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# Effect of Treffinger Model with Open-Ended Approach on Junior High Science Critical Thinking

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**Abstract**: The study examined the effect of implementing the Treffinger learning model with an open-ended approach on students' critical thinking skills in ecology and Indonesian biodiversity topics. It used a quantitative method with a quasi-experimental nonequivalent control group design. The participants were seventh-grade students of Junior High School 24 Surakarta in the 2024/2025 academic year. Two classes were selected through cluster random sampling, with 30 students of Grade 7C played as the experimental group, taught using the Treffinger model with an open-ended approach. Meanwhile, 30 students of Grade 7D played as the control group, taught using the discovery learning model. Data were collected using pre-test and post-test instruments. Before the study, all samples were through an initial equivalence test to ensure the groups had similar baseline conditions. The validity of the instruments was confirmed using the Gregory test and the Product Moment correlation, while reliability was assessed using Cronbach's alpha. It indicated a high to very high reliability. The pre-test and post-test scores were subsequently tested for normality and homogeneity. Data analysis using an independent samples t-test revealed a significant difference in students' critical thinking skills between the experimental and control groups ($p < 0.05$). In addition, the mean of pre-test and post-test scores of the experimental group were higher than the control group. The findings demonstrated that the Treffinger learning model integrated with an open-ended approach significantly enhanced students' critical thinking skills in science learning.
**Keywords**: Critical Thinking Skills, Treffinger, Open-Ended.

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## INTRODUCTION

Education can be understood as a series of communication activities carried out by teachers and students to shape individuals who are prepared for future educational demands (Kurniawan & Rahman, 2024). In the context of the 21st century, education faces increasing demands and challenges, requiring students to develop life skills that allow them to compete not only at the national but also at the global level. To meet these challenges, education plays a vital role in preparing future generations by cultivating 21st-century competencies (Rahayu *et al.,* 2024). According to the framework of Assessment and Teaching for 21st Century (ATC21S), these competencies are categorized into four key areas: critical thinking and problem solving, communication, creativity and innovation, and collaboration (Griffin & Care, 2015; Kemendikbud, 2017).

Among these competencies, critical thinking skills are considered one of the most essential skills in the learning process. This skill allows students to filter useful information and solve complex problems that frequently emerge in the modern era (Sa'adah et al., 2020; Saputra, 2024). Individuals who possess strong critical thinking skills are generally able to quickly identify important information and distinguish it from less relevant data (Pasquinelli & Richard, 2023; Lucaser & Acedera, 2025). Furthermore, critical thinking allows individuals to process and use information effectively in formulating solutions to encountered problems and in making appropriate decisions (Allanta & Puspita,

2021; Shutaleva, 2023). Through critical thinking, individuals are encouraged to evaluate issues rationally based on logic and sound reasoning, thereby avoiding speculative or unfounded information (Aziza, 2019; Živkovił, 2016).

Despite its importance, findings from several studies indicate that students' critical thinking skills is relatively low. Data from science learning at the junior high school level revealed that students' critical thinking skills ranged between 32.5% and 45.7%, placing them in the low to moderate categories (Amarila *et al*., 2021). Supporting this evidence, another study showed that 42% of students were in the low category, 30% in the moderate category, 25% in the high category, and only 3% in the very high category (Mauren *et al*., 2023). Similarly, another study showed that 14.29% of students were in the very low category, 57.14% in the low category, 10.70% in the moderate category, 14.30% in the high category, and only 3.57% in the very high category (Khasani *et al*., 2019).

The low level of students' critical thinking can be attributed to both internal and external factors. Internally, many students show low motivation, underdeveloped intellectual abilities, limited autonomy in learning, weak physical conditions, low curiosity, and a lack of confidence, which often leads to anxiety or fear of receiving criticism (Dores *et al*., 2020). Also, their participation in learning activitie tends to be minimal, as reflected in their limited initiative to ask questions, responses, express opinions, complete tasks, or submit assignments (Ngadha *et al*., 2023). Externally, instructional practices play a significant role; many teachers still struggle to select and apply appropriate models, approaches, or strategies to foster critical thinking (Fitrianingsih *et al*., 2023). Furthermore, the continued reliance on lectures hinders students' engagement and comprehension, particularly in science education (Hesy *et al*., 2023).

