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Mathematical critical thinking ability in terms of mathematical anxiety in Smart Card assisted Brain-Based Learning model

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Abstract

This study aims to analyze the effectiveness of the Smart card-assisted Brain-Based Learning model against mathematical critical thinking skills, to analyze whether the smart card-assisted Brain-Based Learning model is more effective than the Treffinger model for mathematical critical thinking skills, and to describe students' mathematical critical thinking skills in terms of mathematical anxiety. This research applied quantitative method followed by a description. The population in this research were students of the seventh-grades on three of Junior High School in Ungaran in the academic year 2019/2020. This research applied the cluster random sampling technique as the technique for collecting the data. The subject of the research was selected from the experimental class. The researcher was used purposive sampling technique to select the subject of this research. The data was collected by using the test method, the questionnaire method, and the interview method. The quantitative data analysis used classical completeness test, mean difference test, and proportion difference test. The result of this study indicate that smart card-assisted Brain-Based Learning model is effective for mathematical critical thinking skills, but smart card-assisted Brain-Based Learning model is no more effective than Treffinger on mathematical critical thinking skills. In addition, the description of mathematical critical thinking skills in terms of mathematical anxiety is obtained that: (1) subjects with low mathematical anxiety are able to achieve the indicator (A) clarification well, indicator (B) assessments well, indicator (C) concludes well, and indicator (D) strategy well; (2) subjects with moderate mathematical anxiety are able to achieve indicator (A) well, indicator (B) well, indicator (C) quite well, and indicator (D) quite well; (3) subjects with high mathematical anxiety are able to achieve indicator (A) well, indicator (B) is quite good, indicator (D) is quite good.

1. Introduction

Entering the 21st century, technological advances have entered various aspects of life, as well as in Education. It requires various skills to be master by human, such as critical thinking skills, problem-solving skills, communication skills, metacognition, collaboration, information literacy, innovation and creation. In essence, education plays an important role since it is one of the supporting factors to improve and develop the intellectual quality of humanagainst challenges in the 21st century.

Mathematics is one of the subjects that has important role in various disciplines and advances human thinking. In addition, according to Sulistiani & Masrukan (2016) mathematics has an important role in shaping and developing logical, systematic and critical thinking skills. Thus, studying mathematics can develop the intellectual quality of human resources. The purpose of learning mathematics is so that the students have the ability to understand mathematical concepts, explain the relationship between the concepts, and apply concepts or algorithms well, accurate, efficient, and precise way to solve problems (Astuti et al., 2017).

Based on Decree of The Indonesian Minister of Education and Culture Number 20 of 2016, mentioned that Graduation Standard Competence in 2013 curriculum at all educational stages in the skills

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subject are students must have the skills to think and act: a) creative, b) productive, c) critical, d) independent, e) collaborative, and f) communicative. From some of these skills which are 21st century skills are 4C skills, namely: (1) communication; (2) collaboration; (3) critical thinking; and (4) creativity. These 4C skills are included in higher order thinking skills in learning mathematics. One of the things that is the focus of this research is the ability to think critically in mathematics. According to Maftukhin et al. (2014) in studying mathematics it is very important for students to have the ability to think critically, this is because the ability to think critically can support students in applying concepts in different problems and can find solutions that are more effective and efficient. According to Fisher, cited by Nisa' (2016), critical thinking is a type of thinking that does not directly lead to conclusions, or accepts some evidence, demands or decisions just like that, without really thinking about it and critical thinking clearly demands the interpretation and evaluation of observations, communications and other sources of information. Meanwhile, according to Rohaeti (Chotimah et al., 2019) critical thinking in mathematics is a systematic skill and accuracy to combine initial knowledge, mathematical reasoning skills, and cognitive strategies in solving mathematical problems. Based on definition above, it can be concluded that the ability to think critically in mathematics is the ability of students to use their intellectual potential in solving mathematical problems systematically by combining learned concepts, interpreting data and applying concepts.

