Journal of Advanced Sciences and Mathematics Education

Volume 6, Issue 3, 326-350.
e_ISSN: 2798-1606
DOI: 10.58524/jasme.v6i3.1480

Comparative predictive roles of mathematical self-efficacy and learning motivation on students' critical thinking skills: Evidence from structural equation modeling

Nanang Khuzaini*
Universitas Mercu Buana, INDONESIA

Nuryadi
Universitas Mercu Buana, INDONESIA

Muhammad Irfan Rumasoreng
Universitas Mercu Buana, INDONESIA

Muhammad Farid Nasrulloh
Universitas Wahab Hasbulloh, INDONESIA

Arie Purwanto
Universitas Mercu Buana, INDONESIA

Article Info

Article history:

Received: May 10, 2026
Revised: June 25, 2026
Accepted: Augst 01, 2026

Keywords:

Critical Thinking; Learning Motivation; Mathematical Self-Efficacy; Secondary Mathematics Education; Structural Equation Modeling.

Abstract

Background: Critical thinking is a key competency in mathematics education that enables students to analyze information, justify reasoning, and solve problems effectively. Although learning motivation and mathematical self-efficacy are widely recognized as important affective factors, their comparative contributions to students' critical thinking remain unclear.

Aims: This study aimed to compare the predictive roles of learning motivation and mathematical self-efficacy in explaining students' critical thinking skills in solving Pythagorean theorem problems.

Method: A quantitative cross-sectional correlational design was employed involving 34 eighth-grade students selected through simple random sampling. Data were collected using an ARCS-based learning motivation questionnaire, a mathematical self-efficacy questionnaire, and an Ennis-based critical thinking test. Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM) with LISREL 8.80 were used to evaluate the proposed model.

Results: The measurement model demonstrated satisfactory validity and reliability (KMO = 0.892; factor loadings ≥ 0.50). The refined structural model achieved acceptable fit (NNFI = 0.97, CFI = 0.98, NFI = 0.96, RFI = 0.94, RMSEA = 0.093). Mathematical self-efficacy positively predicted critical thinking (t = 4.40), whereas learning motivation showed a significant negative association (t = −2.26).

Conclusion: Mathematical self-efficacy was a stronger predictor of critical thinking than learning motivation, indicating that students' confidence in performing mathematical tasks is more closely associated with higher-order reasoning. Given the limited sample size, these findings should be interpreted as preliminary evidence requiring further validation.

To cite this article: Khuzaini, N., Nuryadi., Rumasoreng, M. I., Nasrulloh, M. F. & Purwanto, A. (2026). Comparative predictive roles of mathematical self-efficacy and learning motivation on students' critical thinking skills: Evidence from structural equation modeling. *Journal of Advanced Sciences and Mathematics Education, 6*(3), 326-350.

INTRODUCTION

Critical thinking has become one of the most essential competencies in mathematics education because students are expected not only to obtain correct answers but also to analyse information, justify solution strategies, evaluate arguments, and draw logically defensible conclusions. Mathematical critical thinking is particularly important when students encounter non-routine problems that cannot be solved through memorised procedures alone (Agusman et al., 2025; Kholid et al., 2024; Kurniawan et al., 2022; Rahmatin et al., 2025). Such problems require students to understand problem situations, identify relevant mathematical information, establish conceptual relationships, compare alternative solution strategies, and evaluate the validity of their reasoning

***Corresponding author:**
Nanang Khuzaini, Universitas Mercu Buana, Indonesia
nanang@mercubuana-yogya.ac.id

before drawing conclusions. These cognitive processes enable students to construct meaningful mathematical understanding rather than merely applying memorised algorithms. Consequently, critical thinking has become an important learning outcome that supports mathematical reasoning, problem solving, and decision making across diverse mathematical contexts (Sachdeva & Eggen, 2021; Shanta & Wells, 2022; Szabo et al., 2020). Despite its recognised importance, many secondary school students continue to experience difficulties in analysing mathematical problems and explaining the rationale underlying their solutions. Students frequently rely on procedural approaches without adequately evaluating whether their chosen strategies are logically appropriate or mathematically justified. Such tendencies indicate that students often demonstrate procedural proficiency while lacking deeper conceptual and analytical reasoning. As a result, improving students' critical thinking remains one of the major challenges confronting contemporary mathematics education. Therefore, identifying the factors that contribute to students' critical thinking has become an increasingly important concern for mathematics education researchers and practitioners.

The development of students' critical thinking is influenced not only by cognitive competence but also by affective factors that shape how students approach challenging mathematical tasks. Among the affective variables most frequently associated with mathematics learning are learning motivation and mathematical self-efficacy. Learning motivation encourages students to participate actively in classroom activities, maintain persistence during learning, and direct their efforts toward achieving academic goals. Students with higher learning motivation are generally expected to devote greater attention, demonstrate stronger perseverance, and willingly engage with difficult mathematical problems. Such behavioural characteristics are theoretically assumed to facilitate deeper cognitive engagement during mathematical reasoning and problem-solving activities (Chiu et al., 2022; Lyu et al., 2025; Shwartz & Fuchs, 2025; Zou et al., 2025). Nevertheless, empirical findings concerning the relationship between learning motivation and mathematical thinking remain inconsistent across different educational settings. That academic self-motivation demonstrated limited or no significant relationship with secondary school students' mathematical thinking (Alotaibi, 2020). These findings suggest that students' willingness to learn does not necessarily translate into stronger analytical reasoning or higher levels of critical thinking when solving mathematical problems. Consequently, learning motivation may function as an important prerequisite for learning engagement without directly determining students' critical thinking performance. This inconsistency indicates that additional psychological factors should be considered to explain variations in students' mathematical critical thinking.

One psychological factor that has consistently demonstrated a close relationship with mathematical performance is mathematical self-efficacy, which refers to students' beliefs about their capability to successfully perform mathematical tasks (Chan et al., 2022; Pajares & Miller, 1995; Yuliyanto et al., 2021; Zakariya, 2022). Unlike learning motivation, which primarily reflects students' willingness to engage in learning activities, mathematical self-efficacy concerns students' confidence in organising and executing the actions required to solve mathematical problems successfully. Students possessing strong mathematical self-efficacy are generally more willing to attempt challenging tasks, persist after experiencing difficulties, test alternative solution strategies, and interpret mistakes as valuable learning experiences rather than as failures. Conversely, students with low mathematical self-efficacy tend to avoid complex problems, rely heavily on routine procedures, and terminate problem-solving efforts prematurely. Recent studies have also demonstrated that mathematical self-efficacy varies considerably across educational levels and student characteristics, highlighting the importance of strengthening students' confidence in mathematics learning (Paudel & Ghimire, 2024). Previous empirical studies further reported that mathematical self-efficacy contributes significantly to students' mathematical critical thinking and interacts with instructional approaches implemented in mathematics classrooms (Yulianto et al., 2024). Similarly, found a strong positive relationship between mathematical self-efficacy and students' critical thinking in solving Pythagorean theorem problems (Marlena & Nugraheni, 2026). Collectively, these findings indicate that mathematical self-efficacy functions as an important psychological foundation supporting students' engagement in higher-order mathematical reasoning. However, most previous studies have examined mathematical self-efficacy independently or within particular instructional interventions rather than comparing its predictive contribution with other affective variables within a unified structural model. Therefore, further investigation is required to clarify the comparative role of mathematical self-efficacy relative to learning motivation in explaining students' critical thinking skills.