In response to these challenges, one promising solution to strengthen students' critical thinking is the implementation of appropriate learning approaches (Aprina *et al*., 2024). A learning approach serves as a framework for addressing instructional challenges, organizing content, and managing learning processes to ensure students' mastery of essential knowledge and skills (Sukino, 2023). Among the approaches, which the open-ended approach has been identified as effective in enhancing students' critical thinking (Hidayat *et al*., 2019). By presenting problems with multiple possible answers, this approach requires students to analyze deeply, reconsider various perspectives, and generate creative ideas (Sinaga *et al*., 2022). Moreover, it allows students the freedom to express diverse solutions using their perspectives and prior experiences, which lead to encouraging them to think critically while exploring multiple alternatives (Koriyah & Harta, 2015; Yamti, 2016).

Although beneficial, the open-ended approach has limitation. For example, the absence of a systematic framework in problem-solving often leads to unpredictable student's responses during learning activities (Wulandari, 2019). In addition, it requires considerable time for students to reflect and apply various strategies to solve problems (Sinurat, 2020). Students may also face difficulties in understanding or responding correctly to the questions (Sulistyaningsih, 2018). Nevertheless, the open-ended approach can be applied more effectively when integrated into an appropriate learning model, including Treffinger learning model. This model provides structured opportunities for students to engage in problem-solving while fostering independent and critical thinking (Sugiartini *et al*., 2023).

The Treffinger learning model integrates affective and cognitive dimensions through three essential components: basic tools, practice with process, and working with real problems (Munandar, 2016). In the basic tools stage, students are equipped with foundational skills that serve as the foundation for developing critical thinking. The practice with the process stage trains students to apply critical thinking functions such as analysis, evaluation, and analogy, which allows them to explore problems more systematically. In the final stage, working with real problems, students apply the skills acquired in the previous stages to address real-life challenges (Wirahayu et al., 2018). Through these stages, the model involves complex thinking processes and actively blends students in learning, thereby fostering the development of critical thinking skills through direct involvement in problem analysis and the formulation of solution (Zahra et al., 2021).

Furthermore, the Treffinger model emphasizes the learning process rather than focusing on final outcomes; therefore, each stage of the learning process becomes an important component of assessment (Kusniawati et al., 2020). This learning model is feasible for students with diverse ways of thinking because it provides opportunities for them to independently develop and express their ideas. In addition, the Treffinger model encourages students to communicate their ideas and opinions effectively with their peers (Indrawati, 2019). Moreover, it allows students to discover information or concepts independently


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through direct experiences in the teaching and learning process (Rezkyana et al., 2023). Consequently, the focus of this learning process is not only on helping students gain a deeper understanding of the subject but also on fostering the development of their critical thinking skills. Through the implementation of this model, learning becomes easier to understand, more memorable, and more effective in enhancing students' abilities (Shoimin, 2014).

Previous studies have predominantly examined the effects of the Treffinger learning model or the open-ended approach on critical thinking skills separately (Alatas, 2014; Sari et al., 2016). However, limited research has integrated both approaches simultaneously, particularly in the context of junior high school science learning. Therefore, this study aims to address this gap by examining the combined implementation of the Treffinger learning model and the open-ended approach to enhance students' critical thinking skills in junior high school science education.

In particular, this study investigates whether there is a significant difference in critical thinking skills between students taught using the Treffinger learning model combined with an open-ended approach and those taught using the discovery learning model. Furthermore, this study examines whether students who learn through the Treffinger model with an open-ended approach demonstrate higher critical thinking skills compared to students in the control group.

To address these research objectives, this study employed a quasi-experimental research design, involving an experimental group and a control group. The experimental group received a learning using the Treffinger learning model integrated with an open-ended approach, while the control group was taught using the discovery learning model. Students' critical thinking skills were measured using pre-test and post-test instruments. Meanwhile, the collected data were analyzed using statistical tests to determine the significance of the differences between the two groups.

## METHOD

The study employed a quantitative approach using a quasi-experimental design. In quasi-experimental research, the control group does not fully function to control external variables that may influence the implementation of the experiment (Sugiyono, 2019). The research design used a nonequivalent control group design with a pretest–posttest control group design. This design involved two groups. The first group served as the control group and was taught using the discovery learning model, which is the instructional model commonly applied by teachers. Meanwhile, the second group served as the experimental group and was taught using the Treffinger learning model combined with an open-ended approach.

