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The Effect of Game-Based Learning through an Escape Room on Mathematical Critical Thinking Skills

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Abstract
This study was motivated by the low level of critical thinking skills among students in mathematics learning. The study aims to determine the differences in critical thinking skills between students who learn using a game-based learning model through an escape room game and those who learn through direct instruction, as well as to analyze the improvement in critical thinking skills before and after the intervention. This study employs a quantitative approach using a quasi-experimental design. The sample was selected using cluster random sampling, involving an experimental class and a control class. Data collection was conducted through critical thinking ability tests in the form of pre-test and post-test. Data analysis utilized the Mann-Whitney U test, the Wilcoxon Signed Rank test, N-Gain, and Effect Size. The results indicate a significant difference in the improvement of critical thinking skills between the experimental class and the control class ($Z = -2.82; p < 0.05$). Additionally, there was a significant improvement in the experimental class before and after the intervention ($Z = -4.52; p < 0.05$). The N-Gain value of 0.19 falls into the low category, while the Effect Size value of 0.95 indicates a high effect. Thus, the game-based learning model through an escape room game influences the improvement of students' critical thinking skills and can be used as an alternative learning method that fosters critical thinking in mathematics education.
Keywords: *Critical Thinking Skills, Game-Based Learning, Game Escape Room, Junior High School Students, Mathematics Education*

INTRODUCTION

Mathematics plays a vital role in the advancement of science and technology. This subject also helps develop students' thinking skills, particularly critical thinking skills (Rawa & Yasa, 2018). Critical thinking is one of the 21st-century skills that students must prossess; this skill is related to the ability to analyze information, solve problems, make decisions, and devise logical solutions to problems (Hidayat & Sari, 2019). According to Ennis (2015), critical thinking is necessary so that students do not merely receive the final answer. Students must also be able to explain their reasoning, analyze relationships between concepts, and draw conclusions based on a sound process. However, the reality in schools indicates that students' critical thinking skills in mathematics learning still need to be improved.

Students' low critical thinking skills are evident in the large number of students who struggle to solve math problems requiring higher order thinking skills. Research by Miladina, Wulandari & Zauri (2023) indicates that many students have not yet met the standards for Higher Order Thinking Skill (HOTS) in mathematics learning. HOTS are higher order thinking skills that involve analysis, evaluation, and drawing conclusions (Abraham, Tjall, & Indrajit, 2021). In mathematics learning, these skills are essential. Students must understand

problems, analyze information, evaluate solution strategies, and draw logical conclusions. Kemprimase, Ayal, & Ngilawajan (2019) state that HOTS questions are important to use in mathematics learning. These questions train students' critical thinking skills through diverse real-word problem-solving. Faradisa, Utami, & Aini (2022) explain that solving HOTS questions requires step-by-step and systematic critical thinking. Therefore, strong analytical and evaluative skills are required.

This issue also occurs at SMP Negeri 25 Purworejo. An initial critical thinking skills test administered to 64 students yielded an average score of 57.8. According to Agnafia (2019), this score falls into the moderate category. An analysis of the indicators revealed average scores of 41.1 for evaluation and 44.8 for inference, both of which fall into the low category. This indicates that students still struggle to evaluate problem-solving strategies and draw logical conclusions. Additionally, interviews with mathematics teachers revealed that instruction still relies on a direct teaching model involving lectures and practice problems. According to Mirdad (2020), learning models play an important role in organizing effective learning processes and influencing student learning outcomes. This approach renders students passive and limits their opportunities to develop critical thinking skills through discussion, problem-solving, or group work.

One alternative learning method to increase student engagement and foster critical thinking is game-based learning. The game-based learning approach uses game elements to create an active, enjoyable, and challenging learning experience (Athiyyah & Amalia, 2024). Putra et al. (2020) explain that game-based learning is a learning model that integrates educational content with game elements to increase motivation, participation, and student engagement in learning activities. In practice, students do not merely receive information passively. Students are directly involved in problem-solving, decision-making, and group collaboration. Research by Nuroniyah (2022) shows that game-based learning can improve students' critical thinking skills. Research by Siahaan, Murdiyanti, & Meidianingsih (2024) also found an improvement in students' critical thinking skills in mathematics through game-based learning.