Several important research gaps remain in the existing literature regarding the relationships among learning motivation, mathematical self-efficacy, and students' critical thinking in mathematics education. First, previous studies have predominantly examined learning motivation and mathematical self-efficacy as independent predictors of mathematical learning outcomes rather than comparing their unique contributions within a unified analytical framework. Studies investigating learning motivation have primarily focused on its relationship with mathematical thinking without simultaneously considering mathematical self-efficacy as a competing predictor, whereas research on mathematical self-efficacy has generally examined its contribution to critical thinking under different instructional contexts without directly comparing its predictive strength with learning motivation (Alotaibi, 2020; Marlena & Nugraheni, 2026; Yulianto et al., 2024). Consequently, existing evidence has not adequately determined whether either construct retains a significant unique contribution after the shared variance between learning motivation and mathematical self-efficacy is statistically controlled. Second, studies that have simultaneously examined learning motivation and mathematical self-efficacy have mainly investigated how instructional interventions improve both constructs rather than evaluating their relative predictive effects on students' critical thinking. More recent theoretical perspectives also suggest that learning motivation functions as an upstream motivational factor, whereas mathematical self-efficacy represents a more proximal determinant of cognitive engagement and mathematical problem solving; however, this proposition has rarely been empirically examined using Structural Equation Modeling (SEM) to explain students' critical thinking (Dai et al., 2025; Ismail et al., 2026; Robinson, 2023). Third, previous studies generally assume that higher learning motivation naturally leads to stronger higher-order thinking while giving limited attention to the possibility that the magnitude or even the direction of its contribution may change after mathematical self-efficacy is incorporated into the same structural model. Fourth, research specifically investigating students' critical thinking in solving Pythagorean theorem problems remains relatively limited, despite the fact that such problems require students to interpret mathematical information, identify conceptual relationships, justify solution strategies, evaluate evidence, and formulate logically defensible conclusions. Moreover, no previous study has explicitly compared the relative predictive contributions of learning motivation and mathematical self-efficacy toward critical thinking within a single structural model, leaving the comparative mechanism underlying these affective factors insufficiently understood. Therefore, this study addresses these theoretical and empirical gaps by simultaneously estimating and comparing the predictive contributions of learning motivation and mathematical self-efficacy to students' critical thinking skills using Structural Equation Modeling, thereby providing a more comprehensive explanation of how these affective constructs influence higher-order mathematical thinking.

Based on the identified research gaps, this study aims to compare the predictive contributions of learning motivation and mathematical self-efficacy to students' critical thinking skills in solving Pythagorean theorem problems using Structural Equation Modeling (SEM). Specifically, the study examines whether learning motivation significantly predicts students' critical thinking skills in mathematics. The study also investigates whether mathematical self-efficacy significantly predicts students' critical thinking skills when solving mathematical problems. Furthermore, the study compares the relative predictive strength of learning motivation and mathematical self-efficacy when both constructs are simultaneously estimated within a single structural model. Unlike previous studies that have primarily investigated these variables independently, this study adopts a comparative structural perspective to determine which affective construct provides the stronger direct contribution to students' critical thinking. This comparative approach is expected to provide a deeper understanding of the distinct psychological roles of students' willingness to learn and their confidence in performing mathematical tasks. From a theoretical perspective, the findings are expected to enrich the literature on affective factors influencing higher-order thinking by clarifying the comparative mechanism through which learning motivation and mathematical self-efficacy contribute to critical thinking in mathematics education. From a methodological perspective, the application of Structural Equation Modeling enables the simultaneous estimation of relationships among multiple latent constructs, thereby providing a more comprehensive analytical framework than conventional correlational analyses. From a practical perspective, the findings are expected to provide empirical evidence that can assist mathematics teachers in designing instructional strategies that not only enhance students' motivation to learn but also strengthen their confidence in solving complex mathematical problems. Ultimately, this study seeks to contribute to the development of evidence-based mathematics instruction that effectively promotes students' critical thinking and supports the achievement of higher-order learning outcomes in secondary mathematics education.

LITERATURE REVIEW

Critical thinking is widely recognized as one of the fundamental competencies required in mathematics education because it enables students to analyze information systematically, evaluate evidence, justify mathematical reasoning, and formulate logical conclusions when solving problems. Rather than focusing solely on obtaining correct answers, critical thinking emphasizes the quality of reasoning that underlies mathematical decision-making and problem-solving processes. In mathematics learning, critical thinking becomes particularly important when students encounter non-routine problems that require conceptual understanding, strategic planning, and reflective evaluation instead of the direct application of memorized procedures. Students with well-developed critical thinking skills are generally able to identify relevant information (Dulun & Lane, 2023; Li et al., 2020; Okolie et al., 2022; Zlatkin-Troitschanskaia et al., 2020), distinguish assumptions from evidence, compare alternative solution strategies, and evaluate the validity of their conclusions before making mathematical judgments. These cognitive processes promote meaningful learning because students actively construct mathematical knowledge through reasoning rather than passive knowledge acquisition. Conceptualizes critical thinking as reasonable and reflective thinking directed toward deciding what to believe or do, and proposes several dimensions, including elementary clarification, basis for decision, inference, advanced clarification, and strategy and reflection. These dimensions have been widely adopted in mathematics education research because they comprehensively represent students' analytical, evaluative, and reflective reasoning during mathematical problem solving. Previous empirical studies consistently demonstrate that students with stronger critical thinking skills achieve better mathematical problem-solving performance, conceptual understanding, and reasoning ability than those with lower critical thinking skills (Agusman et al., 2025; Kholid et al., 2024; Kurniawan et al., 2022; Rahmatin et al., 2025). Consequently, developing students' critical thinking has become one of the primary objectives of contemporary mathematics education and an important indicator of successful mathematics instruction. Therefore, understanding the psychological factors that facilitate the development of mathematical critical thinking remains an important area of investigation for mathematics education researchers.

Learning motivation represents one of the most influential affective factors shaping students' engagement, persistence, and achievement during mathematics learning. Motivation explains why students are willing to initiate learning activities, sustain effort when encountering difficulties, and continue pursuing academic goals despite experiencing challenges. Motivational model conceptualizes learning motivation as consisting of four interrelated dimensions, namely attention, relevance, confidence, and satisfaction, which collectively influence students' willingness to participate actively in learning activities. The attention dimension emphasizes students' ability to maintain interest throughout learning, whereas relevance concerns the perceived usefulness and meaningfulness of learning activities for achieving personal goals. Confidence reflects students' expectations of successfully completing learning tasks, while satisfaction represents the positive feelings that arise after accomplishing learning objectives. Within mathematics education, motivated students generally demonstrate greater classroom participation, invest more cognitive effort, employ more effective learning strategies, and persist longer when solving complex mathematical problems (Granello et al., 2026; Kitsantas et al., 2021; Lugosi & Uribe, 2022; Supriadi et al., 2024; Zuo et al., 2024). Such behavioral characteristics are theoretically expected to promote deeper cognitive processing and ultimately improve higher-order thinking skills, including mathematical critical thinking. Nevertheless, empirical evidence regarding the relationship between learning motivation and mathematical critical thinking remains inconsistent across different educational contexts. Some studies report that learning motivation positively predicts mathematical reasoning and academic achievement, whereas other findings suggest that motivation alone is insufficient to explain students' mathematical thinking after other psychological variables are considered (Alotaibi, 2020). These inconsistencies indicate that learning motivation should be examined together with other affective constructs to obtain a more comprehensive explanation of students' critical thinking performance in mathematics.