**Table 1**. Nonequivalent Control Group Design

| Group | Pretest | Treatment | Posttest |
|---|---|---|---|
| **Experiental** | $O_1$ | $X_1$ | $O_2$ |
| **Control** | $O_1$ | $X_2$ | $O_2$ |

Where:

$O_1$ : Administration of the pre-test to both groups
$O_2$ : Administration of the post-test to both groups
$X_1$ : Treatment using the Treffinger learning model with an open-ended approach
$X_2$ : Treatment using the Discovery Learning model

The particular study examined both an independent and a dependent variable. The independent variable is defined as the factor that drives changes in the dependent variable (Sukardjo & Salam, 2020). The independent variable was the instructional model applied during the teaching and learning process. Conversely, the dependent variable was the outcome influenced by the independent variable (Azinah et al., 2022). In the control group, the discovery learning model served as the independent variable, while the experimental group was exposed to the Treffinger learning model integrated with an open-ended approach. The assessed dependent variable was students' critical thinking skills.

The selection of Discovery Learning as the instructional model for the control group and the Treffinger model combined with an open-ended approach for the experimental group was based on both theoretical and contextual considerations. Discovery Learning is widely recognized as a student-centered learning model that emphasizes students' active involvement in constructing knowledge


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through exploration, investigation, and problem-solving activities. In the context of science education, Discovery Learning is commonly implemented as part of inquiry-based learning practices and has been widely adopted in classroom instruction. Therefore, it represents a relevant instructional approach that reflects commonly used teaching practices in many educational settings.

From a theoretical perspective, Discovery Learning and the Treffinger learning model share similarities in promoting active students engagement and encouraging learners to construct knowledge through meaningful learning experiences. However, the Treffinger model offers a more structured framework specifically designed to develop higher-order thinking skills through its sequential stages of basic tools, practice with process, and working with real problems. These stages systematically guide students from the development of fundamental thinking skills toward the application of those skills in solving authentic and complex problems. When combined with an open-ended approach, the Treffinger model further allows students to explore multiple solution strategies and express diverse ideas, which may enhance the development of critical thinking skills.

This study was carried out at Junior High School 24 Surakarta, located in Surakarta City, Central Java Province. The research was conducted during the even semester of the 2024/2025 academic year. The implementation included two sessions dedicated to the pre-test and post-test, and ten sessions for instructional activities. The target population consisted all students from grades 7 A to 7 H. The sampling was selected using cluster random sampling technique due to the large size of the population and the need to select intact groups (classes) rather than individual of students. This method also ensured sample stability throughout the treatment phase and consider both internal and external factors that could influence the research process (Sugiyono, 2019). A total of two classes, consisting of 60 students, were selected as the research sample and assigned different instructional treatments. Grade 7 D served as the control group, receiving instruction through the discovery learning model commonly applied by the teacher. Meanwhile, Grade 7 C functioned as the experimental group and was taught using the Treffinger learning model combined with an open-ended approach. Before the intervention, an initial equivalence test was conducted to verify that both groups were comparable in baseline conditions.

In the control class, the discovery learning model syntax is used, which includes stimulation (presentation of a problem), problem identification, data collection, data processing, verification, and generalization. Meanwhile, the experimental class used the Treffinger learning model syntax. According to Treffinger (1986), it includes basic tools, practice with process, and working with real problems, as well as the open-ended approach, according to Yudhi (2017), which student activities must be open, learning activities have a variety of thinking, and student activities and learning activities are a unity.

Data collection was conducted using a written test in the form of essay questions, consisting of a pre-test and a post-test, each has six items. The pre-test aims to measure students' critical thinking skills before the treatment, while the post-test aims to assess students' critical thinking skills after the treatment (Isnawan, 2020). The test items were developed based on critical thinking indicators proposed by Facione, (2015) which include interpretation, analysis, inference, evaluation, explanation, and self-regulation. The test content covered topics related to ecology and Indonesian biodiversity.

Before selecting the research samples, an initial equivalence test was conducted using an independent samples t-test to ensure that the classes chosen as samples had comparable baseline conditions and no significant differences ($0.05 < 0.844$). The instruments consisted of student worksheets, three sets of test items containing six questions, and learning modules or instructional plans. The learning modules included the instructional content, learning objectives, teaching procedures, and embedded assessment components, which were systematically integrated into the lesson plan to guide both the teaching process and the evaluation of student learning outcomes. Before their implementation, all research instruments were validated by expert lecturers through a content validity test using the Gregory formula. The results indicated a validity score of 1 for the teaching modules, student worksheets, and test instruments, reflecting very high content validity.

Subsequently, a pilot test was conducted with eighth-grade students, which aimed to evaluate the quality of the test items. The pilot test data were analyzed using IBM SPSS Statistics 25. Construct validity was examined using the Product-Moment correlation with a significance level of 0.05. The analysis indicated that one test item was invalid, while the remaining items were valid. Reliability analysis was assessed using Cronbach's alpha, yielded coefficients of 0.745 for test package 1 (very high reliability), 0.859 for test package 2 (high reliability), and 0.644 for test package 3 (high reliability).