Mathematical critical thinking skills are the ability that need to be improved and developed in mathematics learning (Chotimah et al., 2019). Id addition, Fariha (2013) stated that mathematical critical thinking skills are needed so that students are able to solve mathematical problems. In addition, Maftukhin et al. (2014) mentioned that critical thinking skills have an important role in increasing students' creativity. Thus mathematical critical thinking skills play an important role in other mathematical skills.

Based on the observation results at three of Junior High School in Ungaran, they uses the 2013 curriculum and the learning model that is commonly used is the Problem-Based Learning model but sometimes they still uses the Direct Instruction model. Based on the interview results with one of the mathematics teachers at three of Junior High School in Ungaran, that there were several difficulties faced by students when do the mathematics test, these difficulties were (1) students tended to be unwilling to write down important information that is known and what is asked while doing the test.

Based on the preliminary study results of mathematical critical thinking skills at three of Junior High School in Ungaran towards 64 students with comparison material, the students' answer analysis results had an 45,56 average score of mathematical critical thinking skills. It is caused of students' difficulty in understanding problems that requires high critical thinking skills. Meanwhile, most students was tended not to write down the information that was known and asked, but also they did not write down the formulas or concepts used to solve the problems that affect students' inaccuracy in solving the problems.

Besides from cognitive aspects, it is also necessary to pay attention to affective aspects of students. According to one of the mathematics teachers at three of Junior High School in Ungaran, students are lack of activeness during mathematics learning process in class. One of the strategies for developing critical thinking skills in mathematics learning is learning activity that makes students active (Arpin et al., 2015).Students tend to be unwilling to ask the teacher when there are material that they don't understand. It might be caused of embarrassment or fear of asking questions. Students who feel less confident, afraid or embarrassed during mathematics learning process are caused b anxiety (Freedman, 2012). According to Peker (2009) many factors that caused the students have difficulties in solving mathematic problems, one of them is mathematical anxiety. It means, anxiety is considered as a factor that hampers students from learning which interfered with concentrating, remembering, concept formation, and problem solving.

Mathematics' anxiety will cause students to feel anxious, worried, and tend to be afraid if the questions that being tested are difficult or poorly understood by themselves, and students tend to be pessimistic, so it will affect in low learning outcomes (Nurhayati, 2009). According to Setyowati (2013) "in learning mathematics, students with low anxiety are more willing to ask or express their opinions compared to other students who have high anxiety levels." It is confirmed by the research of Arpin *et al*. (2015) regarding the relationship between mathematics anxiety and students critical thinking skills, which shows that the higher the level of students' mathematical anxiety, the lower their critical thinking skills.

Mathematical critical thinking ability is also influenced by the learning methods applied by the teacher. The necessary of learning model that can explore and involve students actively and creatively. One of learning models referred to is the Brain-Based Learning model. Solihah (2019) stated that the Brain-Based Learning model is an effective model that can affect students' learning outcomes, students' responses, and students' activeness in class. According to Jensen (2008) Brain-Based Learning is a learning approach that is in accordance with the way brain works naturally designed for learning. The

same thing was mentioned by Saparina et al. (2015) Brain-Based Learning is learning that is aligned with the way the brain is designed naturally to learn, so that students are active to build their knowledge based on the cognitive structures they have and are based on how the brain works so that learning can be absorbed by the maximum amount of brain.

According to Jensen (2008) the Brain-Based Learning model has a learning syntax, namely: (1) pre-exposure, this stage provides reviews to the students about new learning, (2) preparation, at this stage the teacher must create curiosity and pleasure on students, (3) initation and acquisition, this stage is the stage of the creation of connection, (4) elaboration, information processing stage, (5) incubation and memory insertion, this stage emphasize the importance of rest time and time to repeat, (6) verification and confidence checking, this stage the teacher checks students' understanding of the material that has been studied, and (7) celebration and integration, this stage embeds all the important meanings of love of learning. Students' mathematical critical thinking skills can be seen at the verification stage, where students will be given the opportunity to maximize the work of brain to investigate, reason, analyze, and deepen learning and apply concepts. The syntax of this model allows students to develop their mathematical critical thinking skills.