Mathematical self-efficacy represents students' beliefs about their capability to organize and execute the actions required to successfully complete mathematical tasks and solve mathematical problems. According to Social Cognitive Theory, self-efficacy influences how individuals think, feel, behave, and persist when confronted with challenging situations because confidence in one's capability determines the amount of effort and perseverance invested in task completion (Kitsantas et al., 2021; Meng & Zhang, 2023; Namono et al., 2024; Schunk & DiBenedetto, 2021). In mathematics education, mathematical self-efficacy extends beyond general academic confidence by specifically reflecting students' beliefs regarding their competence in understanding mathematical concepts, applying mathematical procedures, and solving unfamiliar mathematical problems. Bandura conceptualized self-efficacy through three dimensions, namely level, strength, and generality, which describe individuals' confidence across varying task difficulties, the intensity of their confidence, and the transferability of their confidence across different situations. Students possessing high mathematical self-efficacy are generally more willing to attempt challenging problems, sustain their effort despite repeated failures, regulate their learning strategies, and interpret mistakes as opportunities for improvement rather than indicators of inability. Conversely, students with low mathematical self-efficacy often avoid cognitively demanding tasks, experience greater mathematics anxiety, and rely on routine procedures without exploring alternative solution strategies. Numerous empirical studies have consistently reported that mathematical self-efficacy positively predicts mathematics achievement, conceptual understanding, mathematical reasoning, and problem-solving performance across different educational levels (Chan et al., 2022; Paudel & Ghimire, 2024; Yuliyanto et al., 2021; Zakariya, 2022). Recent evidence also indicates that mathematical self-efficacy contributes significantly to students' mathematical critical thinking because confident learners are more likely to engage in analytical reasoning, evaluate evidence critically, and justify their mathematical decisions when solving complex problems (Marlena & Nugraheni, 2026; Yulianto et al., 2024). These findings suggest that mathematical self-efficacy functions as a proximal psychological mechanism linking students' beliefs about their mathematical capability with their ability to perform higher-order cognitive processes during mathematical learning. Therefore, mathematical self-efficacy has become one of the most influential affective constructs for explaining individual differences in students' mathematical critical thinking and higher-order reasoning.

Learning motivation and mathematical self-efficacy are conceptually related because both influence students' engagement and persistence during mathematics learning, yet they represent different psychological mechanisms underlying learning behavior. Learning motivation primarily explains why students are willing to participate in learning activities, whereas mathematical self-efficacy determines whether students believe they possess the capability to successfully complete mathematical tasks and overcome learning difficulties (Abdulla & Ibrahim, 2023; Peng & Fu, 2021; Raes et al., 2020; Zhu et al., 2020). Social Cognitive Theory proposes that self-efficacy functions as a more proximal determinant of cognitive performance because students' confidence directly influences their strategic thinking, self-regulation, persistence, and decision-making during problem solving. In contrast, learning motivation serves as an antecedent that encourages students to initiate learning activities but does not necessarily ensure successful cognitive performance when students lack confidence in their mathematical abilities. Previous studies have generally reported positive associations between learning motivation, mathematical self-efficacy, and mathematics achievement, although the relative contribution of each construct to critical thinking remains inconclusive (Alotaibi, 2020; Marlena & Nugraheni, 2026; Yulianto et al., 2024). Several intervention studies further demonstrated that instructional approaches designed to improve motivation often simultaneously strengthen students' mathematical self-efficacy, indicating substantial conceptual overlap between these affective constructs. Nevertheless, the majority of existing studies have focused on examining the independent effects of motivation or self-efficacy rather than comparing their predictive contributions within a single structural model. Consequently, it remains unclear whether learning motivation continues to exert a meaningful influence on students' critical thinking after the contribution of mathematical self-efficacy has been statistically controlled. Addressing this issue is important because distinguishing the relative roles of these two affective constructs may provide a more accurate theoretical explanation of how students develop higher-order mathematical thinking. Accordingly, the present study employs Structural Equation Modeling (SEM) to simultaneously estimate and compare the predictive contributions of learning motivation and mathematical self-efficacy toward students' critical thinking, thereby providing a stronger theoretical foundation for improving mathematics instruction and fostering higher-order thinking skills.

METHOD

Research Design

This study employed a quantitative cross-sectional correlational design to investigate the relationships among learning motivation, mathematical self-efficacy, and students' critical thinking skills in mathematics. The study aimed to examine the direct effects of learning motivation and mathematical self-efficacy on students' critical thinking skills using Structural Equation Modeling (SEM). A hypothetical structural model was developed based on Bandura's Social Cognitive Theory and the theoretical framework of critical thinking proposed by Ennis. The proposed model assumed that learning motivation and mathematical self-efficacy function as exogenous variables, whereas students' critical thinking skills constitute the endogenous variable. The structural relationships among these constructs were estimated using LISREL 8.80.

Participant

The research was conducted at Ma'arif Kalibawang Junior High School, Kulon Progo Regency, Yogyakarta, Indonesia. The target population comprised all eighth-grade students enrolled during the 2024/2025 academic year, totaling 76 students. A sample of 34 students (17 males and 17 females) was selected using a simple random sampling technique. Each student in the population was assigned an identification number, and the participants were selected using a computer-generated random-number procedure, ensuring that every student had an equal probability of being included in the study. All selected students agreed to participate, completed the research procedures, and provided complete datasets; therefore, no participants were excluded from the final analysis. Prior to data collection, permission to conduct the study was obtained from the school administration. Written informed consent was obtained from the students' parents or legal guardians, and assent was obtained from all participating students. The participants were informed about the objectives of the study, and participation was entirely voluntary. According to the institutional policy, formal ethics committee approval was not required for this educational research involving minimal risk. All collected data were treated confidentially and used solely for research purposes.

Instrument

Learning Motivation Questionnaire

Students' learning motivation was measured using a self-report questionnaire developed based on Keller's ARCS motivational model, comprising four dimensions: Attention, Relevance, Confidence, and Satisfaction. The instrument consisted of [insert number] items, each rated on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating higher levels of learning motivation. Representative items included "I pay close attention during mathematics lessons" (Attention), "The mathematics lessons are relevant to my daily life" (Relevance), "I am confident that I can successfully complete mathematics tasks" (Confidence), and "I feel satisfied after successfully solving mathematics problems" (Satisfaction). Negatively worded items, if any, were reverse-coded prior to data analysis so that higher scores consistently reflected higher learning motivation. The instrument was adapted from Keller's ARCS motivational framework and demonstrated good internal consistency, with a Cronbach's alpha/Construct Reliability (CR) of [insert value] in the present study. Responses were recorded on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Mathematical Self-Efficacy Questionnaire

Mathematical self-efficacy was assessed using a questionnaire adapted from Bandura's self-efficacy framework (Bandura, 2006). The instrument measured three dimensions of mathematical self-efficacy: Level, Strength, and Generality, reflecting students' confidence in performing mathematical tasks with varying levels of complexity, persistence in overcoming mathematical difficulties, and the transferability of their confidence across different mathematical situations. The questionnaire employed a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating higher levels of mathematical self-efficacy. The instrument was translated and adapted to the Indonesian junior high school context and was reviewed by mathematics education experts to ensure linguistic clarity, cultural appropriateness, and content validity prior to administration.The instrument measured three dimensions:
a. Level; b. Strength; c. Generality

The questionnaire evaluated students' confidence in completing mathematical tasks specifically related to the Pythagorean Theorem with varying levels of complexity. The items were designed to assess students' beliefs in their capability to understand Pythagorean concepts, select appropriate solution strategies, solve contextual Pythagorean problems, and justify their mathematical reasoning. This domain-specific approach is consistent with Bandura's recommendation that self-efficacy should be measured as closely as possible to the target performance domain in order to enhance its predictive validity.

