

The Effect of Problem-Based Learning and Make-a-Match Learning Model Assisted by Puzzle Media on Problem-Solving and Critical Thinking Skills in Terms of Self-Efficacy

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Abstract: This study aims to determine (1) which approach the make a match learning model assisted by puzzle media or the problem-based learning model produces better critical thinking and problem-solving skills; (2) which results in better critical thinking and problem-solving skills among students with low, medium, or high self-efficacy; and (3) whether there is an interaction between the learning model and self-efficacy on students' critical thinking and problem-solving skills. This study employed a 2 x 3 factorial quasi-experimental design. The research data were analyzed using multivariate analysis of variance (MANOVA) in SPSS. The study population consisted of 256 students at SMP N 4 Karanganyar. The sample was selected using cluster random sampling, with Class VIIIB (32 students) chosen as Experimental Class 1, receiving instruction using the make a match assisted by puzzle media, while Class VIIIF (32 students) was selected as Experimental Class 2, receiving instruction through problem-based learning. The research instruments included a problem-solving ability test, a critical thinking ability test, and a self-efficacy questionnaire. The validity of the test instruments, including content validity, difficulty level, discriminant validity, and reliability, was assessed. The questionnaires were tested for content validity, internal consistency, and reliability. The results of the study indicate that (1) the implementation of the make a match assisted by puzzle media on Pythagoras material resulted in better critical thinking and problem-solving skills compared to the problem-based learning model; (2) students with low, moderate, and high self-efficacy did not show significant differences in critical thinking skills, while students with high and moderate self-efficacy demonstrated better problem-solving skills than those with low self-efficacy; however, students with moderate and high self-efficacy did not differ in their problem-solving skills; and (3) there was no interaction between the learning model and self-efficacy regarding students' critical thinking and problem-solving skills.

Keywords: problem-based learning, make a match assisted by puzzle media, self-efficacy, critical thinking skills, problem-solving skills.

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■ INTRODUCTION

The application of information and communication technology in various aspects of life is a defining feature of 21st-century global development. Technology facilitates the rapid dissemination of information. The field of education has also evolved in response to changing times. The education system is currently

undergoing a curriculum revision. Schools must shift their teaching approach from teacher-centered to student-centered. According to the Ministry of Education and Culture of the Republic of Indonesia, the 21st-century learning paradigm emphasizes students' ability to gather information from various sources, analyze problems, think critically, and collaborate to solve problems.

Critical thinking and problem-solving skills are essential in all fields of expertise. These skills are so important that various parties, including educational institutions, are required to develop them (Masek & Yamin, 2012). Critical thinking is the process of using thinking skills to analyze, evaluate, and make decisions about what to believe or do. Critical thinking has the following characteristics: (1) solving problems with a specific goal in mind (Vincent Lancrin, 2023), (2) analyzing, generalizing, and organizing ideas based on available facts and information, and (3) drawing conclusions to solve problems systematically with sound arguments (Facione, 1990). Critical thinking is necessary in the learning process across all subjects, including mathematics. Critical thinking skills are essential in mathematics education because they help students understand concepts, analyze challenges, and identify the best solutions to math problems. Critical thinking skills determine a person's resilience in competing to be the best because they can enhance competitiveness. Critical thinking improves a person's ability to solve problems optimally by analyzing problems from various perspectives, thereby enabling them to find several appropriate solutions to the problems at hand.

Problem-solving is an important component of the learning process and involves efforts to resolve problems to achieve desired goals (Santos-Trigo, 2024). Problem-solving involves efforts to overcome problems to achieve desired goals. Problem-solving is defined as the process of applying previously learned knowledge to new, unfamiliar situations. Problem-solving should be an integral part of all mathematics learning activities because it enables students to generate ideas that lead to new knowledge and skills. According to the NCTM, all students should learn new mathematical concepts through problem-solving. This is because, during the problem-solving process, students strive to understand unfamiliar problems as part of their learning experience (Mauliyda, 2019).

Problem-based learning (PBL) is one of the alternative learning models proposed by the government for implementation in the learning process because it can develop students' critical thinking and problem-solving skills through learning activities. PBL is a learning model that focuses on solving everyday problems. The purpose of implementing this model in learning is to engage students in a research process that requires them to identify problems, collect data, and then use that data to solve problems. This learning model can stimulate students' ability to think critically, creatively, analytically, systematically, and logically by exploring data empirically to find alternative solutions and foster a scientific attitude. This enables students to build their knowledge, thereby honing their critical thinking and problem-solving skills (Nurmanita et al., 2019).

In addition to the PBL paradigm, the make-a-match learning model can help students develop critical thinking and problem-solving skills. This is consistent with Pamungkas et al. (2024). The study found that the make-a-match learning model influences students' critical thinking skills. Putra et al. (2021) found that the make-a-match learning model significantly improves students' problem-solving skills compared to conventional instruction. Similarly, Maulidawati et al. (2020) found that students taught using the make-a-match learning model demonstrated significantly better math skills than those taught through conventional science instruction. The make-a-match learning model is a learning paradigm that integrates the learning process with a matching card game, thereby creating a fun and engaging classroom atmosphere. The questions on the cards in this matching game are designed to help students develop critical thinking skills. As facilitators and motivators, teachers encourage students to communicate and work together. This learning paradigm requires students to actively tackle challenges by discussing and developing ideas together in order to find the best solutions.