The research results by Susanti et al., (2016) showed that learning with the Brain-Based Learning model can be used to improve mathematical critical thinking skills. Meanwhile, Solihah (2019)stated that students' mathematical critical thinking skills that using the Brain-Based Learning model are more better than the control class which using conventional learning model. It encourages researchers to use the Brain-Based Learning model in this study.

On the other hand, a learning model that also leads to critical thinking skills is Treffinger learning model. According to Alifia (2018), the Treffinger learning model is a learning model that emphasizes the development of creative and critical thinking by paying attention on awareness of its mathematical abilities, especially in the mathematical thinking process. Juanti *et al*. (2016) revealed that there are three important stages in the Treffinger learning model, namely: (1) the divergent function development stage is the basic tool stage; (2) the stage of developing more complex thinking is the practice with process stage; (3) the stage of developing involvement in real challenges is the stage of working with real problems.

Alifia (2018) stated that there is an enhancement in mathematical critical thinking skills in classes using the Treffinger learning model. Meanwhile, Wahyuni et al., (2017) mentioned that the students' mathematical critical thinking skills in the experimental class using the Treffinger model were better than the control class using the Direct Instruction model. This encourages the researcher to use the Treffinger model in this study.

Skinner's theory mentioned that reinforcement has a very important role in the learning process. The results of Hoque's (2013) research showed that the experimental class with reinforcement gives a higher average weekly quiz score than the control class as well as an enhancement in students participation and interaction during the learning process. Meanwhile, Afrida et al., (2015) stated that the use of reinforcement in the form of Smart Stickers during learning process makes the students motivated and unsaturated to pay attention to lessons. Based on these statements, It can be concluded that the use of reinforcement in the form of smart cards in learning process will be more optimal. Thus, the researcher are encouraged to use reinforcement in the form of smart cards in this study.

In this study, the researcher conducted research on mathematical critical thinking skills in terms of mathematical anxiety in the smart card-assisted Brain-Based Learning model. The learning material used in this research is social arithmetic. The choice of this material is caused the material contains several mathematical concepts so that it can be used to measure students' mathematical critical thinking skills.

The objectives of this research are: (1) to determine whether learning with the smart card-assisted Brain-Based Learning model was effective in mathematical critical thinking skills; (2) determine whether the Treffinger model is effective in mathematical critical thinking skills; (3) determine whether learning process with the smart card-assisted Brain-Based Learning model is more effective than learning process with the Treffinger model; (4) to describe students' mathematical critical thinking skills in terms of mathematical anxiety in the smart card-assisted Brain-Based Learning. The hypothesis in this study is as follows. (1) Students' mathematical critical thinking skills in the smart card-assisted Brain-Based Learning achieve classical completeness. (2) Students' mathematical critical thinking skills in the Treffinger learning model achieve classical completeness. (3) the completeness proportion of students' mathematical critical thinking skills with the smart card-assisted Brain-Based Learning is higher than the completeness proportion of mathematical critical thinking skills with the Treffinger learning model.

2. Methods

The method used in this study is a quantitative method followed by a description. This study uses experimental designs, specifically quasi experimental design with the form of the nonequivalent posttest-only control group design. A research design description can be seen in Table 1.

Table 1. The Nonequivalent Posttest-Only Control Group Design

Class	Treatment	Evaluation
Experiment	X_1	Y_1
Control	X_2	Y_2

Information :
X_1 : class was treated with Brain-Based Learning assisted by smart
X_2 : class was treated with Treffinger learning
Y_1 : the results of the mathematical critical thinking skills test in experimental class
Y_1 : the results of the mathematical critical thinking skills test in control class

The population in this research were students of the seventh-grades on three of Junior High School in Ungaran in the academic year 2019/2020. The selection of the experimental class and control class is done by cluster random sampling technique. VII G class was treated with Brain-Based Learning assisted by smart card as an experimental class. VII H class was given Treffinger learning as control class.