Critical Thinking Test

Students' critical thinking skills were assessed using an essay-based mathematics test developed within the context of the Pythagorean Theorem. The instrument was constructed based on Ennis' critical thinking framework and measured five dimensions: elementary clarification, basis for decision, inference, advanced clarification, and strategy and reflection. The test consisted of essay problems requiring students to analyse contextual mathematical situations, identify relevant information, justify their solution strategies, perform mathematical reasoning, and explain the validity of their conclusions. Students completed the test during the allocated instructional period under teacher supervision. Responses were evaluated using an analytic scoring rubric aligned with the five critical thinking dimensions proposed by Ennis, with higher scores indicating higher levels of critical thinking performance. To ensure scoring consistency, all responses were assessed independently by two mathematics education lecturers using the same scoring rubric. Any discrepancies in scoring were resolved through discussion until consensus was reached. Prior to implementation, both the instrument and the scoring rubric were reviewed by mathematics education experts to establish content validity.The assessment was constructed according to Ennis' critical thinking framework, encompassing five indicators:
a. Elementary clarification
b. Basis for decision
c. Inference
d. Advanced clarification
e. Strategy and reflection

Prior to implementation, all research instruments were subjected to expert judgment to establish content validity. The validation process involved three experts in mathematics education, each holding a doctoral degree and having extensive experience in mathematics teaching, educational assessment, and instrument development. The experts evaluated the instruments in terms of content relevance, construct representation, language clarity, readability, and suitability for junior high school students. The degree of agreement among the experts was quantified using Aiken's V, and all items achieved values above the recommended threshold for acceptable content validity. Based on the experts' recommendations, several items were revised to improve wording, clarity, and alignment with the intended constructs before the instruments were administered in the main study.

Data Collection Procedure

Data collection was carried out during regular mathematics lessons. Students first completed the learning motivation questionnaire, followed by the mathematical self-efficacy questionnaire. Subsequently, they worked individually on the critical thinking test under teacher supervision within the allocated instructional time. All responses were coded before being entered into the statistical software for analysis.

Data analysis was conducted using IBM SPSS Statistics 26 and LISREL 8.80.

Descriptive statistics were first calculated to summarize the characteristics of the participants and each research variable. Before estimating the structural model, the underlying statistical assumptions were evaluated. The assessment indicated that the data satisfied the assumptions required for Structural Equation Modeling. Multivariate normality was examined using LISREL, and the results indicated that the data did not exhibit substantial departures from multivariate normality. Multicollinearity was assessed by examining the correlations among the latent constructs as well as the tolerance and Variance Inflation Factor (VIF) values. The results showed no evidence of problematic multicollinearity, with all tolerance values exceeding 0.10 and all VIF values remaining below the recommended threshold of 10. In addition, tests of linearity and homogeneity confirmed that the data met the assumptions necessary for SEM analysis. These findings indicate that the estimated structural relationships were not adversely affected by violations of the underlying statistical assumptions and that the proposed model was appropriate for subsequent hypothesis testing.

The measurement quality of each construct was evaluated through validity and reliability analyses. Construct validity was examined using standardized factor loadings, while construct reliability was assessed using Composite Reliability (CR) and Average Variance Extracted (AVE). A construct was considered acceptable when standardized factor loadings exceeded 0.50, Composite Reliability was greater than 0.70, and Average Variance Extracted exceeded 0.50. The structural relationships among variables were subsequently analyzed using Structural Equation Modeling (SEM) with LISREL 8.80. Model adequacy was evaluated using several goodness-of-fit indices, including Chi-square (χ^2), Chi-square/degrees of freedom (χ^2/df), Root Mean Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), Goodness-of-Fit Index (GFI), Adjusted Goodness-of-Fit Index (AGFI), and Standardized Root Mean Square Residual (SRMR). The model was considered acceptable when the goodness-of-fit indices met commonly recommended threshold values. Hypothesis testing was performed by examining the standardized path coefficients (β), t-values, and p-values. Structural relationships were considered statistically significant when the t-value exceeded ±1.96 ($\alpha = 0.05$). In addition, the coefficient of determination (R^2) was used to evaluate the proportion of variance in students' critical thinking skills explained by learning motivation and mathematical self-efficacy.

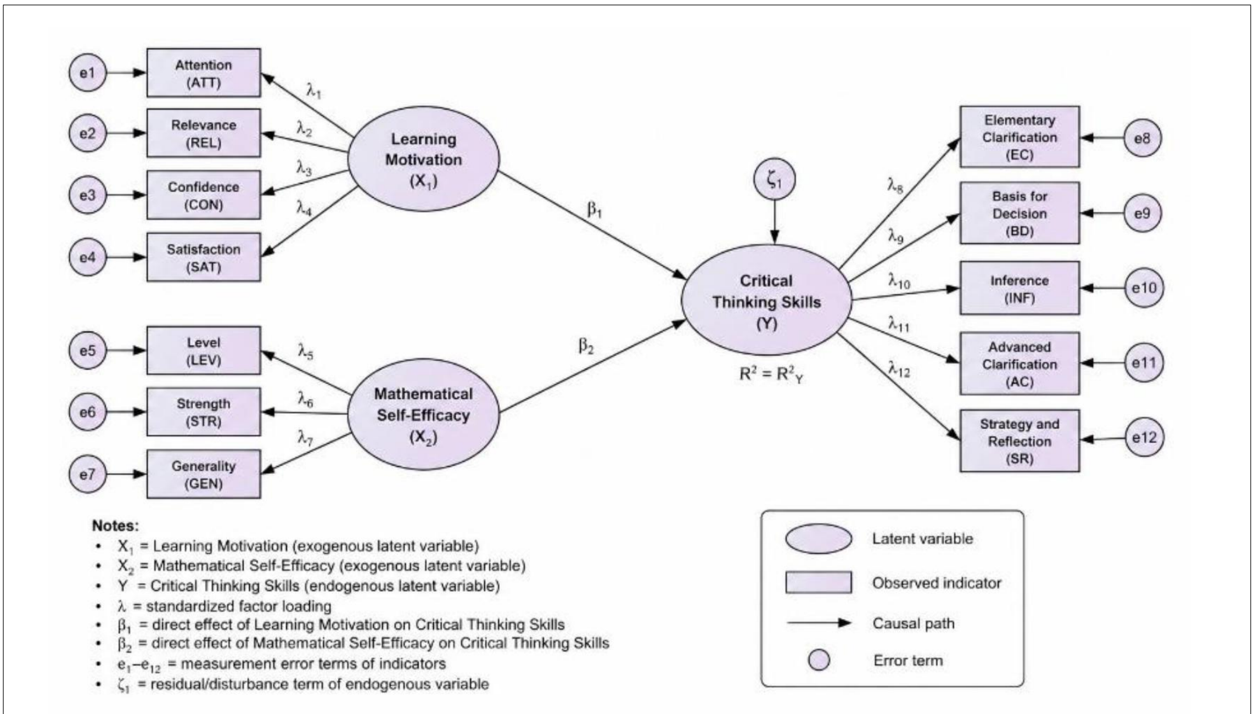


Figure 1. Proposed structural equation model of the study.