At the junior high school level, students' abstract thinking skills are not yet optimally developed. This is evidenced by the analysis of 8th-grade students' results at SMP Negeri 4 Karanganyar regarding the Pythagorean topic, which showed that 56.38% scored below the learning objective attainment criteria. These figures indicate that understanding abstract mathematical concepts remains a challenge for some students. Therefore, teaching should use learning resources that help students grasp these abstract mathematical concepts. It is hoped that using puzzles to teach the Pythagorean Theorem will help students understand the concepts involved. Using puzzle media in learning activities will make it easier for students to construct learning materials, increase student activity, and create a pleasant classroom atmosphere. Puzzle media is expected to attract students' attention during the learning process and increase learning motivation so that learning runs more smoothly. It is envisaged that the activities in the application of the Make a match learning model, helped by puzzle media, will help to refine critical thinking and problem-solving skills, allowing learning objectives to be achieved.

Students' critical thinking and problem-solving abilities are influenced not just by external factors, such as learning models, but also by internal elements, including self-efficacy. Self-efficacy is a person's confidence in their ability to take action to attain a specific objective. Self-efficacy is vital in everyday life; if a person believes in himself, he will be able to maximize his potential. Low self-efficacy can cause anxiety and an unwillingness to engage in activities that could exacerbate the situation. Individuals with poor self-efficacy believe they lack the skills to deal with difficulties. As a result, self-efficacy significantly affects a person's confidence in taking action or making decisions when confronted with a challenge.

Although the potential of the problem based learning and make a match learning models as well as the influence of self-efficacy on critical thinking and problem-solving skills has been widely discussed, further examination is needed regarding the differences in how these two models affect students' critical thinking and problem-solving abilities. Therefore, this study is designed to address the following research questions: (1) which learning model problem based learning or the make a match learning model assisted by puzzle media yielded better critical thinking and problem-solving skills; (2) which group demonstrated superior critical thinking and problem-solving skills based on self-efficacy levels (low, moderate, or high); and (3) whether there was an interaction between the learning model and self-efficacy regarding students' critical thinking and problem-solving skills

■ METHOD

Research Design

This study employed a 2×3 factorial quasi-experimental design. This is in accordance with the opinion of Campbell et al. (1963), "The purpose of quasi-experimental research is to obtain information that is an estimate of the information that can be obtained through real experiments in circumstances that do not allow all relevant external variables to be controlled". This study involved independent variables. The first independent variable was the learning model, consisting of two levels (problem-based learning and make-a-match assisted by puzzle media). The second independent variable was students' self-efficacy, classified into three levels (low, Moderate, and high). The dependent variables were students' critical thinking skills and problem-solving skills. Data were analyzed using a two-way Multivariate Analysis of Variance (MANOVA) to examine the main effects of the learning model and self-efficacy, as well as their

interaction effects on the two dependent variables.

Data Collecting Technique

Data were collected using documentation, tests, and questionnaires. The documentation method gathered end-of-odd-semester assessment scores to establish the students' baseline ability prior to the study. Tests were administered to measure critical thinking and problem-solving skills, while the questionnaire was used to assess self-efficacy levels. Data collection for the self-efficacy questionnaire was conducted before the intervention, with a 30-minute time allocation.

The assessment instruments used in this study comprised tests of critical thinking and problem-solving skills, presented in the form of essay-type questions, as well as a questionnaire on students' self-efficacy. Before data collection, these instruments were assessed for suitability. The test instruments were deemed valid as experts determined that they met all relevant review criteria regarding construction, content, and language. The test items achieved a minimum discrimination index of 0.3 and a moderate difficulty index ranging from 0.3 to 0.7, while the test as a whole demonstrated a minimum reliability coefficient of 0.7. Similarly, the questionnaire satisfied all review criteria regarding construction, content, and language. Each questionnaire item yielded a minimum internal consistency index of 0.3, and the questionnaire overall showed a reliability coefficient of 0.7.

The self-efficacy questionnaire scores were categorised into low, moderate, and high levels based on ideal norm-referenced standards using the mean and standard deviation ($X \pm 0.5SD$). Based on this criterion, students were classified as having low self-efficacy if $X < 77$, moderate self-efficacy if $77 \leq X < 87$, and high self-efficacy if $X \geq 87$.

Prior to conducting the research, a test of equality of means was conducted to determine whether the two research samples had comparable baseline abilities. This test required two assumptions to be satisfied: normality of the data and homogeneity of variances. The Shapiro-Wilk test was used to assess the normality of the initial ability data because the sample size was relatively small ($n = 32$). The results showed that the p-value for the class using the Make a Match model assisted by puzzle media was $0.099 > 0.05$, while the p-value for the class using problem-based learning was $0.604 > 0.05$. These results indicate that the initial ability data in both experimental classes were normally distributed. Meanwhile, the homogeneity of variances was assessed using Levene's test. The results showed a significance value of $0.279 > 0.05$, indicating that the variances of the initial ability data in the two classes were homogeneous. Subsequently, a t-test was conducted to assess whether the mean initial abilities differed between the two experimental classes, yielding a two-tailed significance value of 0.153. Since the significance value was greater than 0.05, there was no significant difference in the mean initial ability between the two experimental classes.