One form of game-based learning for mathematics is the escape room game. Wiemker, Elumir, & Clare (2015) explain that an escape room game is a challenge-based game. Students must solve a series of puzzles or problems whitin a certain time limit to achieve the goal . in the learning process, this game encourages students to think critically, collaborate, analyze information, and choose the right solution strategy. The interactive and challenging learning environment also increases student engagement throughout the process. Several previous studies have demonstrated the potential of escape room games in education. (Ulfa & Roza, 2022;Yustina & Yahfizham, 2023) state that escape room games improve student learning outcomes. A study by Febriana, Muliyati, & Sunaryo (2023) found that escape room games increase student engagement because the learning process is both enjoyable and challenging. Selamet, et.al (2024) added that gamification in mathematics learning increases students' interest in learning and participation. However, specific research on the influence of game-

based learning through escape room games on mathematical critical thinking skills still needs to be developed.

This study aims to analyze the effect of game-based learning through escape room games on students' mathematical critical thinking skills. This study is expected to contribute to the development of innovative learning models in mathematics. This model could serve as an alternative for improving students' critical thinking skills in junior high school.

METHODS

Research Design

This study employs a quantative approach using a quasi-experimental method. The design implemented is a pre-test post-test control group design involving two groups: an experimental class and a control class. The experimental class was taught using a game-based learning model through an escape room game, while the control class was taught using a direct instruction model. Before and after the intervention, both classes took pre-test and post-test to measure the students' critical thinking skills.

Table 1. Research Design

Class	*Pre-test*	Treatment	*Post-test*
Experimental	O_1	X_1	O_2
Control	O_3	X_2	O_4

As presented in Table 1, both the experimental and control classes were assessed before and after the intervention. The symbols O_1 and O_3 represent the pre-tests administered to the experimental and control classes, respectively, to measure students' initial critical thinking skills. The experimental class then received treatment (X_1), which consisted of game-based learning through an escape room game, whereas the control class received treatment (X_2) in the form of direct instruction. After the learning intervention, the experimental class completed the post-test represented by O_2, while the control class completed the post-test represented by O_4. The comparison between the pre-test and post-test results was used to determine the improvement in critical thinking skills within each class, while the comparison between the two classes was used to evaluate the effect of the escape room-based learning model.

Population and Sample

The population in this study consisted of all 8th-grade students at SMP Negeri 25 Purworejo in the 2025/2026 academic year, totaling 192 students distributed across six classes. The research sample was selected using a cluster random sampling technique. Based on the sampling results, two classes were selected: one class as the experimental class and one class as the control class. There were 32 students in each class.

Research Procedure

This study was conducted during the second semester of the 2025/2026 academic year through four main stages. The first stage was preparation, which involved developing the learning materials, designing the research instruments, and validating the instruments through expert judgment. The second stage was implementation. At the beginning of this stage, both the experimental and control classes were given a pre-test to assess their initial

critical thinking skills. The learning activities were then conducted over four sessions in each class. The experimental class received game-based learning using an escape room game, whereas the control class was taught through direct instruction. After the intervention was completed, both classes were given a post-test to measure changes in their critical thinking skills. Finally, the pre-test and post-test data were analyzed to determine the effectiveness of the intervention and to test the research hypothesis.

Research Instruments

The research instruments consisted of test and non-test instruments. The test instrument comprised open-ended questions designed to measure students' critical thinking skills. It was administered in the form of a pre-test and a post-test, both of which were developed based on four indicators of critical thinking: interpretation, analysis, evaluation, and inference. The test consisted of three questions, with a maximum total score of 100. Meanwhile, the non-test instruments included an observation sheet and an interview guide. The observation sheet was used to record students' performance and activities during the learning process, whereas the interview guide was used to obtain preliminary information regarding the learning conditions at the school.

Validity and Reliability of the Instruments

The content validity of the instrument was assessed by three expert validators using the Aiken index. The results of the analysis showed that the content validity scores were 0.819 for the pre-test and 0.829 for the post-test, which fall into the high category. Construct validity was tested using product-moment correlation. All test items had a value of t score>t table, thus being deemed valid. The reliability of the instrument was calculated using Cronbach's Alpha. That results showed reliability values of 0.629 (pre-test) and of 0.614 (post-test), which fall into the high category. In addition, the results of the difficulty level analysis indicate that the test items fall into the moderate and difficult categories, while the discriminative power falls into the adequate to good categories. Thus, the instrument is deemed suitable for use in this study.

Data Collection Techniques

Research data were collected using observation, interviews, tests, and documentation, as suggested by Sugiyono (2019). Observation was conducted to obtain data regarding the implementation of the learning process in both the experimental and control classes. Interviews were used to gather preliminary information about the conditions and practices of mathematics learning at the school. The test technique was employed to measure students' critical thinking skills through the administration of a pre-test before the intervention and a post-test after the intervention. In addition, documentation was used to support the research data, including student lists and records of the learning activities conducted during the study.

