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THE INFLUENCE OF THE TREFFINGER LEARNING MODEL AND SELF-DIRECTED LEARNING ON STUDENTS' MATHEMATIC CRITICAL THINKING SKILLS

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ABSTRACT

The study investigated the influence of the Treffinger learning model and self-directed learning on the critical thinking skills of junior high school students. The Treffinger learning model is one of the few models addressing the problem of creativity and providing practical suggestions on how to achieve cohesion. On the other hand, self-directed learning is a mental process to increase the knowledge, skills, and self-achievement of individuals with self-planned and self-conducted activities. The research employed a post-test experiment and control group design with two groups. The study employed two groups; one group was treated using the Treffinger learning model, while the other group was treated using a conventional model. Both groups were analyzed using a self-directed learning questionnaire and a critical mathematical thinking skills test. The sample of this research comprised 88 Grade 8 students purposefully selected in relation to the research objectives. The results of the study showed that the Treffinger learning model was statistically significant in enhancing critical mathematical thinking skills compared to the conventional learning models. Additionally, the study found that students who exhibited high levels of self-directed learning were more likely to benefit from the Treffinger learning model than the conventional model, with a statistically significant mean difference of 3.05 points.

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INTRODUCTION

Mathematics education emphasizes developing critical and creative thinking skills, enabling students to interpret, analyze, and solve complex mathematical problems (Susanti, 2019). In addition to the five primary competencies Fajri (2017) identified: mathematical understanding, problem-solving, mathematical communication, mathematical connection, and mathematical reasoning, critical and creative thinking are crucial for students to acquire (Sari & Hidayat, 2019; Widyatiningtyas et al., 2015). Critical thinking involves acquiring, evaluating, analyzing, synthesizing, and conceptualizing information to develop an independent thought process emphasizing the importance of making decisions about one's beliefs and actions (Fatah et al., 2016; Firdaus et al., 2015). On the other hand, creative thinking refers to the ability to discern meaningful and irrelevant combinations of ideas.

These higher order thinking skills are the primary objective of learning, consisting of four essential components: explaining and clarifying, asking the correct questions to clarify, considering the credibility of sources, solving problems, and drawing conclusions (Birgili, 2015). By cultivating critical and creative thinking in mathematics, students can deepen their understanding of mathematical concepts and become better problem-solvers and decision-makers in various contexts.

The ability of students to learn and effectively solve mathematical problems is contingent upon the teacher's ability to deliver content using a learning model that is both appealing to students and tailored to their characteristics (Shafto et al., 2014). Unfortunately, many classrooms rely on teacher-centered approaches, providing limited opportunities for active student engagement and seldom challenging students to think beyond routine problem-solving (Stephan, 2020). This trend has been linked to a lack of critical thinking skills among Indonesian students, who often struggle to solve non-routine problems (OECD, 2019) and are generally limited to thinking at the lower levels of Bloom's taxonomy, such as recall and understanding (Krathwohl, 2002). These findings are supported by data from The Trends in International Mathematics and Science Study (TIMSS), which ranks Indonesia 45 out of 50 countries, with a score of 397 points lower than the worldwide average (Mullis et al., 2016). Hence, students must be provided with learning models that promote the development of higher-order thinking skills, including critical and creative thinking (Birgili, 2015). The Treffinger learning model is one such approach that has proven effective in enhancing students' critical thinking abilities (Ridwan

et al., 2019; Treffinger, 1980). As outlined by Treffinger (1980), this practical model for developing creativity and mathematics achievement integrates cognitive and affective dimensions at each level of learning, from remembering and understanding to applying, analyzing, evaluating, and creating, and thus presents a promising solution to enhancing students' critical thinking skills.

The learning stages in the Treffinger learning model start from the basic tools in which students can think openly without being afraid that their opinions will be rejected or accepted. In this stage, students will be asked to reflect back on what they have learned and then be given a new problem and work on it in group discussions. The next step is practice the process in which students are faced with complex problems so that it allows students to bring out their potential in solving the problems they face. This step will require students to express their opinions in group discussions and present them in front of the class. The last step is working with real problems, involving students in real-life challenges and encouraging students to find their problems. This third stage allows students to know the problem contextually, where students are asked to think about solving real-world problems. Students will practice forming a problem and creating strategies to solve the problem (Treffinger, 1980).