Data Sources or Participants

The population in this study comprised all eighth-grade students at SMP N 4 Karanganyar, totaling 256 students, divided into eight classes: eighth grade A through eighth grade H. Data collection was conducted using a cluster random sampling approach. Of these eight classes, experimental class 1 was Class VIIIB and experimental class 2 was Class VIIIF. Each class consisted of 32 students. In Experimental Class 1, instruction used the make a match assisted by puzzle media through the following stages: (1) Communicating the objectives and motivating students. In this stage, the teacher explains the

learning objectives to be achieved, emphasizes the importance of studying the material, and motivates the students; (2) Presenting information. In this stage, the teacher connects students' prior knowledge with the new material to be studied and provides a brief overview of the scope of the material, the steps of the activity, and the evaluation criteria to be used; (3) Organize students into learning groups. At this stage, the teacher distributes interlocking puzzles to each group, with even-numbered groups receiving the question pieces and odd-numbered groups receiving the answer pieces, and distributes worksheets for each pair to record the results of their discussion, while also explaining how to conduct the learning activity using the provided puzzles; (4) Guide the groups as they work and learn. At this stage, students who have successfully completed the worksheet discuss with their group partners to fill out the conclusion sheet based on the activities they have carried out; (5) Evaluation: At this stage, several groups give presentations, and the teacher provides feedback on the group presentations. At this stage, awards were also given to the groups that successfully solved the puzzle correctly. In Experimental Class 2, instruction utilized the problem-based learning model through the following stages: (1) Orienting students to a problem. At this stage, the teacher communicates the learning objectives to be achieved, connects students' prior knowledge to the new material to be studied, emphasizes the importance of learning the material, and provides a brief overview of the scope of the material, the steps of the activities, and the evaluation criteria to be used; (2) Organizing students for learning. At this stage, the teacher divides students into learning groups, and students discuss to identify what they know, what questions they have, and what information is needed to solve the problem; (3) Guiding individual and group investigations. At this stage, the teacher guides students in gathering relevant

information and data and then conducting an investigation to find a solution to the problem; (4) Developing and presenting results. At this stage, several groups present the results of their discussions; (5) Analyzing and evaluating problem-solving. At this stage, the teacher reflects on and evaluates the stages of the investigation and the results obtained.

Data Analysis Technique

Data were analyzed using Multivariate Analysis of Variance (MANOVA) using IBM SPSS Statistics. Before hypothesis testing, MANOVA assumptions (multivariate normality, homogeneity of variance) were checked using Levene's test, and homogeneity of the covariance matrix was assessed using Box's M-test. Next, a two-way MANOVA was conducted to examine the main effects of learning model and self-efficacy, as well as their interaction effect, on students' critical thinking skills and problem-solving skills. When the multivariate test showed significant differences, Tests of Between-Subjects Effects were conducted for each dependent variable. In addition, a Bonferroni post hoc test was conducted to identify differences between self-efficacy groups. Statistical significance was determined at the 0.05 level.

■ RESULT AND DISCUSSION

Experimental research on problem-based learning models and cooperative learning models of the Make a match type assisted by puzzle media in terms of self-efficacy on Pythagoras material was conducted at SMP N 4 Karanganyar. This study aims to determine (1) which produces better critical thinking and problem-solving skills between the application of the problem-based learning model or the make a match learning model assisted by puzzle media, (2) which produces better critical thinking and problem-solving skills among high, moderate, or low self-efficacy levels, (3) whether there is an interaction between

learning models and self-efficacy on students' critical thinking and problem-solving skills. This study involves two research variables: (1) the independent variable consists of learning models and self-efficacy, and (2) the dependent variable consists of students' problem-solving skills and critical thinking skills.

In this study, the data were analysed using the Multivariate Analysis of Variance (MANOVA) test after prerequisite tests such as the Normality Test and Homogeneity Test. The research data for this study were analysed with

SPSS Statistics. The results of data processing using SPSS Statistics are described below.

Normality Test

Before conducting the prerequisite tests, the data on problem-solving skills and critical thinking abilities were analyzed descriptively to determine the data distribution. A summary of the mean, standard deviation, and sample size for each treatment group, as well as the level of self-efficacy, is presented in Table 1.

Table 1. Summary statistics for dependent variables across groups

Dependent Variables	Learning Models	Self-efficacy	Mean	Std. Deviation	N
Critical Thinking Skills	Make a Match Assisted by Puzzle	Low	86.8750	6.28916	8
		Moderate	91.5385	5.98074	13
		High	91.3636	6.51572	11
		Total	90.3125	6.36744	32
	Problem-Based Learning	Low	77.8000	8.06639	10
		Moderate	80.5714	6.13583	14
		High	81.7500	4.89168	8
		Total	80.0000	6.52538	32
	Total	Low	81.8333	8.50087	18
		Moderate	85.8519	8.15571	27
		High	87.3158	7.52811	19
		Total	85.1562	8.24086	64
Problem-solving Skills	Make a Match Assisted by Puzzle	Low	71.0000	7.32900	8
		Moderate	86.2308	8.35817	13
		High	90.5455	9.55368	11
		Total	83.9062	11.38012	32
	Problem-Based Learning	Low	64.0000	11.46977	10
		Moderate	74.6429	9.74764	14
		High	81.3750	11.12189	8
		Total	73.0000	12.30526	32
	Total	Low	67.1111	10.22620	18
		Moderate	80.2222	10.70346	27
		High	86.6842	10.97498	19
		Total	78.4531	12.97853	64