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Furthermore, the item discrimination analysis indicated two items of poor category, two items of moderate category, eleven items of good category, and three items of very good category. Meanwhile, the item difficulty analysis revealed that one item was classified as difficult, ten items as moderate, and seven items as easy. Based on these results, items that did not meet the required criteria were removed, while the remaining items were used in the study.

Data processing was carried out after obtained a complete dataset. The analysis consisted of prerequisite testing, followed by hypothesis testing. The prerequisite tests consisted of normality and homogeneity assessments to ensure that the data met the assumptions required for further statistical analysis. The Kolmogorov–Smirnov test was used to examine the normality of the data, while Levene's test was applied to evaluate homogeneity. The data were normally and homogeneously distributed if the significance value was greater than 0.05 (Setyawan, 2021; Tjahjono & Adawiyah, 2019).

To test the research hypothesis, an independent samples t-test was employed to determine a statistically significant difference between the two groups based on data-variations (Palupi et al., 2021). The hypothesis stated that the implementation of the Treffinger learning model combined with an open-ended approach has a significant effect on junior high school students' science critical thinking skills. The decision rule for the t-test was that if the Sig. (2-tailed) value was less than 0.05, the null hypothesis ($H_0$) is rejected in favor of the alternative hypothesis ($H_1$). In addition, the mean pre-test score of the control class was lower than the experimental class (51.67 < 66.33), and the mean posttest score of the control class was lower than the experimental class (66.8 < 82.1).

The research procedure began with the formulation of the research title, which was developed based on the identification of current issues related to science learning. This was followed by the preparation, development, and validation of the research instruments, as well as conducting instrument trials. The subsequent phase involved data collection, which encompassed three key components: conducting the pre-test, implementing the instructional activities, and administering the post-test. During the learning phase, the experimental group engaged in lessons utilizing the Treffinger learning model integrated with an open-ended approach to foster students' critical thinking skills. In contrast, the control group received instruction through the discovery learning model, a teaching strategy commonly employed by educators, serving as a foundation for comparison. After all data had been collected, the final stage was statistical data analysis to determine the research results. The final step was the preparation of a report containing a discussion of the analysis results, leading to the formulation of conclusions.

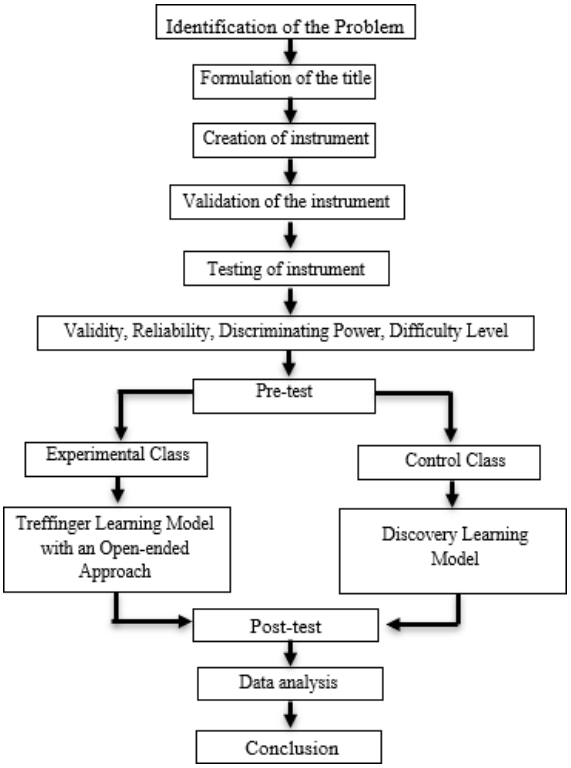


**Figure 1.** Research Flow


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## RESULT AND DISCUSSION

The study investigated the effect of applying the Treffinger learning model combined with an open-ended approach on students' critical thinking skills in the subject area of ecology and biodiversity in Indonesia. The research was conducted with two groups: an experimental class and a control class, each group consisting of 30 students. The experimental class was taught using the Treffinger model integrated with open-ended learning strategies. Whereas, the control class received instruction using the discovery learning model, which is commonly used by the teacher. The instructional process performed in a face-to-face format, consisting of two sessions for administering the pre-test and post-test, and ten sessions for delivering the learning intervention.