In addition to learning models and mathematical critical thinking skills, there is an affective aspect that needs to be considered in learning. The affective aspect is important in learning because it involves attitudes, beliefs, and emotions influencing student motivation and engagement, impacting learning outcomes (Vermunt, 1996). Self-directed learning refers to the affective aspect. Self-directed learning is a process in which an individual analyzes his or her learning needs and is supported by activities conducted to identify and seek out information (Lee et al., 2014). This process is individual in nature where, with or without the help of others. Several components support the process: metacognition, time management, learning desire, and systematic learning, enabling an individual to take the initiative in diagnosing learning needs, creating learning objectives, selecting and implementing appropriate learning strategies, and evaluating learning results (Knowles, 1975; Örs, 2018; Robinson & Persky, 2020). Students with high math scores have the initiative to do practice questions even though they are not given instructions by the teacher (Sukardjo and Salam, 2020). Meanwhile, students who have low math scores tend not to have the initiative to start learning and wait for the teacher's instructions to do something. The case is also uniquely similar in the workplace as found by Lejeune et al.

(2021), where self-directed learning positively influences employees' job performance. In addition, a study conducted by Rahayu (2015) revealed that there was a relationship between the learning model and students' self-directed learning abilities on students' cognitive learning outcomes.

After reviewing the literature, the study has identified several issues that must be addressed. Firstly, students lack higher-order thinking skills in solving mathematical problems. Secondly, students are not adequately trained to tackle non-routine problems that necessitate the use of critical and creative thinking skills. Thirdly, students are only accustomed to answering low-level questions during classroom learning. Fourthly, students require a fresh and innovative teaching approach to learn mathematics. Fifthly, teachers need new and effective models to facilitate the learning process in the classroom. Lastly, the study has also recognized a gap in the literature regarding the impact of self-directed learning on the development of students' mathematical critical thinking skills.

Based on the background and problems identified, the study investigates the following research question: How is the influence of the Treffinger learning model and self-directed learning model on the students' mathematic critical thinking skills?. This study provides an alternative model of learning mathematics that is suitable and engaging for students to enhance students critical thinking abilities. In addition, the study will also fill the gap of previous studies that only covers physics (Alatas, 2014) and provide an alternative model for improving students' self-directed learning in learning mathematics.

METHOD

The study utilized a post-test experiment design with a control group comprising two groups: one treated with the Treffinger learning model and the other with a conventional model. The analysis employed a self-directed learning questionnaire and a critical mathematical thinking skills test. A purposive sampling technique was used to select a sample of 88 Grade 8 students based on their self-directed learning levels. Mathematical critical thinking was considered the dependent variable, while the learning model was considered the independent variable, and self-directed learning was treated as the moderator variable. The target population was all students in 99 Junior High School in East Jakarta, and the moderator variable was defined in accordance with the definition given by Aguinis and Pierce (1998) and Saunders (1955).

Data collection involved a self-directed learning questionnaire and a critical mathematical thinking skills test. The critical mathematical thinking skills test was used to collect data on mathematical critical thinking skills, while the self-directed learning questionnaire was used to collect data on students' self-directed learning. The critical mathematical thinking skills test was employed to provide a measurement of students' following abilities: 1) providing a simple explanation, 2) developing basic skills, 3) drawing conclusions, 4) providing a further explanation, and 5) strategizing and planning tactics. The test instrument of mathematical critical thinking ability has been validated by experts and, through empirical tests and reliability calculations, has been applied with a reliability coefficient of 0.673. Meanwhile, the questionnaire was used to collect data about students' self-learning and designed based on these self-directed learning indicators: 1) managing learning activities, 2) initiative and motivation, 3) utilizing and finding relevant sources, 4) monitoring and evaluating learning. The questionnaire was validated by experts and through empirical tests, with a reliability score of 0.962. The score was obtained from student responses in the form of a Likert scale that measures self-directed learning.

In this study, the hypotheses were tested using normality and homogeneity tests. The data was analyzed using a two-way covariance analysis with a two-by-two factorial experimental design treatment by level. The descriptive and hypothesis testing methodology was used to analyze the data. The research hypothesis for variance analysis approaches was tested using the ANOVA hypothesis test. The ANOVA test aimed to determine the influence of self-directed learning and the Treffinger learning model on critical thinking abilities.

RESULT AND DISCUSSION

This study aimed to comprehensively examine the impact of the Treffinger learning model and self-directed learning on the mathematics critical thinking skills of junior high school students. The first hypothesis was tested to determine whether there was a significant difference in the mathematical critical thinking skills of two groups who received different treatments. The descriptive analysis and hypothesis testing revealed variations in the mathematical critical thinking skills between the groups learning using the Treffinger learning model and the conventional model. Table 1 compares the scores of mathematical critical thinking and self-directed learning of students who received the Treffinger learning model to those who received the conventional model.