Multivariate normality tests were conducted on both dependent variables: problem-solving skills and critical thinking skills. Each data group was tested for normality using a multivariate approach, including (1) learning models

comprising Experimental Group 1, which used the make-a-match assisted by puzzle media, and Experimental Group 2, which used Problem-Based Learning, and (2) high, moderate, and low levels of self-efficacy. The normality test showed

a significance value greater than 0.05. Thus, it can be concluded that the sample represents a normally distributed population

Homogeneity Test

The homogeneity test of the variance-covariance matrix using Box's M test statistics resulted in a sig value of $0.787 > 0.05$, which indicated that the data variance was homogeneous and the research samples were taken from a homogeneously distributed population. In addition, a univariate homogeneity test was conducted with Levene's Test statistics. This test was conducted on both dependent variables, namely problem-solving skills and critical thinking skills. The results of Levene's Test statistics are as follows: (1) In critical thinking skills, the sig value is $0.579 > 0.05$, so it can be concluded that the sample on critical thinking skills comes from a homogeneous population; (2) On problem-solving skills, the sig value is $0.602 > 0.05$, so it can be concluded that the sample of problem-solving skills comes from a homogeneous population.

Multivariate Analysis of Variance Test

The learning model's multivariate analysis of variance test (Wilks' Lambda test) yielded a

significant value of $0.000 < 0.05$. This demonstrates that the Make a Match cooperative learning model, aided by puzzle media and Problem-Based Learning, significantly affects students' critical thinking and mathematical problem-solving abilities, so a two-way univariate analysis of variance test on these aspects was conducted.

The Effect of Learning Models on Critical Thinking and Problem-Solving Skills.

The multivariate analysis showed a Wilks' Lambda value of 0.612, with an F-value of 18.068 and a significance level of $0.000 < 0.05$. This indicates that implementing the learning model significantly affects students' critical thinking and problem-solving skills.

Critical thinking skill achievement in the make a match assisted by puzzle media and the problem-based learning model

Based on the results of the Test of Between-Subjects Effects, the sig. value of $0.000 < 0.05$; therefore, there is a significant effect of the make-a-match learning model assisted by puzzle media and problem-based learning on critical thinking skills. The following diagram shows the differences in the effects of the learning models.

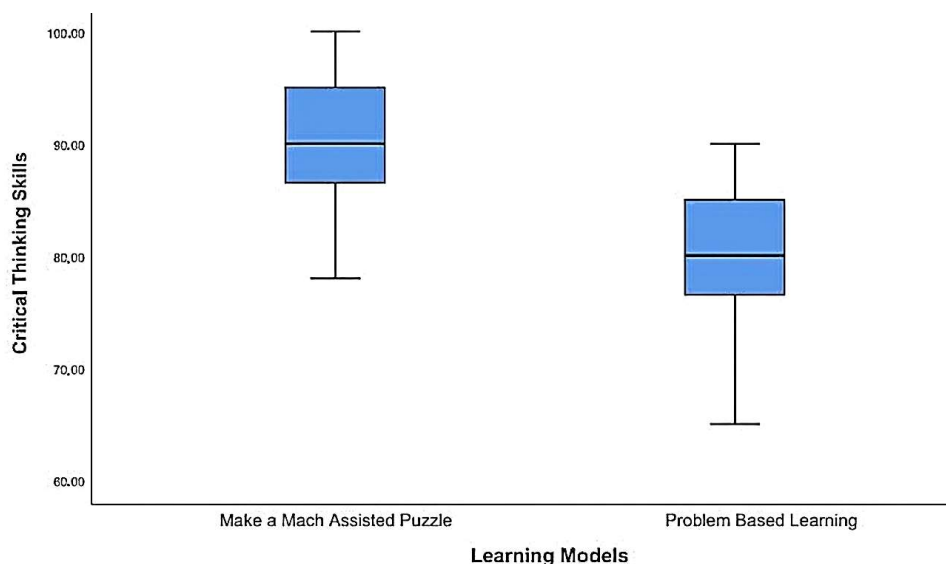


Figure 1. Distribution of critical thinking skill scores based on learning models

Figure 1 shows that the make-a-match model assisted by puzzle media resulted in better critical thinking skills (median = 90; Q1 = 86.5; Q3 = 95) than the problem-based learning model (median = 80; Q1 = 76.5; Q3 = 85). Regarding data dispersion, the interquartile range (IQR) for the make-a-match assisted by puzzle media and the problem-based learning model is the same, namely 8.5. This indicates that the data distribution for the middle 50% of students in both learning models is almost identical. However, the overall spread of data in the problem-based learning model is wider due to a low outlier value (score of 65). This indicates that problem-based learning models do not yet fully accommodate students with low initial critical thinking skills. Critical thinking requires high-level cognitive processes to analyze information and generate solutions to problems. Without concrete aids that can transform abstract mathematical concepts into understandable forms, students with low initial critical thinking skills are likely to face difficulties.

According to the diagram above, using the make a match learning model with puzzle media to acquire Pythagoras content results in greater critical thinking skills than the Problem-Based Learning model. These findings are consistent with research by Ratnasari & Indarini (2023), who found that the make a match type learning model, aided by concrete media, can improve students' critical thinking skills and learning outcomes. This is due to the use of concrete teaching aids, which have a significant positive impact on mathematics learning outcomes because concrete materials help students build conceptual understanding through direct experience, thereby supporting reasoning and enhancing critical thinking skills (Carbonneau et al., 2013).