The learning process was carried out based on the lesson plans provided in the learning module and was supported by student worksheets. Before implementation, both the learning module and the student worksheets were validated by two experts in the field. The learning activities were implemented according to the instructional syntax of each class: the control class followed the syntax of the discovery learning model. Meanwhile, the experimental class followed the syntax of the Treffinger learning model integrated with aspects of the open-ended approach. Both classes used the same learning material, focusing on ecology and biodiversity.

Before the implementation of the learning model intervention, both the experimental and control groups were administered a pre-test using the critical thinking indicators to evaluate students' initial skill levels. The pretest results indicated that both groups had comparable baseline abilities, confirming the equivalence of their initial conditions. During the intervention phase, the experimental group received instruction through the Treffinger learning model, which consists of three key phases: basic tools, practice with process, and working with real problems (Treffinger, 1986), combined with the open-ended approach. This approach emphasizes open-ended student tasks, diverse thinking processes, and the integration of student engagement within the overall learning experience (Yudhi, 2017). In contrast, the control group was taught using the structured stages of the discovery learning model.

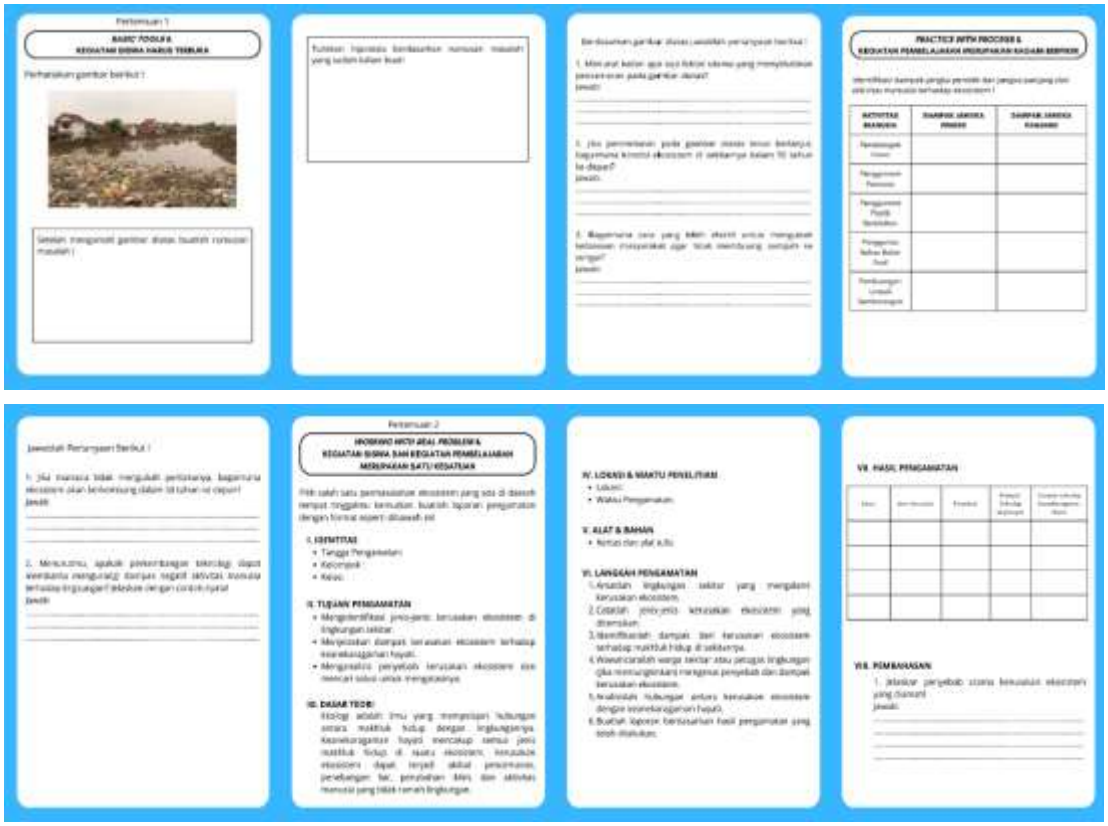


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**Figure 2.** Example of the Student Worksheet

After the instructional treatments were completed, a post-test was administered to both groups. The post-test results indicated an improvement in students' critical thinking skills in both the experimental and control groups; however, the experimental group has a markedly greater increase. Then, the integration of the Treffinger learning model with an open-ended approach had a more pronounced effect on fostering students' critical thinking skills than the discovery learning model. Data analysis was conducted by calculating the pretest and posttest scores using Microsoft Excel and IBM SPSS Statistics 25. The distribution of pre-test and post-test scores is presented in Table 2 and Figure 3.