The instruments used in this study are instruments of mathematical critical thinking ability, mathematical anxiety instruments, and interview devices. The test used is a test in the form of essay test to measure students' critical thinking skills. An anxiety mathematical questionnaire was given to the experimental class to classify those students in high, medium, and low mathematical anxiety. Furthermore, the questionnaire in this study was validated by mathematicians and psychologists. The interview guidance for this questionnaire is questions that is used as a reference to collect the data. The indicators used to compile instruments for mathematical critical thinking capabilities can be seen in Table 2 as follows.

Table 2. Indicator of Mathematical Critical Thinking Ability

Code	Step	Indicator
A	Clarification	Analyses, discusses the scope of the problem.
B	Assessment	Gathers and assesses relevant information.
C	Inference	Frames relationships among the different parts of the problem.
D	Strategies	Take action in the form of problem solving.

The data obtained in this study were the results of the mathematical critical thinking skills test, the results of mathematical anxiety questionnaire, and the results of interview. Mathematical critical thinking ability test results as quantitative data to do the hypothetical test with quantitative data analysis, include normality test, homogeneity test, classical completeness test, average difference test, and proportion difference test. The normality test in this study using the Kolmogorov Smirnov test, while the homogeneity test in this study using the Levene test. The classical completeness test was carried out to determine whether students' mathematical critical thinking skills with the Brain-Based Learning model assisted by smart cards could achieve classical completeness. The classical completeness test used the proportion test. The average difference test is used to determine whether the average achievement of students 'mathematical critical thinking skills with the Brain-Based Learning model is higher than the average achievement ability of students' critical thinking with the Treffinger learning model. The proportion difference test is used to determine the proportion of students achieving mathematical critical thinking ability with smart card-assisted Brain-Based Learning model higher than the proportion of students achieving mathematical critical thingking ability with the Treffinger learning model.

Based on mathematical anxiety questionnaire results, 3 research subjects were selected at each level of mathematical anxiety, which is 3 high mathematical anxiety subjects, 3 moderate mathematical anxiety subjects, and 3 low mathematical anxiety subjects. The subjects' selection was carried out by using

purposive sampling technique. Interviews were conducted to strengthen quantitative data related to mathematical critical thinking skills. Researcher determined the subjects by considering the mathematical anxiety levels and students' test results. The research subject tests and interview results were used to describe the mathematical critical thinking skills in terms of students' mathematical anxiety in learning process using Brain-Based Learning assisted smart card model.

3. Results and Discussion

3.1 Initial Data Analysis

The initial data used in this study were the preliminary test results of students' mathematical critical thinking skills in the experimental class and the control class. Based on the homogeneity test of the population with the Levene test using SPSS, it was concluded that the population was homogeneous. Based on the normality test using the Kolmogorov Smirov test with SPSS software, it was concluded that the data were normally distributed.

3.2 Quantitative Data Analysis

Based on the homogeneity test on the results of the experimental and control class tests with the Levene test using SPSS software, it was found that the data had the same or homogeneous variance. Based on the normality test using the Kolmogorov Smirnov and ShapiroWilk tests on each experimental class data, control class, and combined experimental and control classes, the results showed that the experimental class data, control class, and experimental and control class combinations were normally distributed. The classical completeness test is used to find out whether the percentage of completeness of the experimental class and control class students reaches a set percentage of 75% of the number of students in the class obtaining a value of more than or equal to 70. The hypothesis for the experimental class is tested as follows.