Table 1 Descriptive Statistics Data of Mathematical Critical Thinking Ability

Self-directed learning	Instrument	Treffinger learning model					Conventional Model				
		Number of Students	Min	Max	Average	SD	Number of Students	Min	Max	Average	SD
High	Test	22	35	47	40.23	3.56	22	31	45	37.18	3.59
Low	Test	22	25	35	30.42	3.23	22	26	35	30.41	3.13
Total		44	25	47	35.32	6.03	44	26	45	33.80	4.78

Table 2 presents the results of the analysis of variance (ANOVA) on the critical thinking test scores based on the students' self-directed learning levels and the learning models used. The table reveals that students with poor self-directed learning exhibited more homogeneous critical thinking test scores than those with high self-directed learning. Additionally, the critical thinking test scores of students treated with the conventional model were more homogeneous than those treated with the Treffinger learning model ($F = 4.384$, $p < .05$).

One possible explanation for these findings is the Cognitive Load Theory (CLT) proposed by Sweller (1988), which suggests that the cognitive load imposed on learners can affect their learning outcomes. Students with high self-directed learning may adopt various problem-solving approaches, resulting in more diverse cognitive loads. In contrast, students with poor self-directed learning may rely on similar problem-solving strategies, leading to more homogeneous cognitive loads. Therefore, the diverse cognitive loads experienced by students with high self-directed learning may contribute to the more variable critical thinking test scores observed. Overall, the results suggest that the students treated with the Treffinger learning model exhibited greater mathematical critical thinking skills than those treated with the conventional model.

To determine whether the Treffinger learning model has an effect and a statistically significant difference, the one-way ANOVA was employed. The necessary tests of normality and homogeneity were performed and provided satisfying results. Table 2 below summarizes the outcomes of the hypothesis.

Table 2 Mathematical Critical Thinking Ability

Main Effect	Sig
Learning Model	0.044
Self-directed learning	0.000
Learning Model * *Self-directed learning*	0.032

The influence of the learning model was analyzed using a one-way ANOVA, and the result is presented in Table 2 ($F(1.58) = 4.27$, $p = .044$)). The results indicate a statistically

significant difference in mathematical critical thinking skills between students experiencing the Treffinger learning model and those experiencing the conventional model. The average results in Table 1 show that the mathematical critical thinking skills of students exposed to the Treffinger learning model were greater than that of those exposed to the conventional model. An additional analysis was conducted to examine the interaction effect of the learning model and self-directed learning on critical thinking skills, as depicted in Table 2 ($p= 0.032$), representing the interaction effect. The higher the level of self-directed learning, the greater the critical thinking skills acquired, particularly among the students treated with the Treffinger learning model. Specifically, students with a high level of self-directed learning treated with the Treffinger learning model will have more critical thinking skills than students with a high level of self-directed learning treated with conventional models.

The aforementioned finding demonstrates that the Treffinger learning model has an effect on students' mathematical critical thinking abilities. Self-directed learning has an impact on critical thinking abilities in addition to the learning model. Hence, there is interaction, specifically the usage of the Treffinger and traditional models on students' self-directed learning-dependent mathematical critical thinking skills. Compared to the conventional paradigm, it is believed that the Treffinger learning model can have a greater impact on students' self-directed learning. The interaction indicates that the Treffinger learning model-treated group has a higher average level of mathematical critical thinking. Mathematical critical thinking skills of students treated with the Treffinger learning model and high self-directed learning were greater than those of students treated with traditional models and high self-directed learning.

Students with a high level of self-direction who were treated with the Treffinger learning model were able to develop their mathematics critical thinking skills. Self-directed learning is a process in which individuals take the initiative with or without the assistance of others (Knowles, 1975). High self-directed learning, if supported by the Treffinger learning model, which demands students' engagement, will increase students' awareness of learning, their knowledge of learning objectives, and ability to determine their strategies. Knowles (1975) suggested that individuals take responsibility for their learning, identify their learning needs, and determine the strategies and resources necessary to achieve their goals. The finding aligns with the idea that self-directed learning positively impacts critical thinking skills, as students who can take charge of their learning are more likely to develop the skills necessary to think

critically about new information.

To effectively integrate the Treffinger learning model in the classroom, teachers should take into account the following suggestions: Firstly, it is crucial for teachers to communicate the implementation stages of the model explicitly to aid students in learning more efficiently. Additionally, teachers should guide those who encounter difficulties in problem-solving. Secondly, teachers should assess students' self-directed learning levels via a questionnaire to ensure well-balanced grouping based on their abilities. Thirdly, teachers should follow the scoring guidelines meticulously when evaluating the critical thinking ability test to prevent calculation errors in determining the students' scores. Lastly, teachers can enhance students' mathematical critical thinking skills by fostering a favorable learning environment that promotes active student participation and inspires a sense of fun and challenge in the classroom.