Data Analysis Techniques

Data analysis was performed using Microsoft Excel software with a significance level of 5%. Prerequisite Test, the preliminary test included a normality test using the Liliefors test to determine the data distribution and a homogeneity test using Bartlett's test to determine the equality of variance.

The first hypothesis was testes using the nonparametric Mann-Whitney U test because the data did not meet the assumptions of a parametric test. This test was used to determine the difference in the improvement of critical thinking skills between the experimental and control classes based on N-Gain data (Sundayana, 2018).

Testing criteria:

H_0 rejected if $Z_{score} < -Z_{table}$ or $Z_{score} > Z_{table}$

The second hypothesis was tested using the Wilcoxon Signed-Rank test to determine the improvement in critical thinking skills before and after the intervention in the experimental class (Sundayana, 2018).

Testing criteria:

H_0 rejected if $Z_{score} < -Z_{table}$

The improvement in critical thinking skills was analyzed using the N-Gain index, calculated from the difference between pre-test and post-test scores normalized against the maximum score. The magnitude of the treatment effect was calculated using the Effect Size Cohen's d for paired data. Interpretation of the Effect Size value refers to the criteria (Cohen, 1998), namely small ($d \leq 0.2$), moderate ($0.2 < d < 0.8$), and large ($d \geq 0.8$).

RESULTS

The research findings are presented in two main analyses. The first analysis examines the difference in the improvement of critical thinking skills between the experimental and control classes. This analysis includes descriptive statistics of the pre-test, post-test, and N-Gain scores, followed by the Mann–Whitney U test to determine whether the difference between the two classes was statistically significant. The second analysis examines the improvement in critical thinking skills within the experimental class before and after the implementation of game-based learning through an escape room game. This analysis includes descriptive statistics, N-Gain, Effect Size, and the Wilcoxon Signed-Rank test. The results of these analyses are presented in Tables 2–5.

Table 2. Descriptive Statistics of Critical Thinking Skills in the Experimental and Control Classes

Class	Mean Pre-test	Mean Post-test	N-Gain	Category
Experimental	26.72	40.78	0.19	Low
Control	21.56	26.03	0.06	Very Low

Table 2 presents the descriptive statistics of students' critical thinking skills in the experimental and control classes. The results show that both classes experienced an increase in mean scores from the pre-test to the post-test. However, the experimental class obtained a higher mean post-test score and N-Gain value than the control class. The N-Gain score of the experimental class was categorized as low, whereas that of the control class was categorized as very low. These descriptive results indicate that students who participated in game-based learning through an escape room game demonstrated a greater improvement in critical thinking skills than students who received direct instruction.

Table 3. Result of the Mann-Whitney U test on the Improvement of Critical Thinking Skills

Statistical Test	Z Score	Significance Level	Decision
Mann-Whitney U test	-2.82	5%	H_0 Rejected

Table 3 presents the results of the Mann–Whitney U test conducted to determine whether there was a significant difference in the improvement of critical thinking skills between the experimental and control classes. The analysis produced a Z score of −2.82 at a significance level of 5%. Based on the established testing criteria, the null hypothesis was rejected. Therefore, there was a statistically significant difference in the improvement of critical thinking skills between the two classes. When considered together with the descriptive results in Table 2, this finding confirms that the improvement achieved by the experimental class was significantly greater than that achieved by the control class.

Table 4. Descriptive Statistics of Critical Thinking Skills in the Experimental Class

Pre-test	Post-test	N-Gain	Effect Size
26.72	40.78	0.19 (low)	0.95 $(high)$

Table 4 presents the descriptive statistics of students' critical thinking skills in the experimental class before and after the implementation of game-based learning through an escape room game. The mean score increased from 26.72 on the pre-test to 40.78 on the post-test, indicating an improvement in students' performance following the intervention. Although the N-Gain score was categorized as low, the Effect Size was categorized as high. This means that the quantitative increase relative to the maximum possible score remained limited, but the difference between the pre-test and post-test scores represented a substantial treatment effect.

Table 5. Result of the Wilcoxon Signed-Rank Test on Students' Critical Thinking Skills

Statistical Test	Z Score	Significance Level	Decision
Wilcoxon Signed-Rank Test	-4.52	5%	H_0 Rejected

Table 5 presents the results of the Wilcoxon Signed-Rank test used to compare the pre-test and post-test scores of students in the experimental class. The analysis yielded a Z score of −4.52 at a significance level of 5%. Based on the testing criteria, the null hypothesis was rejected. Thus, there was a statistically significant difference between students' critical thinking skills before and after the implementation of game-based learning through an escape room game. This result supports the descriptive findings in Table 4, demonstrating that students' critical thinking skills improved significantly following the intervention.