This is because, when using the Make a Match cooperative learning model with puzzles as a moderator, students collaborate in a card-matching game. Collaboration among students enhances reasoning, problem-solving, and critical

thinking through positive interdependence (Johnson & Johnson, 2009). This game trains students to answer questions quickly while also honing their critical and creative thinking skills when facing problems. Matching questions and answers requires students to understand the concepts underlying the questions, rather than simply memorizing them. This helps students develop analytical and synthetic skills, which are essential for critical thinking. Collaboration during the card game allows students to communicate, interact, and exchange ideas, thereby deepening their understanding of mathematical topics. Using puzzles makes learning more engaging and enjoyable, encouraging active student participation in the learning process. This active engagement influences students' dedication and interest in solving the problems presented by the teacher. Furthermore, according to evolutionary-based cognitive load theory, the Pythagoras theorem constitutes secondary biological knowledge that naturally places a burden on students' working memory. When using puzzle media, students use their motor systems and spatial coordination through the physical manipulation of puzzle pieces. Engaging motor systems and spatial coordination involves primary biological knowledge, which shifts cognitive load. Consequently, manipulating concrete objects helps students grasp the abstract concepts of the Pythagoras theorem without causing cognitive overload (Paas & Sweller, 2011). Puzzle-based activities can be developed with various relevant problem scenarios to help students connect their learning to real-world situations, thereby increasing the relevance and students' understanding of the learning material (Plass et al., 2015).

Meanwhile, although PBL encourages students to develop reasoning, problem-solving, critical thinking, and independent learning (Hmelo & Silver, 2004), students still struggle to understand contextual problems, which serve as

the foundation for building mathematical concepts. Contextual problems are often complex, so students have difficulty identifying key information, understanding the situation, and selecting solution strategies (Jonassen, 2011). Problem-based learning in the classroom uses group discussion methods; however, during these discussions, students tend to focus too much on finding the final solution and pay less attention to the thinking process and analysis (Kirschner et al., 2006). Furthermore, the quality of group interaction, communication, and member participation is crucial to learning success (Gillies, 2016), so differences in collaborative skills among group members affect problem-solving ability. Problem-Based Learning requires a high degree of independence from students. For some students,

implementing Problem-Based Learning may create uncertainty when working on assignments, thereby hindering the development of critical thinking skills.

Problem-solving skill achievement in the make a match assisted by puzzle media and the problem-based learning model

Based on the results of the Test of Between-Subjects Effects, the significance is as follows: A value of $0.000 < 0.05$ indicates that the cooperative learning model of the Make a Match type assisted by puzzle media and the Problem-Based Learning model has a significant effect on problem-solving skills. The diagram below depicts the differences in the influence of the learning models.

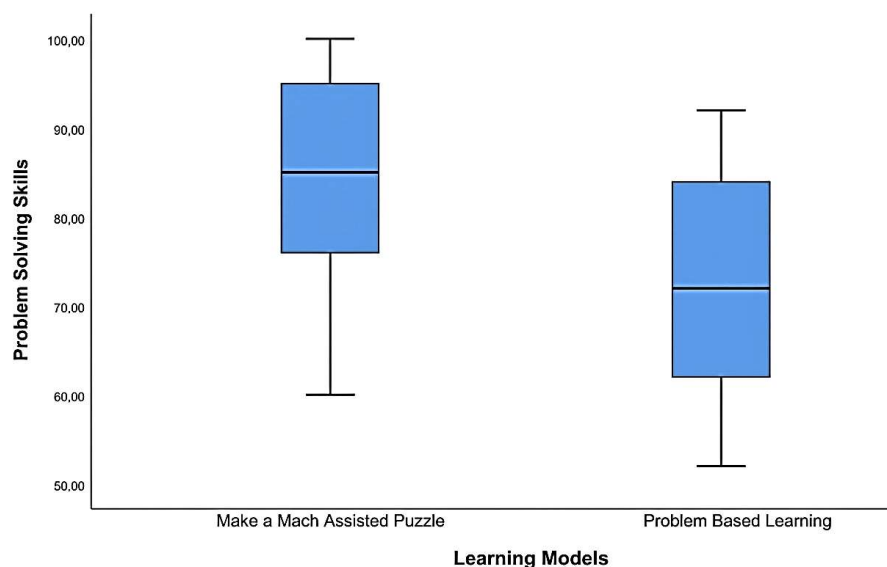


Figure 2. Distribution of problem-solving skill scores based on learning models

Figure 2 shows that the make a match learning model assisted by puzzle media yields better problem-solving skills than the problem-based learning model. This is evident from the median problem-solving skills score, which was 85 for the make a match learning model assisted by puzzle media, whilst it was 72 for the problem-based learning model. Fifty per cent of the data for the make a match learning model assisted by

puzzle media fell within the range of 76–95, whilst for the problem-based learning model, the range was 62–84. Regarding the data distribution, the interquartile range (IQR) for the make a match learning model assisted by puzzle media was 19, narrower than that of the problem-based learning model, which had an IQR of 22. This indicates that score variation is relatively greater in the problem-based learning model. The presence of

an outlier in the make a match learning model assisted by puzzle media, with a score of 60, indicates that some students have problem-solving skills significantly lower than those of most students in that group. These descriptive findings are consistent with the results of statistical tests, which indicate a significant difference in problem-solving skills between the make a match learning model assisted by puzzle media and problem-based learning.