**Table 2.** Distribution of Critical Thinking Skills Scores

| Data Description | Experimental Class | | Control Class | |
|---|---|---|---|---|
| | ***Pre-test*** | ***Post-test*** | ***Pre-test*** | ***Post-test*** |
| Lowest Score | 55 | 69 | 45 | 56 |
| Highest Score | 76 | 95 | 60 | 79 |
| Mean | 66,33 | 82,1 | 51,67 | 66,8 |

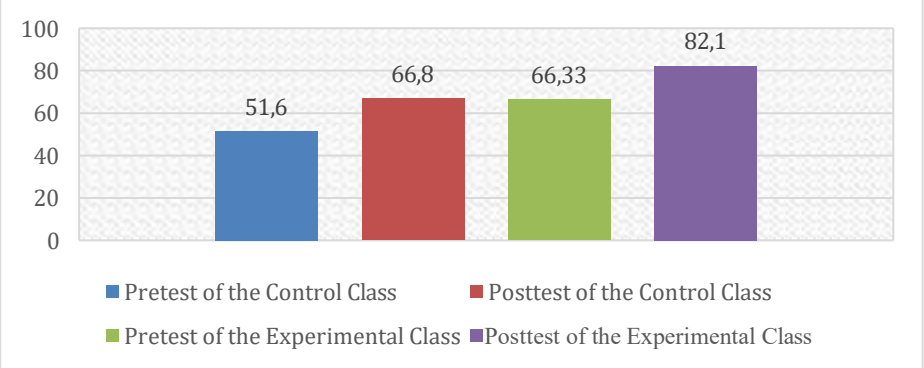


**Figure 3.** Average Pretest and Posttest Scores of the Control and Experimental Classes


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The data presented in the table 2 and figure 3 indicate that the experimental class achieved a higher average score compared to the control class. Specifically, the experimental group's average score increased from 66.33 on the pretest to 82.1 on the posttest. Meanwhile, the control group's average score increased from 51.67 on the pretest to 66.8 on the posttest. This reflects a score improvement of 15.13 points in the control group and a slightly greater increase of 15.77 points in the experimental group. Additionally, a comparative analysis was conducted on each aspect of the critical thinking skill indicators between the two groups. A comparison of critical thinking skills for each aspect is presented in Figure 4.


**Figure 4.** Scores of Each Aspect of Critical Thinking Skill Indicators

Figure 4 illustrates the comparison of students' critical thinking skill scores across six indicator aspects, namely interpretation, analysis, inference, evaluation, explanation, and self-regulation, as measured through pre-test and post-test results in both the control and experimental classes. Overall, the graph shows an increase in scores across all indicators after the implementation of the learning process. However, the improvement observed in the experimental class is greater and more consistent than the control class. It indicates a positive effect of the applied instructional treatment.

In the learning activities, the syntax of the Treffinger learning model was integrated with aspects of the open-ended approach. In the first meeting, the lesson began with the basic tools stage of the Treffinger model and the open-ended activity aspect of "students' activities must be open," in which students were given a stimulus in the form of real-life problems related to environmental pollution. Students were asked to observe and analyze an image showing ecosystem damage. They were then instructed to formulate problems and hypotheses based on the image. This activity stimulated critical thinking, indicators of interpretation, and analysis during the learning process. The interpretation indicator is defined as the ability to understand and express the meaning of various situations and data (Facione, 2015). In this context, students demonstrated interpretation when they understand the information based on the stimulus. Students' interpretation skills improved when they actively engaged in constructing their knowledge by understanding learning concepts through problem-solving activities in groups (Nugraha & Mahmudi, 2015). Bringing real-world problems into the classroom allowed students to choose topics that they wanted to explore, encouraging them to grasp the meaning, context, and information within the problems—an essential part of interpretation in critical thinking. Through this process, learning became more collaborative and meaningful, fostering the creation of quality education. As their interpretation skills improved, students' ideas also developed, along with their ability to explore and solve problems both independently and collaboratively (Fristadi & Bharata, 2015). This learning activity enhanced the analysis indicator. In this context, analysis was evident when students observed the images and analyze cause-and-effect relationships related to ecosystem damage. Analytical thinking skills emerged as students built causal relationships and evaluated behaviors in response to problems presented that were relevant to everyday life (Facione, 2015; Riantika & Wibawa, 2024).