H_o : $\pi \leq 0.745$ (percentage students who get score ≥ 70 have not achieved classical completeness)

H_1 : $\pi > 0.745$ (percentage students who get score ≥ 70 have achieved classical completeness)

The test criteria are by testing the proportions of the left with a significant level of 5% H_0 reject criteria if $z_{count} \geq z_{0,5-\alpha}$. Based on the calculation results obtained $z_{count} = 2.09$ dan obtained $z_{table} = 1.64$. The result is that $z_{count} > z_{table}$, so H_o is rejected. So the percentage of students in the experimental class who scored ≥70 had achieved classical completeness.

The hypothesis for the control class is tested as follows.

H_o : $\pi \leq 0.745$ (percentage students who get score ≥ 70 have not achieved classical completeness)

H_1 : $\pi > 0.745$ (percentage students who get score ≥ 70 have achieved classical completeness)

The test criteria are by testing the proportions of the left with a significant level of 5% H_0 reject criteria if $z_{count} \geq z_{0,5-\alpha}$. Based on the calculation results obtained $z_{count} = 1.197$ dan obtained $z_{table} = 1.64$. The result is that $z_{count} < z_{table}$, so H_0 is received. So the percentage of students in the control class who scored ≥70 had not achieved classical completeness.

The average difference test is used to determine whether the average achievement of students' mathematical critical thinking skills with the Brain-Based Learning model is higher than the average achievement ability of students' critical thinking with the Treffinger learning model. The hypothesis is tested as follows.

H_o : $\mu_1 \leq \mu_2$ (the average of mathematic critical thinking ability of the experimental class students is no better than the control class)

H_1 : $\mu_1 > \mu_2$ (the average of mathematic critical thinking ability of the experimental class students is better than the control class)

It is known that $\sigma_1 = \sigma_2$, then H_0 testing criteria is accepted if $t_{count} < t_{1-a(dk)}$. Degrees of freedom $dk = n_1 + n_2 - 2$. Based on the calculation results obtained $t_{count} = 1.02$ with $\alpha = 5\%$, $n_1 = 32$, and $n_2 = 31$ obtained $t_{table} = 1.67$. The result is that $t_{count} < t_{table}$, so H_0 is accepted. So, the average mathematical critical thinking ability of students with the smart card-assisted Brain-Based Learning model was not higher than the average mathematical critical thinking ability of Treffinger model.

Based on the proportion test used to determine the proportion of students achieving mathematical critical thinking ability with smart card-assisted Brain-Based Learning model higher than the proportion of students achieving mathematical critical thingking ability with the Treffinger learning model. The hypothesis is tested as follows.

$H_0 : \pi_1 \leq \pi_2$ (the proportion of mathematic critical thinking ability of the experimental class students is no better than the control class)

$H_1 : \pi_1 > \pi_2$ (the proportion of mathematic critical thinking ability of the experimental class students is better than the control class)

H_0 testing criteria is rejected if $z_{count} > z_{(0,5-a)}$, with $\alpha = 5\%$. Based on the calculation results obtained $z_{count} = 1.67$ dan obtained $z_{table} = 1.64$. The result is that $z_{count} > z_{table}$ so H_0 is rejected. So, the proportion of students' mathematical critical thinking abilities with the smart card-assisted Brain-Based Learning model is higher than the proportion of students' mathematical critical thingking abilities in Treffinger model.

3.3 Analysis of Students' Mathematical Anxiety

Students' mathematical anxiety data were obtained through a mathematical anxiety questionnaire which was given after the students had tested their mathematical critical thinking skills. The percentage of students in each category of mathematical anxiety in the experimental class was 25% of students with high mathematical anxiety, 59% of students with moderate mathematical anxiety, and 16% of students with low mathematical anxiety. Based on the classification of mathematical anxiety, 3 students were selected for each category.