RESULTS AND DISCUSSION

Results

Preliminary Analysis

Before evaluating the structural relationships among the latent variables, the adequacy of the measurement model was assessed. This evaluation aimed to ensure that the collected data were appropriate for factor analysis and that the observed indicators adequately represented their respective latent constructs. The assessment consisted of the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy, Bartlett's Test of Sphericity, and Confirmatory Factor Analysis (CFA).

Kaiser–Meyer–Olkin (KMO) and Bartlett's Test

The Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity were conducted to determine whether the correlation matrix was suitable for factor analysis. The KMO statistic evaluates sampling adequacy by examining whether the observed correlations among variables are sufficiently compact to produce reliable latent factors. According to Kaiser, KMO values above 0.50 indicate that the sample is adequate for factor analysis, whereas values exceeding 0.70 indicate good sampling adequacy. Bartlett's Test examines whether the correlation matrix differs significantly from an identity matrix. A statistically significant result ($p < 0.05$) indicates that sufficient correlations exist among the observed variables to justify factor analysis. The results of the KMO and Bartlett's Test are presented in Table 1.

Table 1. Kaiser–Meyer–Olkin (KMO) and Bartlett's Test

Test Value	Test Value
Kaiser–Meyer–Olkin Measure	0.892
Bartlett's Test Chi-Square	1307.307
df	66
Sig.	0.000

Before evaluating the measurement model, the Kaiser–Meyer–Olkin (KMO) measure and Bartlett's Test of Sphericity were conducted to ensure that the collected data satisfied the assumptions required for factor analysis. The results indicated a KMO value of 0.892, demonstrating excellent sampling adequacy for factor analysis. This finding suggests that the indicators representing the constructs of learning motivation, mathematical self-efficacy, and critical thinking skills shared substantial common variance, enabling them to adequately represent their respective latent constructs. Furthermore, Bartlett's Test of Sphericity yielded a statistically significant result ($\chi^2 = 1307.307$, df = 66, $p < 0.001$), indicating that the correlation matrix differed significantly from an identity matrix. This result confirms that strong correlations exist among the observed indicators, supporting the identification of the underlying latent constructs through factor analysis. Overall, the KMO measure and Bartlett's Test indicate that the data were suitable for factor analysis and provided an appropriate basis for conducting Confirmatory Factor Analysis (CFA). However, the adequacy of the measurement model was primarily established through the CFA results, including standardized factor loadings, construct reliability, and convergent validity, which collectively demonstrated that the proposed measurement model was acceptable for subsequent structural model analysis. Therefore, the proposed measurement model possesses an adequate empirical foundation for evaluating construct validity. Consequently, the analysis proceeded to the assessment of the measurement model using Confirmatory Factor Analysis (CFA), followed by the evaluation of the structural relationships among the latent constructs through Structural Equation Modeling (SEM) using LISREL

Confirmatory Factor Analysis (CFA)

After the data were confirmed to satisfy the prerequisites for factor analysis, the next step was to evaluate construct validity using Confirmatory Factor Analysis (CFA). This analysis was conducted to verify whether each observed indicator adequately represented its corresponding latent construct, namely learning motivation, mathematical self-efficacy, and critical thinking skills. Construct validity was assessed based on the standardized factor loading, with indicators considered valid when their standardized loading factor was 0.50 or higher. The CFA results revealed that all indicators had standardized factor loadings ranging from 0.50 to 0.85, indicating that every indicator met the recommended criterion for construct validity. Although one indicator exhibited the minimum acceptable loading value of 0.50, it still satisfied the established threshold. Furthermore, most indicators demonstrated loading values above 0.70, indicating strong relationships with their respective latent constructs. These findings suggest that each indicator adequately explained the latent variable it was intended to measure; therefore, all indicators were retained in the measurement model. Overall, the CFA results provide evidence of satisfactory convergent validity for the measurement model. The findings indicate that the indicators consistently measured the constructs of learning motivation, mathematical self-efficacy, and critical thinking skills in accordance with their underlying theoretical framework. Consequently, the measurement model was considered sufficiently valid to serve as the basis for evaluating the structural relationships among the latent variables through Structural Equation Modeling (SEM) using LISREL.

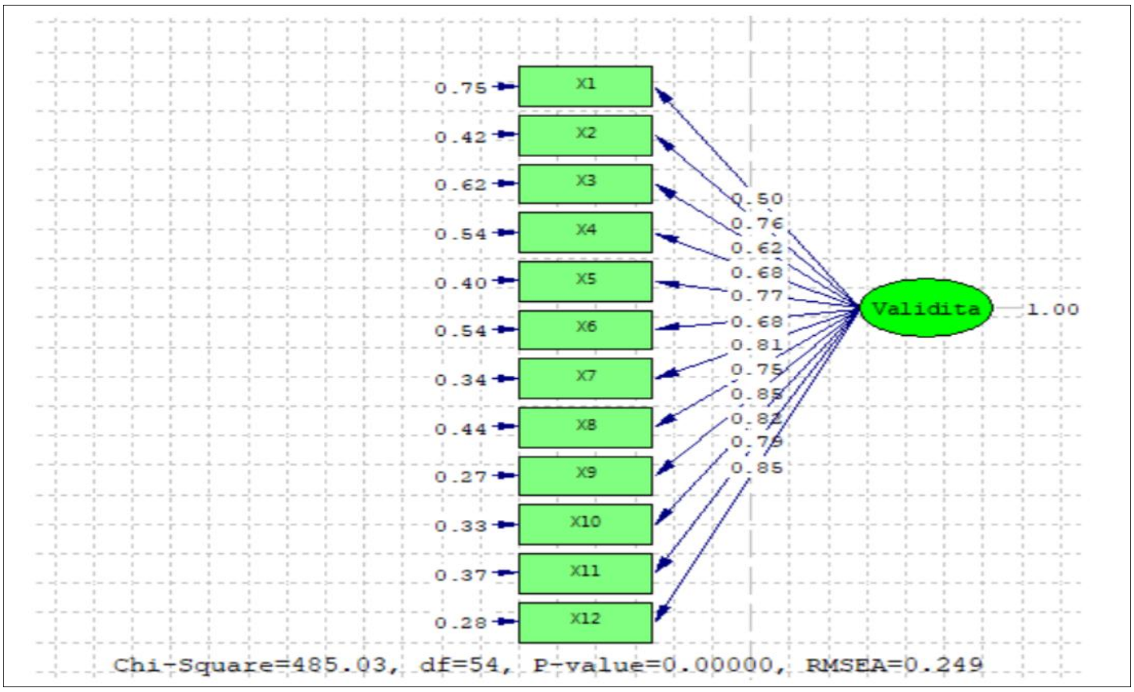


Figure 2. CFA Test

Construct Reliability (CR) dan AVE

Tabel 2. Standardized Loading Factor

Indikator	Loading (λ)	Error Variance (ε)
X1	0,50	0,75
X2	0,76	0,42
X3	0,62	0,62
X4	0,68	0,54
X5	0,77	0,40
X6	0,68	0,54
X7	0,81	0,34