From the diagram above, it appears that applying the make a match learning model assisted by puzzle media in learning Pythagoras material produces better mathematical problem-solving skills than the problem-based learning model. The make-a-match cooperative learning model helps students develop social and communication skills. These skills are important in the problem-solving process, especially when discussing various strategies. Group discussions improve the quality of reasoning, enhance problem-solving abilities, and help students build knowledge by explaining concepts to their groupmates (Gillies & Khan, 2009). Group discussions encourage active interaction among students, helping them exchange ideas and strategies, which in turn strengthens their understanding of mathematical concepts. Cooperative learning encourages meaningful discussion, improves the quality of reasoning, helps students explain their problem-solving strategies, deepens conceptual understanding, and enhances higher-order thinking (Gillies, 2016).

In the Make a Match learning model, students play a card-matching activity in pairs. Matching questions and answers while playing cards in pairs provides a clearer structure. Students can easily understand the steps needed to solve problems. In this activity, students can immediately tell whether their answers are correct. This rapid feedback allows students to quickly identify and correct their mistakes, accelerate

strategy refinement, improve learning outcomes, and strengthen problem-solving skills (Zhang & Fiorella, 2024). In addition, puzzles can be designed with different types of mathematical problems, providing students with diverse and relevant learning experiences. Puzzles can help students apply concepts in real situations. Using puzzle media in this learning model makes learning more interesting and interactive. This active involvement increases motivation and helps students stay focused during the problem-solving process.

In implementing instruction, although the make-a-match activity assisted by puzzles as a teaching aid and the problem-based learning class were allotted the same amount of time, the problem-based learning framework required more time during the phase of guiding individual and group investigations. During this phase, students gathered information and data and then conducted investigations to find solutions to the problems. Students cannot fully develop problem-solving skills in a time-constrained environment. Problem-based learning requires cognitive scaffolding so that students can interpret problems and develop effective strategies to solve them (Jonassen, 2011). Without clear guidance, students feel confused. This can make it even more difficult for them to tackle challenges with confidence. Group learning is integrated into problem-based learning designs. More dominant students often lead discussions in these group activities, which reduces the involvement of other students who may also be capable of solving problems. This affects how students receive training to improve their problem-solving skills (Wiggins et al., 2016).

The Effect of Self-Efficacy on Critical Thinking and Problem-Solving Skills

Regarding self-efficacy level, the multivariate analysis results show a Wilks'

Lambda value of 0.576, an F-value of 9.042, and a significance value of 0.000 ($p < 0.05$). This indicates that students' self-efficacy levels significantly influence their critical thinking and problem-solving skills.

Critical thinking skill achievement based on self-efficacy levels

The following data show the marginal mean of critical thinking skills among students with high, moderate, and low self-efficacy.

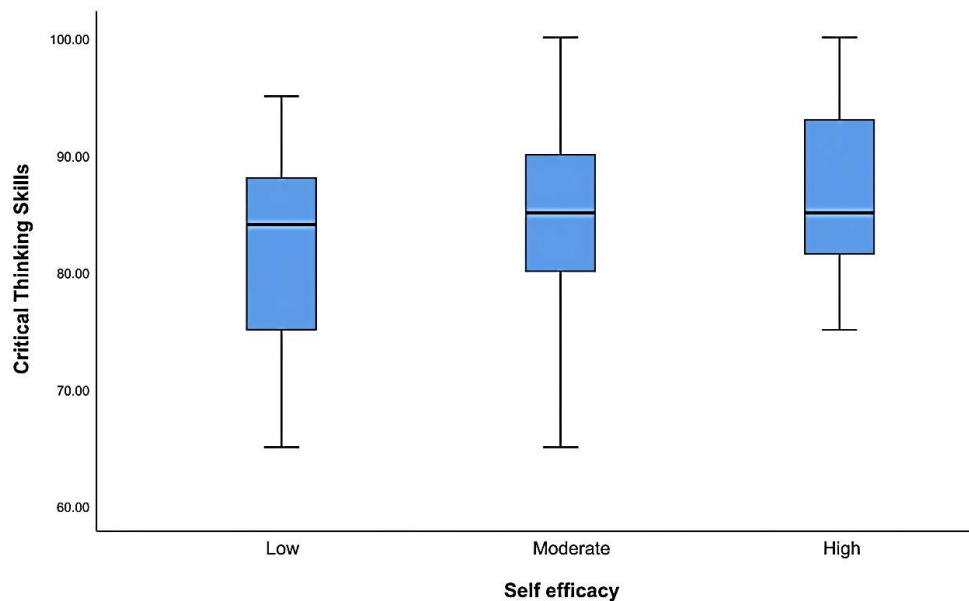


Figure 3. Distribution of critical thinking skill scores based on self-efficacy

Based on the diagram above, although the average marginal critical thinking ability in the low self-efficacy group < moderate self-efficacy group < high self-efficacy group, the results of the Between-Subjects Effects Test showed a significance value of $0.096 > 0.05$; therefore, it can be concluded that there is no significant effect of self-efficacy level on students' critical thinking ability.