DISCUSSION

This difference in improvement is closely related to the characteristics of the learning model implemented. In the experimental class, game-based learning through an escape room game encouraged students to solve problems step-by-step (Faradisa, Utami, & Aini, 2023). Students did not merely receive information but were also required to understand the problem, devise strategies, and verify their answers before proceeding to the next stage.

These findings align with the research by Wiemker, Elumir, & Clare (2015), which states that game-based learning particularly escape room games can enhance students' engagement and cognitive activity in problem-solving. Furthermore, learning that presents challenges has proven to be more effective in developing critical thinking skills than direct instruction. Nevertheless, the improvement in the experimental class remained in the low category. This indicates that the implementation of the learning model has not yet been fully optimized. Several influencing factors include: students not yet being accustomed to game-based learning models, limited learning time, and the nature of the questions requiring critical thinking skills. Critical thinking questions in mathematics generally required students to analyze information, evaluate solution strategies, connect mathematical concepts, and draw logical conclusions. In this study, students were required to solve HOTS-based problems through escape room activities that involved interpretation, analysis, evaluation, and inference at each stage of problem-solving. Therefore, learning through the escape room provide students with greater opportunities to actively develop critical thinking skills compared to direct instruction.

These findings indicate that the implementation of game-based learning through an escape room game significantly improved critical thinking skills, although the quantitative increase was still categorized as low. The significance of the increase indicates that the changes observed are consistent, while the high Effect Size suggests that the learning model had a strong influence on improvements in critical thinking skills. However, the low N-Gain value indicates that the improvement is not yet optimal in quantitative terms. This condition may occur because the N-Gain value (Sundayana, 2018) measure the magnitude of score improvement quantitatively based on the difference between pre-test and post-test scores, whereas Effect Size (Cohen, 1998) indicates how strong the effect of the treatment is on the improvement of students' critical thinking skills. In this study, the post-test questions remained relatively difficult because they were HOTS-based and required analytical, evaluative, and in-depth reasoning skills (Abraham, Tjalla, & Indrajit, 2021). Critical thinking questions in mathematics generally require students to anlyze information, evaluate solution strategies, identify relationships between mathematical concept, and draw logical and systematic conclutions (Facione, 2015). In addition, solving HOTS problems requires systematic and step-by-step critical thinking processes in understanding and solving mathematical problems (Faradisa, Utami, & Aini, 2022). Through the escape room activities, students were required to perform interpretation, analysis, evaluation, and inference at each stage of problem-solving (Wiemker, Elumir, & Clare, 2015). As a result, although students experienced improvement in critical thinking skills after the treatment, the quantitative increase in score remained in the low category because students were still adapting to higher order thinking processes and problem-solving -based learning. This condition indicates that critical thinking skills require continuous practice and habituation so that their development occurs gradually (Siahaan et. al, 2024).

This improvement in critical thinking skills may occur because the escape room game learning activity includes the following elements:

a. Time pressure, which encourages students to think quickly and accurately.
b. Step-by-step problem-solving that trains analytical skills.
c. Answer verification, which develops evaluation skills.
d. A trial-and-error process that trains reflection and strategy refinement.

These four activities directly foster the indicators of critical thinking skills, namely interpretation, analysis, evaluation, and inference. This aligns with Facione's (2015) theory, which states that critical thinking skills encompass these four aspects. Furthermore, the teacher's role as a facilitator helps foster a learning environment that encourages independent thinking. Students are given the opportunity to explore solution independently through group discussions, thereby making the learning process more meaningful. However, the fact that the improvement has not yet been optimal indicates that critical thinking skills require a continuous process of practice. These skills do not develop overnight but require consistent practice in various problem-solving contexts.

CONCLUSION

Based on the research findings, it can be concluded that the implementation of a game-based learning model using escape room game has an impact on students' critical thinking skills. This is demonstrated by the difference in the improvement of critical thinking skills between the experimental and control classes, as well as the significant improvement in the experimental class before and after treatment. Although the N-Gain value falls into the low category, the high Effect Size indicates that the learning model has a strong influence on changes in critical thinking skills. Thus, this model is capable of facilitating students in the critical thinking process. Therefore, it is recommended that teachers implement this learning model continuously, future researchers should expand this study with a broader scope and a longer duration, and the results of this study can be considered in the development of learning innovations that support critical thinking skills.

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