human locomotor system ( $F=87.082$ ;  $P=0.000$ ), (2) there were significant effects of science-related attitudes on students' critical thinking skills for the topic of human locomotor system ( $F=2.493$ ;  $P=0.040$ ), (3) there were interactions between VM and science-related attitudes on students' critical thinking skills for the topic of human locomotor system ( $F=2.037$ ;  $P=0.000$ ), (4) there were significant effects of VM on students' problem solving skills for the topic of human locomotor system ( $F=94.214$ ;  $P=0.000$ ), (5) there were significant effects of science-related attitudes on students' problem solving skills for the topic of human locomotor system ( $F=3.397$ ;  $P=0.031$ ), and there were interactions between VM and science-related attitudes on students' problem solving skills for the topic of human locomotor system ( $F=2.915$ ;  $P=0.000$ ).

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