This finding is consistent with the boxplot in Figure 3, which displays the distribution of students' critical thinking skills across the high, moderate, and low self-efficacy groups. The high self-efficacy group showed a median of 85, Q_1 of 81.5, and Q_3 of 93; the moderate self-efficacy group showed a median of 85, Q_1 of 80, and Q_3 of 90; and the low self-efficacy group showed a median of 84, Q_1 of 75, and Q_3 of 88. Descriptively, the IQR values for the high self-efficacy group (11.5), the moderate self-efficacy

group (10), and the low self-efficacy group (13) are relatively close, indicating that the middle 50% of the data across the three groups is similar.

This study found that self-efficacy is not significantly associated with critical thinking skills. This finding differs from several previous studies that showed a positive relationship between self-efficacy and critical thinking skills. For example, Tasgin & Dilek (2023) found that high school students' self-efficacy levels significantly predicted their tendency to think critically in a positive and meaningful way. This means that the higher a student's self-efficacy, the greater their tendency to think critically. However, some findings are consistent with this study, such as research by Talsma et al. (2019), which found that high self-efficacy is not always accompanied by high academic achievement because a person's belief in their abilities may differ from their actual abilities. Many students exhibit a discrepancy

between what they believe they can do and their objective performance outcomes. Students with low achievement tend to overestimate their abilities (over-efficacious), while students with high achievement tend to underestimate their own abilities (under-efficacious). Thus, high self-confidence without an accurate assessment of one's actual abilities can actually hinder cognitive performance by fostering a false sense of confidence (Talsma et al., 2019).

Problem-solving skill achievement based on self-efficacy levels

Based on the results of the Test of Between-Subjects Effects, the significance value of

$0.000 < 0.05$ can be concluded that there is a significant effect of students' self-efficacy level on students' mathematical problem-solving ability. This means that the students' math problem-solving skills are influenced by their self-efficacy.

Further Bonferroni tests showed that, in terms of mathematical problem-solving ability, the low self-efficacy group differed significantly from the Moderate group ($p = 0.000 < 0.05$) and the high group ($p = 0.000 < 0.05$). Conversely, there was no significant difference between the Moderate and high self-efficacy groups ($p = 0.088 > 0.05$).

Figure 4 shows a fairly varied distribution of students' problem-solving skills based on their

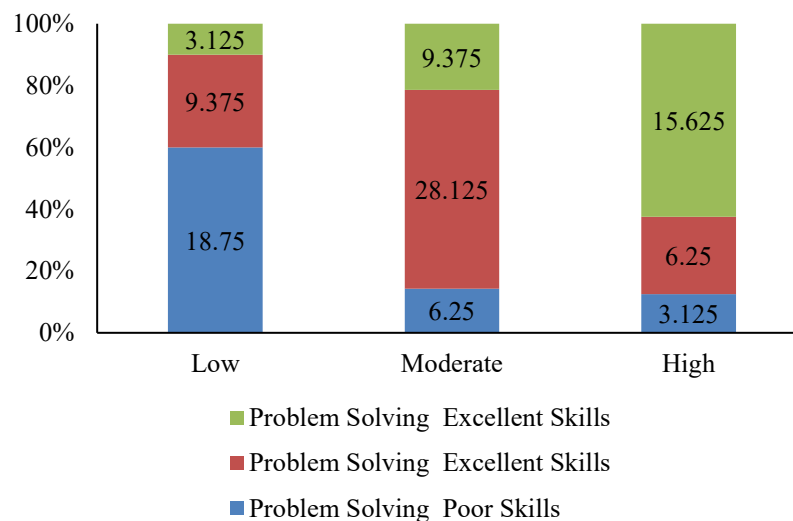


Figure 4. Distribution of problem-solving skills scores based on self-efficacy

self-efficacy. In the group of students with moderate self-efficacy, most had moderate problem-solving skills (28.125 percent). However, as many as 9.37% possessed excellent problem-solving skills. A similar pattern was also observed in the high self-efficacy group. However, 15.625% achieved excellent problem-solving skills; some students still had moderate problem-solving skills (6.25%) and poor problem-solving skills (3.125%).

This frequency distribution clarifies the findings of the statistical test, which showed no significant difference between moderate and high

levels of self-efficacy in relation to problem-solving ability. This suggests that students in both categories are likely to exhibit relatively similar levels of perseverance and effort in managing their learning. Consequently, an increase in self-efficacy from a moderate to a high level may not result in a substantial improvement in overall performance in mathematical problem-solving. This aligns with research findings indicating a moderate positive correlation between self-efficacy and mathematical ability ($r = 0.553$). This means that while self-efficacy is related to mathematical ability, the relationship is not perfect; therefore,

an increase in self-efficacy does not automatically lead to a proportional increase in ability (Suparman & Juandi, 2022). In line with social cognitive theory, students with adequate levels of self-efficacy, whether moderate or high, are equally likely to be prepared to participate and persevere when faced with complex mathematical problems, thereby achieving comparable performance (Panjares & Kranzler, 1995). Furthermore, self-efficacy improves students' performance by boosting their perseverance, effort, and self-confidence when tackling challenging tasks. Students with high self-efficacy participate with greater enthusiasm, work harder, persevere for longer, and experience fewer negative emotional reactions when faced with difficulties (Zimmerman, 2000).