Indikator	Loading (λ)	Error Variance (ε)
X8	0,75	0,44
X9	0,85	0,27
X10	0,82	0,33
X11	0,79	0,37
X12	0,85	0,28

Construct Reliability (CR):

$$CR = \frac{(\sum\lambda)2}{(\sum\lambda)2 + \sum\varepsilon}$$

Calculation results:

$\sum\lambda$ = 8,58
$(\sum\lambda)2$ = 73,62
$\sum\varepsilon$ = 5,30

so that

$$CR = \frac{73{,}62}{73{,}62 + 5{,}30} = 0{,}933$$

Construct Reliability = 0,933
This value is well above the minimum threshold of 0.70; therefore, the validity construct exhibits very high reliability.
Average Variance Extracted (AVE)
AVE is calculated using

$$AVE = \frac{\sum\lambda 2}{\mathrm{n}}$$

Sum of squared loadings

$\sum\lambda 2$ = 6,70

With n = 12

So

$$AVE = \frac{6{,}70}{12} = 0{,}558$$

The AVE value exceeded the recommended threshold of 0.50, indicating that the construct satisfied the criterion for convergent validity. In addition to establishing construct validity through Confirmatory Factor Analysis (CFA), the measurement model was further evaluated using Construct Reliability (CR) and Average Variance Extracted (AVE) to assess the internal consistency and convergent validity of the latent constructs. The calculations were performed following the procedures proposed by Fornell and Larcker (1981). Construct validity was evaluated using standardized factor loadings for each latent construct, whereas construct reliability was assessed separately for Learning Motivation, Mathematical Self-Efficacy, and Critical Thinking Skills using Composite Reliability (CR) and Average Variance Extracted (AVE). The results demonstrated satisfactory internal consistency and convergent validity for all three constructs, with CR values exceeding the recommended threshold of 0.70 and AVE values exceeding 0.50, indicating that each construct exhibited adequate reliability and explained more than half of the variance of its respective indicators. The construct-specific CR and AVE values are presented in Table 3.

Overall, the results of the Confirmatory Factor Analysis (CFA), Construct Reliability (CR), and Average Variance Extracted (AVE) provide strong evidence that the measurement model satisfies the requirements for internal reliability and convergent validity. Therefore, the latent constructs employed in this study are considered psychometrically sound and suitable for the subsequent evaluation of the structural model using Structural Equation Modeling (SEM) with LISREL.

Tabel 3. Construct Reliability and Convergent Validity of Each Latent Construct

Construct	Number of Indicators	Composite Reliability (CR)	Average Variance Extracted (AVE)	Interpretation
Learning Motivation	4	**0.738**	**0.418**	Reliable; convergent validity below the recommended threshold
Mathematical Self-Efficacy	3	**0.800**	**0.572**	Reliable and convergently valid
Critical Thinking Skills	5	**0.907**	**0.662**	Highly reliable and convergently valid

Structural Model Evaluation

After the measurement model was confirmed to possess satisfactory construct validity and reliability, the next step was to evaluate the structural model using several goodness-of-fit (GOF) indices. This evaluation aimed to determine whether the proposed conceptual model describing the relationships among learning motivation, mathematical self-efficacy, and critical thinking skills adequately fit the empirical data. The evaluation of the initial structural model, as presented in Figure 3 and Table 3, indicated that the model did not fully satisfy the recommended goodness-of-fit criteria. Among the five fit indices examined, only the Normed Fit Index (NFI = 0.96) met the recommended threshold. In contrast, the Non-Normed Fit Index (NNFI = 0.88), Goodness-of-Fit Index (GFI = 0.88), and Relative Fit Index (RFI = 0.89) remained below the recommended minimum value of 0.90. Furthermore, the Root Mean Square Error of Approximation (RMSEA = 0.150) indicated a relatively high level of approximation error, suggesting that the initial model did not adequately represent the structural relationships among the latent variables.

These findings indicate that the initial conceptual model required further refinement to achieve a better representation of the empirical data. Therefore, the measurement model was re-specified based on the Modification Indices (MI) generated by LISREL. Model refinement was limited to correlating measurement error terms between indicators belonging to the same latent construct when supported by both the Modification Indices and theoretical considerations. Specifically, residual correlations were added between eX2–eX3 (Learning Motivation), eY1–eY2 (Mathematical Self-Efficacy), and eZ2–eZ3 (Critical Thinking), as these indicator pairs measured closely related aspects of the same construct and shared similar wording and conceptual content. The corresponding Modification Indices exceeded the recommended threshold (MI > 3.84), indicating that correlating these residuals would substantially improve model fit. No cross-construct residual correlations or additional structural paths were introduced, thereby preserving the theoretical structure of the proposed model. Following these theoretically justified modifications, the goodness-of-fit indices improved substantially (NNFI = 0.97, CFI = 0.98, NFI = 0.96, RFI = 0.94, RMSEA = 0.093), indicating that the revised model provided a better representation of the observed data. The reanalysis was performed while maintaining the theoretical rationale underlying the proposed relationships among the latent constructs, thereby improving the model without compromising its conceptual foundation.

The results of the reanalyzed model, presented in Figure 4 and Table 4, demonstrate a substantial improvement in overall model fit. Most goodness-of-fit indices satisfied the recommended criteria, indicating that the revised model achieved an acceptable overall fit. The incremental fit indices demonstrated good model fit (NNFI = 0.97, CFI = 0.98, NFI = 0.96, and RFI = 0.94), whereas the RMSEA value (0.093) indicated a marginal but still acceptable level of approximation. Collectively, these results suggest that the revised structural model provides an adequate representation of the observed data and is appropriate for subsequent hypothesis testing, with NNFI = 0.97, Comparative Fit Index (CFI) = 0.98, NFI = 0.96, and RFI = 0.94, all exceeding the recommended threshold of 0.90. Moreover, the RMSEA decreased markedly from 0.150 to 0.093, indicating a substantial reduction in approximation error following model refinement. The improvement in these goodness-of-fit indices demonstrates that the reanalyzed structural model provides a considerably better representation of the empirical data than the initial model. Accordingly, the revised model was considered sufficiently well fitted for testing the proposed structural relationships among the latent constructs. The analysis therefore proceeded to hypothesis testing to examine the effects of learning motivation and mathematical self-efficacy on students' critical thinking skills.