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In the following meeting, the lesson implemented the practice with the process stage of the Treffinger learning model, along with the open-ended approach aspect that emphasizes learning as a variety of thinking processes. The student activity began with group discussions on ecosystem-related problems caused by human activities. Students were asked to identify the short-term and long-term impacts and potential solutions to these problems. This activity elicited the critical thinking indicators of explanation and evaluation during the learning process. The explanation indicator refers to students' ability to express and justify reasoning through consideration of evidence as the basis for conclusions (Facione, 2015). In this context, the explanation indicator was evident when students could articulate the short-term and long-term impacts, and propose solutions to the problems discussed in groups. This skill appeared when students not only conveyed information but also determined appropriate actions and formulated responses to the questions or issues posed by the teacher. Throughout the process, students designed strategies and tactics through active thinking and collaborative discussion, enabling them to generate relevant and targeted solutions (Putri *et al.,* 2020). The next indicator observed in this stage was evaluation, which is defined as the ability to assess the validity of statements or opinions (Facione, 2015). This indicator became clear when students evaluated the short-term and long-term effects of the ecosystem problems being discussed and assessed the feasibility of the proposed solutions in their groups. During the process, students think the advantages and disadvantages of each proposed solution. After that, they selected the most effective and relevant alternative solution based on the outcomes of their discussions. Evaluation activities encouraged students to develop their skills in analyzing and assessing information using logical reasoning to make decisions. This process not only resulted in a deeper understanding of the existing concepts but also allow students to generate new ideas or solutions. These abilities were further enhanced as students focused on selected problems, allowing them not only to grasp the related concepts but also to learn scientific methods to solve them (Fristadi & Bharata, 2015).

The final learning activity implemented the working with real problems stage of the Treffinger learning model, along with the open-ended learning aspect, where learning is regarded as a variety of thinking processes. Students were asked to identify other problems found in their daily lives. They were required to engage in group discussions and observe ecosystem damage around their homes by identifying the types of damage, causes, and the impacts on the environment and biodiversity. Afterward, the teacher guided the students in presenting their ideas and designing steps to solve the problems. This activity elicited the critical thinking indicators of inference and self-regulation during the learning process. The inference indicator refers to students' ability to identify and establish information in order to draw conclusions, formulate hypotheses, and make assumptions based on relevant information (Facione, 2015). This indicator was demonstrated when students summarize their group discussions by concluding the types of ecosystem damage around their homes, identifying the primary causes, and explaining the most significant environmental and biodiversity impacts. This ability indicated that students can address the problem presented by the teacher, through providing reasoning and supporting evidence from relevant sources and clearly articulating the conclusions from their group discussions (Apdolipah *et al.,* 2023). The next indicator observed was self-regulation, which is defined as the process of monitoring one's activities used in analysis and evaluation to validate or revise judgments (Facione, 2015). In this learning activity, self-regulation was evident when students actively managed their thinking processes during group discussions. This was reflected in their ability to plan observation steps, distribute tasks, revise both their own and their peers' opinions, and reflect on the discussion outcomes to ensure accurate understanding. Structured group discussions encouraged students to think optimally while also building teamwork skills. Through this activity, students not only developed continuous critical thinking skills but also learned to interact, communicate, exchange ideas, and complete tasks collaboratively in groups (Ananda & Agusta, 2023).

The pre-test and post-test scores were subsequently analyzed through prerequisite tests, which included tests for normality and homogeneity. The Kolmogorov-Smirnov test was employed to assess the normality of the data, using a significance threshold of 0.05. The normality test aimed to determine a normal distribution of data. The analysis results are presented in Table 3.


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**Table 3**. Normality Test Results

| Type of Test | Class | |
|---|---|---|
| | **Experimental** | **Control** |
| *Pretest* | .200* | .200* |
| *Posttest* | .200* | .197 |

The results of the normality test indicated that all significance values above 0.05, that the pretest and posttest scores for both the experimental and control groups were normally distributed. After that, a homogeneity test was conducted using Levene's test to assess the equality of variances. Data were homogeneous if the significance value was higher than 0.05. The findings of the homogeneity test are presented in Table 4.

**Table 4.** Homogeneity Test Results

| Type of Test | Class | |
|---|---|---|
| | **Experimental** | **Control** |
| *Pretest* | .062 | |
| *Posttest* | .359 | |

According to the results of the homogeneity test, the pretest yielded a significance value of 0.062, and the posttest yielded a value of 0.359. Since both values above 0.05, the data were homogeneous. With the assumptions of normality and homogeneity satisfied, the analysis proceeded to hypothesis testing using the independent samples t-test. This statistical test was employed to assess whether a significant difference existed between the experimental and control groups. It was selected because the data were from two independent groups that met the required assumptions for normal distribution and equal variances (Putri *et al.,* 2023). The test was conducted using only the post-test scores from both the experimental and control classes (Wahyuliani *et al.,* 2016). The results of the independent samples t-test are presented in Table 5.