Table 3 Mathematical Critical Thinking Skills

Self-directed learning	Sig (2-tailed)
High	0,007
Low	0,925

Table 3 indicates that the significance value of critical thinking skills for students with high self-directed learning is 0.0035. It can be concluded that there are differences between groups of students who are provided with Treffinger's learning model and those who are provided with the conventional model for students with high self-directed learning in their mathematics critical thinking skills. The average value in Table 1 indicates that the mathematics critical thinking skills of students treated with the Treffinger learning model was greater than those treated with the conventional model among students with strong self-directed learning.

Table 3 further indicates no significant difference between the critical thinking skills of students with low self-directed learning ($p=0.4625$). The results revealed no difference in the mathematics critical thinking skills of students treated with the Treffinger learning model compared to those with low levels of self-directed learning in a conventional model. This finding can be explained by the Self-Determination Theory (Deci & Ryan, 2013). This theory proposes that students with higher levels of self-directed learning are more likely to be motivated, engaged, and successful in their academic pursuits. Consequently, it can be inferred that students with lower levels of self-directed learning may not have been as motivated or engaged in the learning process. This could have led to no significant difference in their critical thinking skills between the Treffinger model and conventional treatment.

To summarize, the study found no significant difference in the mathematics critical thinking skills between the Treffinger learning model and the conventional model for students with low self-directed learning. It was observed that students with low levels of self-directed learning tend to be more passive in class compared to those with high levels. Kan'an and Osman (2015) suggested that individuals with low levels of self-directed learning prefer a structured learning process, where the teacher plays a more active role in classroom learning. Students with low self-directed learning tend to express few opinions during group activities and struggle to comprehend the first step required to solve the given questions. As a result, when the teacher assigns individual assignments, students with low levels of self-directed learning tend to give up easily since they do not know how to start working on the problems. Based on the findings, it can be concluded that active learning in the classroom does not significantly improve the mathematics critical thinking skills of students with low levels of self-directed learning.

CONCLUSION

This study revealed that the Treffinger learning model effectively enhances mathematics critical thinking skills compared to conventional learning models. Thus, the Treffinger model is recommended to be used in mathematics education to promote critical thinking skills. Furthermore, the results indicated a significant relationship between self-directed learning and learning models for developing mathematical critical thinking skills. Students with high self-directed learning treated with the Treffinger model had higher critical thinking scores than those treated with conventional models. However, there was no significant difference in critical thinking skills between students with low self-directed learning treated with the Treffinger model and those treated with conventional models. This finding suggests that students with low self-directed learning tend to be less motivated and passive in the learning process, which may hinder their acquisition of critical thinking skills.

Thus, those who received the Treffinger learning model treatment had more mathematical critical thinking skills than those who received the conventional model treatment. This can be attributed to the syntax of the Treffinger model, which promotes critical thinking skills. Students with a high level of self-directed learning are better suited to be treated with the Treffinger learning model than the conventional model, as they can identify their own learning needs and benefit from the initiative-taking approach of the model. On the other hand, there was no significant difference between the Treffinger and conventional models in their effects on

students with low self-directed learning. This may be because students with low self-directed learning tend to prefer a traditional learning process where the teacher plays a more active role.

Based on the study's findings, it is reasonable to conclude that the Treffinger learning model has a more significant impact on students' critical thinking abilities than the conventional model. Therefore, it can be used as a model for teaching mathematics in the classroom to enhance students' critical thinking skills. The study also suggests a connection between the learning model, students' self-directed learning, and critical thinking abilities. Students with high levels of self-directed learning can benefit from the Treffinger learning model in developing their mathematics critical thinking skills. Using the Treffinger learning model, students can participate more actively in class discussions, express their ideas, and accept the opinions of others. Additionally, they can design problems and determine the steps to solve them, which can be applied to real-world situations.

To effectively incorporate the Treffinger learning model in the classroom, teachers should consider the following recommendations: First, teachers should communicate the stages involved in implementing the model to enable students to learn more efficiently. Teachers should also guide students who encounter difficulties in problem-solving. Second, teachers should assess students' self-directed learning using a questionnaire to ensure balanced grouping based on abilities. Third, teachers should follow the scoring guidelines closely while evaluating the critical thinking ability test to avoid any calculation errors in determining the students' scores. Finally, teachers can improve students' mathematical critical thinking skills by creating a favorable learning environment that promotes active student participation and fosters a sense of fun and challenge in the classroom.

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