3.3.1 Subjects' Mathematical Critical Thinking Ability with Low Mathematical Anxiety

Subjects with low mathematical anxiety tend to fulfill four indicators of critical thinking, namely clarification, judgment, conclusion, and well strategy. Based on observations during the learning process, subjects with low mathematical anxiety are active in discussion. Subjects with low mathematical anxiety often express their opinions both verbally and written in front of class. In the process of discussion and expressing opinions in front of the class, subjects with low mathematical anxiety can convey their opinions coherently and gradually. In interview section, subjects with low mathematical anxiety tended to look confident, focused, and could answer questions well and clearly.

3.3.2 Subjects' Mathematical Critical Thinking Ability with Moderate Mathematical Anxiety

Subjects with moderate mathematical anxiety tended to fulfill the clarification and assessment indicators well and conclusion and strategies indicators quite well. Based on observations during the learning process, subjects with moderate mathematical anxiety tend to be active in discussion. They tend to be excited and can still participate in group discussion activities. Subjects with moderate mathematical anxiety can also participate in groups and can work on worksheets. At interview section, subjects with moderate mathematical anxiety tended to focus and could answer questions well and clearly.

3.3.3 Subjects' Mathematical Critical Thinking Ability with High Mathematical Anxiety

Subjects with high mathematical anxiety tend to fulfill the clarification indicators well, but have not been able to fulfill the assessment indicators, conclusions and strategies well. Based on observations during the learning process, subjects with high mathematical anxiety tend to be less active in discussions. They tend to be less focused and busy with their own activities. At interview section, subjects with high mathematical anxiety had a tendency to look unfocused and confused when answering questions. In addition, subjects with high mathematically anxiety also hesitated when answering questions and took time to answer questions.

In this study it was found that the higher the level of mathematical anxiety, the lower the students' mathematical critical thinking ability. Students with high mathematical anxiety tend to be difficult to do order, avoid math class, and feel afraid and panic. This makes it difficult for students to focus on learning process. It is the reason why the indicator of students' mathematical critical thinking ability not achieved optimally. As explained by Rinaldy et al., (2018) that attention is needed in the learning process. The higher the students' attention in following learning process will affect to higher learning outcomes, but if there are obstacles such as anxiety, fear, and nervousness, then this can affect students learning achievement. The same thing was mentioned by Nurhayati (2009) that mathematics' anxiety will cause

students to feel anxious, worried, and tend to be afraid if the questions that being tested are difficult or poorly understood by themselves, and students tend to be pessimistic, so it will affect in low learning outcomes. It is confirmed by the research of Arpin et al. (2015) regarding mathematical anxiety and mathematical critical thinking skills have a relationship which shows that the higher students' mathematical anxiety level, the lower the ability to think critically. It means, anxiety is considered as a factor that hampers students from learning which interfered with concentrating, remembering, concept formation, and problem solving.

4. Conclusion

Based on the discussion conducted by the researcher, conclusions were obtained that the smart card-assisted Brain-Based Learning model is effective against students' mathematical critical thinking abilities, but the smart card-assisted Brain-Based Learning model is no more effective than Treffinger model against students' mathematical critical thinking abilities. Based on the results of the study, obtained the average mathematical critical thinking ability of students with the smart card-assisted Brain-Based Learning model was not higher than the average mathematical critical thinking ability of Treffinger model. However, the proportion of students' mathematical critical thinking abilities with the smart card-assisted Brain-Based Learning model is higher than the proportion of students' mathematical critical thinking abilities in Treffinger model. In addition, the description of students' mathematical critical thinking skills in terms of mathematical anxiety is obtained that: (1) subjects with low mathematical anxiety tend to fulfill four indicators of critical thinking, namely clarification, assessment, inference, and well strategy; (2) subjects with moderate mathematical anxiety tended to fulfill the clarification and assessment indicators well and inference and strategies indicators quite well; (3) subjects with high mathematical anxiety tend to fulfill the clarification indicators well, but have not been able to fulfill the assessment indicators, inference and strategies well.

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