**Table 5.** Hypothesis Test Results

| Class | Sig (2-tailed) | Significance Level | Decision |
|---|---|---|---|
| *Post-test of Experimental and Control* | .000 | 0.05 | $H_0$ is rejected<br>$H_1$ is accepted |

Based on data in Table 5, the significance value was 0.000, which is less than the threshold of 0.05 (0.000 < 0.05). This result leads to the rejection of the null hypothesis ($H_0$), indicating that there is a statistically significant difference in critical thinking skills between students in the experimental group who were taught using the Treffinger learning model combined with an open-ended approach and those in the control group, who received instruction through the discovery learning model.

Students' critical thinking skills improved in students taught using the Treffinger learning model with an open-ended approach. The results support the research by Kumalasari & Marianti, (2021), which states the Treffinger learning model with the environmental exploration approach (JAS) in biology subjects on the respiratory system material affects students' critical thinking skills, as evidenced by the average pre-test score of 60.25 and increased to 89.12 on the posttest. Another study on the Treffinger model, such as the research by Ridwan *et al*. (2019), that the Treffinger model is effective in enhancing students' critical thinking at SMK 3 Yogyakarta, as evidenced by the experimental group using the Treffinger learning model achieving higher scores compared to the control group using discovery learning. Next, research on the open-ended approach by Amelia *et al*. (2024), the use of the open-ended approach affects the critical thinking skills of elementary school students in science learning. The results show that the level of critical thinking skills of students in the experimental class after using the open-ended learning approach reached 81.19%, categorized as critical. Meanwhile, the control class only reached 40.57%, categorized as less critical. Another study, such as Mustamiroh *et al*. (2019), the open-ended approach in seventh-grade science classes with the topic of global warming can improve critical thinking skills, as evidenced by the average post-test score of the control class of 31.36%, and increased the average post-test score of the experimental class to 44.29%.


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The application of the Treffinger learning model, combined with an open-ended approach in the classroom, allows students to actively explore various possible solutions to a problem without being restricted to a single correct answer. This finding support Kusniawati et al. (2020), that the consistent implementation of the Treffinger model can foster students' self-confidence in expressing ideas and arguments. In addition, (Novtiar & Aripin, 2017) emphasized that the open-ended approach plays a role in enhancing students' self-confidence while simultaneously promoting critical thinking skills through active engagement in evaluating, solving problems, and making logical decisions. Through this approach, students are encouraged to ask questions, engage in reflection, and evaluate their own thinking processes, thereby enabling the development of more refined and in-depth critical thinking skills. Wulandari et al. (2022) further added that a supportive learning environment facilitated by an open-ended approach promotes collaboration among students, allowing them to learn from diverse perspectives and broaden their critical thinking abilities.

Nevertheless, this study has several limitations. Major limitation lies in the implementation of the Treffinger model syntax combined with the open-ended approach. In practice, the instructional syntax was not fully described in detail, particularly on the specific form of open-ended tasks to elicit students' critical thinking responses. Ideally, open-ended tasks should be presented in the form of open questions or problems that encourage students to generate multiple alternative answers and solution strategies. However, in this study, these prompts were not examined in depth, resulting in limited identification of variations in students' responses. In addition, the successful implementation of this model is highly dependent on the teacher's role as a facilitator who guide students, provide constructive feedback, and create a conducive learning environment (Marizka et al., 2024). Also, teachers must ensure that the tasks and problems are challenging and relevant to students' real-life contexts so that critical thinking skills can develop optimally (Judrah et al., 2024). Therefore, future research is recommended to describe the instructional syntax more systematically, particularly in designing structured open-ended tasks. As the result, the implementation of the Treffinger learning model with an open-ended approach produce more consistent and measurable outcomes in improving students' critical thinking skills.

## CONCLUSION

Based on the completion of the research and subsequent data analysis, it concluded that the application of the Treffinger learning model combined with an open-ended approach significantly enhanced students' critical thinking skills in junior high school science instruction. This conclusion is supported by the results of the independent samples t-test, which yielded a significance value below 0.05 ($0.000 < 0.05$), confirming the acceptance of the research hypothesis. Students in the experimental group, who received instruction through the Treffinger model with an open-ended approach, obtained higher levels of critical thinking compared to control group. These findings confirm the effectiveness of integrating the Treffinger learning model with an open-ended approach in fostering students' critical thinking skills.

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