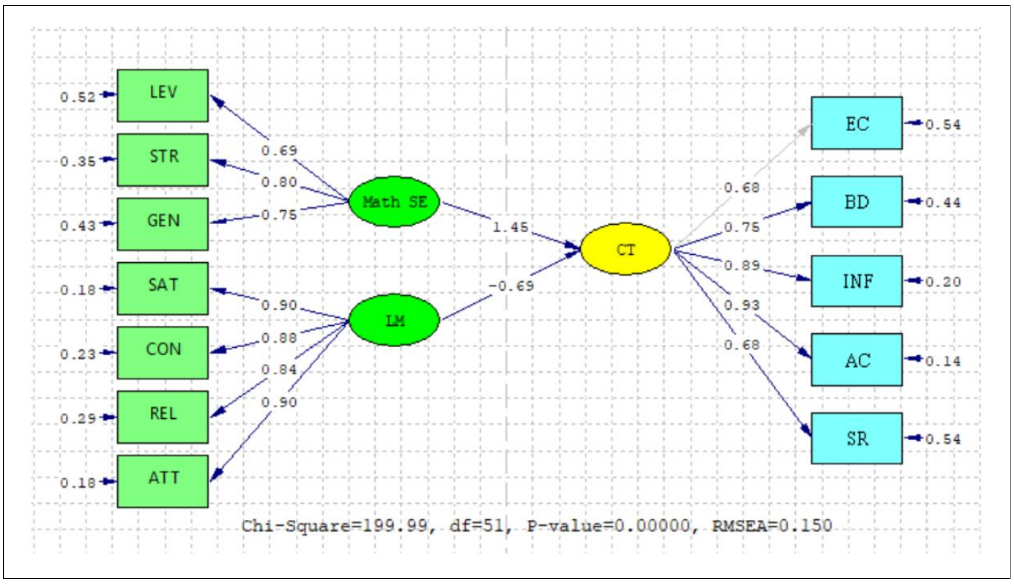
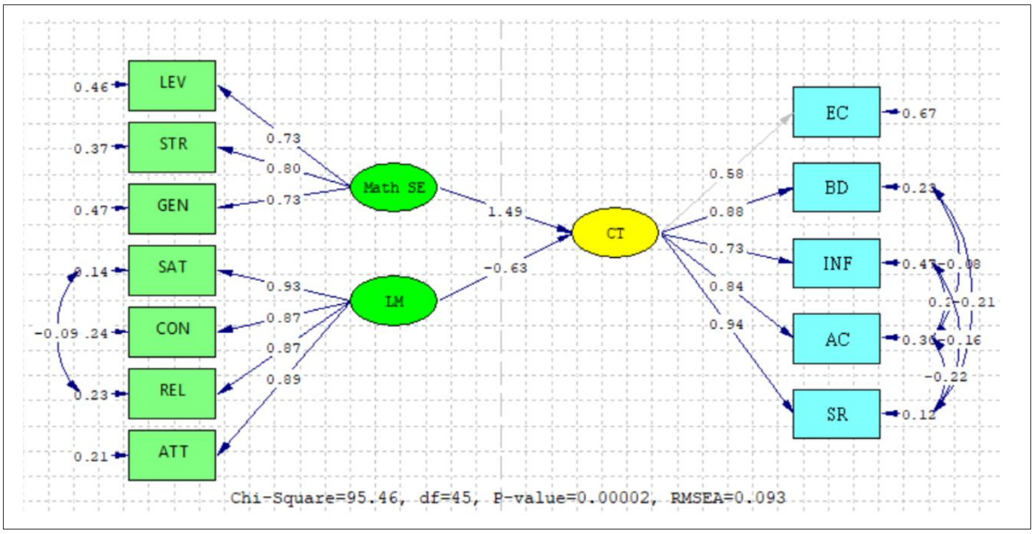


Figure 3. Model SEM

Tabel 4. Goodness-of-Fit model

No	Goodness-of-Fit Index	Cut-off Value	Value	Decision
1	NNFI	≥ 0.90	0.88	Not Good
2	GFI	≥ 0.90	0.88	Not Good
3	NFI	≥ 0.90	0.96	Good
4	RFI	≥ 0.90	0.89	Not Good
5	RMSEA	≤ 0.08	0.150	Not Good



Figuer 4. Re-analysis of the SEM Model

Tabel 5. Reanalisis Goodness-of-Fit model

No	Goodness-of-Fit Index	Cut-off Value	Value	Decision
1	NNFI	≥ 0.90	0.97	Good
2	CFI	≥ 0.90	0.98	Good
3	NFI	≥ 0.90	0.96	Good
4	RFI	≥ 0.90	0.94	Good
5	RMSEA	≤ 0.08	0.093	Acceptable Fit

Unlike the interpretation of standardized factor loadings, the interpretation of t-values focuses on the statistical significance of the estimated parameters rather than the validity of the indicators. Specifically, t-values are used to determine whether the relationships between the observed indicators and their corresponding latent constructs, as well as the structural relationships among latent constructs, are statistically different from zero. As illustrated in Figure 5, all indicator loadings produced t-values greater than 1.96, indicating that each indicator significantly represents its corresponding latent construct at the 5% significance level. Regarding the structural model, the path from Mathematical Self-Efficacy (Math SE) to Critical Thinking (CT) yielded a t-value of 4.40, indicating a statistically significant positive effect. In contrast, the path from Learning Motivation (LM) to Critical Thinking (CT) produced a t-value of −2.26. Although the coefficient is negative, its absolute t-value ($|-2.26| = 2.26$) exceeds the critical value of 1.96, indicating that the relationship is statistically significant but in a negative direction. These findings suggest that mathematical self-efficacy positively contributes to students' critical thinking skills, whereas learning motivation exhibits a significant negative association with critical thinking when both variables are analyzed simultaneously within the structural model. Therefore, the structural relationships were interpreted based on both the statistical significance and the direction of the estimated path coefficients. The results indicated that the effect of Mathematical Self-Efficacy on Critical Thinking Skills was statistically significant and consistent with the hypothesised positive direction, thereby supporting the proposed hypothesis. In contrast, although the effect of Learning Motivation on Critical Thinking Skills was statistically significant, the estimated coefficient was negative rather than positive. Consequently, this relationship cannot be considered supportive of the original directional hypothesis and should instead be interpreted as evidence of a statistically significant inverse association within the present sample.

Significance Testing of the Structural Model

After the structural model was confirmed to satisfy the recommended goodness-of-fit criteria, the significance of the estimated parameters was evaluated using t-values to examine both the relationships between the observed indicators and their corresponding latent constructs, as well as the structural relationships among the latent constructs. Following the recommendation of Jöreskog and Sörbom (1996), an estimated parameter is considered statistically significant when its absolute t-value is 1.96 or greater at the 5% significance level. As presented in Figure 5, all indicators measuring the constructs of Learning Motivation, Mathematical Self-Efficacy, and Critical Thinking produced t-values ranging from 6.45 to 13.63, all of which exceeded the critical value of 1.96. These findings indicate that each observed indicator contributes significantly to its corresponding latent construct. Consequently, the measurement model receives strong empirical support, confirming that all indicators adequately represent the latent variables they were designed to measure.

Table X presents the structural parameter estimates obtained using the Maximum Likelihood estimation procedure in LISREL 8.80. Mathematical Self-Efficacy had a positive and statistically significant effect on Critical Thinking Skills ($B = 1.25$, $SE = 0.29$, $t = 4.40$, $p < 0.001$), indicating that higher levels of mathematical self-efficacy were associated with higher levels of critical thinking. In contrast, Learning Motivation showed a statistically significant negative effect on Critical Thinking Skills ($B = -0.53$, $SE = 0.23$, $t = -2.26$, $p = 0.024$). Although statistically significant, the direction of the coefficient was opposite to the hypothesised positive relationship; therefore, the hypothesis regarding the positive effect of Learning Motivation was not supported. This finding suggests that students with higher levels of mathematical self-efficacy tend to demonstrate stronger critical thinking skills when solving mathematical problems.