Interaction between Learning Models and Self-Efficacy regarding Critical Thinking Skills and Problem-Solving Skills

In the interaction between the learning model and self-efficacy, the multivariate analysis of variance results show a Wilks' Lambda value of 0.986, an F-value of 0.156, and a significance value of $0.960 > 0.05$. This shows no interaction between the learning model and self-efficacy on students' critical thinking ability and problem-solving skills. This means that students' self-efficacy level does not affect the relationship between learning models and critical thinking skills and problem-solving skills. In other words, self-efficacy level does not change the effect of the learning model on students' critical thinking skills and problem-solving skills. This is shown in the following line diagram.

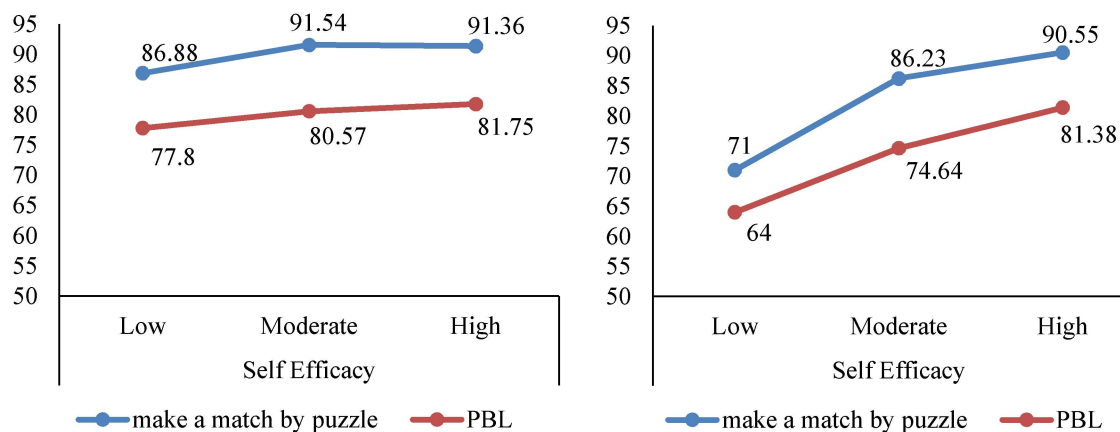


Figure 5. Comparison of marginal means of critical thinking skills and problem-solving skills between the two learning models at each level of self-efficacy

The absence of a significant interaction between the instructional model and the level of self-efficacy indicates that the effectiveness of the instructional model applied does not differ significantly among students with low, moderate, and high levels of self-efficacy. Thus, in this study, students' self-efficacy was not found to alter or influence the effectiveness of the instructional model in improving students' critical thinking and problem-solving skills. This finding is consistent

with previous research, which also showed no interaction between the learning model and self-efficacy. However, the learning model and self-efficacy can each contribute to student learning outcomes (Scholts & Agus Setyaningrum, 2026).

The absence of an interaction between self-efficacy and learning models related to students' critical thinking and problem-solving skills is linked to activities in instructional design, specifically implementing problem-based learning

models and integrating the make-a-match model with highly structured puzzle-based media. Each activity in implementing these learning models requires active student engagement. Problem-based learning trains students to identify, analyze, and solve complex problems under teacher guidance (Barrows, 1986). Furthermore, problem-based learning encourages students to construct knowledge through active inquiry, discussion, and reflection, thereby fostering deep learning (Dolmans et al., 2016). Because implementing the problem-based learning model involves cognitive processes through group discussions and problem analysis, students are systematically guided to engage in deep processing without relying entirely on their self-efficacy (Loyens et al., 2015).

Meanwhile, the make a match learning model, which uses puzzle media, provides a clear structure for understanding and applying concepts through a card-matching game. This may help reduce the impact of variability in students' self-efficacy on their critical thinking and problem-solving abilities. In addition, this study does not consider other factors, such as each student's cognitive abilities and learning experiences, which are likely to influence the interaction between the learning model and self-efficacy (Fauth et al., 2019). Success in critical thinking and mathematical problem-solving is influenced not only by students' self-efficacy but also by prior knowledge, cognitive abilities, learning experiences, and the design of learning tasks. Therefore, self-efficacy may emerge as an independent factor not influenced by the instructional model or learning outcomes (Jonassen, 2011).

■ CONCLUSION

The implementation of the Make a Match learning model, supported by puzzle media, proved more effective than the problem-based learning model in improving students' critical

thinking and problem-solving skills regarding the Pythagoras theorem. Furthermore, although students' self-efficacy levels did not influence their critical thinking skills, students with moderate to high self-efficacy demonstrated better problem-solving skills. No interaction was found between the learning model and self-efficacy in influencing students' critical thinking and problem-solving skills. Based on these findings, it is highly recommended that mathematics educators implement the make a match learning model assisted by puzzle media as an interactive learning strategy in the classroom. Furthermore, teachers and curriculum designers are advised to actively design learning activities that build students' self-efficacy to optimize their problem-solving abilities.

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■ STATEMENT REGARDING GENERATIVE AI AND AI-ASSISTED TECHNOLOGY

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) as an AI-based tool to refine language, improve grammatical accuracy, enhance clarity and readability, and assist in structuring specific sections of the manuscript. The AI tool was not used to generate, manipulate, or analyze research data, nor to determine the study's results or conclusions. All AI-assisted content has been carefully reviewed, verified, and revised by the author. The author bears full responsibility for the accuracy, originality, integrity, and final content of the published article.

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