Table 6. Structural Path Estimates

Structural Path	Unstandardized Coefficient (B)	Standard Error (SE)	*t*-value	*p*-value	Decision
Learning Motivation → Critical Thinking	-0.53	0.23	-2.26	0.024	Significant, but hypothesis not supported
Mathematical Self-Efficacy → Critical Thinking	1.25	0.29	4.40	< 0.001	Supported

In contrast, the path from Learning Motivation to Critical Thinking produced a t-value of −2.26. Although the absolute value exceeds the significance threshold ($|-2.26| > 1.96$), the negative sign indicates an inverse relationship between the two constructs within the estimated structural model. Thus, learning motivation exerts a statistically significant but negative effect on students' critical thinking skills when analyzed simultaneously with mathematical self-efficacy. Overall, the t-value analysis demonstrates that all estimated parameters are statistically significant, providing empirical support for the proposed structural model. These results confirm that the model adequately explains the structural relationships among learning motivation, mathematical self-efficacy, and critical thinking skills, thereby supporting the subsequent interpretation of the hypothesized relationships.

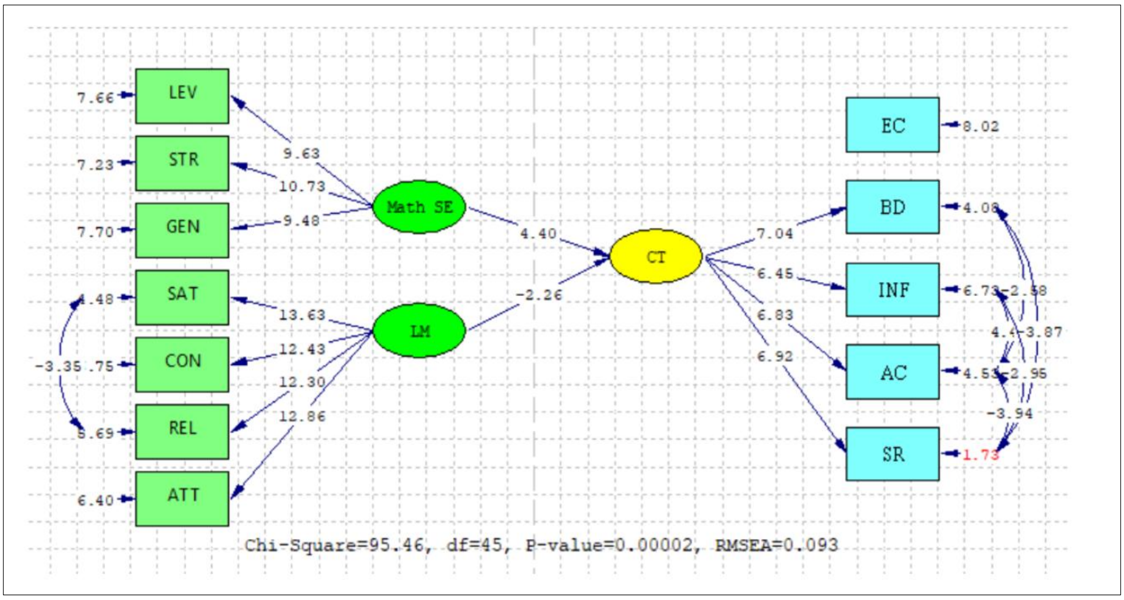


Figure 5. t-value Model SEM

Discussion

The findings demonstrate that the proposed structural model provides an acceptable representation of the relationships among learning motivation, mathematical self-efficacy, and students' critical thinking skills in mathematics. Following model refinement, the goodness-of-fit indices improved substantially, with NNFI, CFI, NFI, and RFI all exceeding the recommended threshold, while the RMSEA value decreased from 0.150 to 0.093, indicating a considerable reduction in model misfit. Although the RMSEA value remained slightly above the conventional criterion for a close-fitting model, values below 0.10 are generally considered indicative of an acceptable or marginal fit for exploratory structural models, particularly when the sample size is relatively limited. These findings suggest that the revised structural model is sufficiently robust to explain the hypothesized relationships among the latent constructs despite the inherent limitations of the dataset. The acceptable fit achieved after model refinement also indicates that the theoretical assumptions underlying the proposed model are largely consistent with the observed empirical relationships. More importantly, the results support the proposition that students' critical thinking skills are shaped not only by cognitive competence but also by affective characteristics that influence how students approach, regulate, and persist in solving mathematical problems. This finding is consistent with contemporary perspectives in mathematics education, which argue that higher-order thinking develops through the interaction between cognitive processes and motivational or self-regulatory factors rather than through conceptual knowledge alone (Tay et al., 2024; Tee et al., 2021; Wu et al., 2026). Consequently, understanding students' affective characteristics becomes essential for explaining variations in mathematical reasoning and critical thinking beyond differences in academic ability. The present findings therefore reinforce the growing recognition that mathematics learning should be viewed as an integrated cognitive-affective process in which psychological variables substantially influence students' reasoning performance. Within this framework, the proposed Structural Equation Modeling (SEM) provides a comprehensive analytical approach for simultaneously examining the complex relationships among multiple affective constructs and their contributions to students' critical thinking skills.

The measurement model further demonstrated that learning motivation was effectively represented by the four dimensions of the ARCS framework, namely attention, relevance, confidence, and satisfaction, with standardized factor loadings ranging from 0.84 to 0.90. The high loading values indicate that all four dimensions consistently captured students' motivational characteristics and collectively provided a reliable representation of the latent construct. Among these dimensions, attention and satisfaction emerged as the strongest indicators, suggesting that students' motivation was primarily reflected in their sustained engagement during mathematics learning and the positive feelings experienced after successfully completing learning activities. This finding implies that students' motivation is strengthened not merely through external encouragement but also through meaningful learning experiences that foster curiosity, active engagement, and a sense of accomplishment (Daniel et al., 2024; Hellín et al., 2023; Owens et al., 2020). The prominence of the attention and satisfaction dimensions supports the theoretical proposition that sustained engagement and positive learning experiences are fundamental components in maintaining students' motivation throughout the learning process. Although the confidence dimension also demonstrated a relatively high loading, it should be distinguished conceptually from mathematical self-efficacy because it represents students' general expectations of success during learning rather than their beliefs regarding their capability to perform specific mathematical tasks successfully. This distinction is particularly important because the conceptual similarity between the confidence dimension of the ARCS model and mathematical self-efficacy may create overlapping variance when both constructs are simultaneously estimated within the same structural model. Such conceptual overlap provides a plausible explanation for why the contribution of learning motivation changed after mathematical self-efficacy was incorporated into the structural model. Similar findings have been reported in previous studies showing that instructional approaches capable of enhancing learning motivation frequently strengthen mathematical self-efficacy simultaneously (Huang et al., 2020; Zakariya, 2022), thereby making the empirical separation of these constructs increasingly challenging during multivariate analyses. Therefore, the present findings suggest that learning motivation should not be interpreted as an entirely independent psychological determinant of critical thinking but rather as an affective construct whose contribution is closely intertwined with students' confidence in their mathematical capabilities.

Mathematical self-efficacy emerged as a significant positive predictor of students' critical thinking skills, indicating that students who possessed stronger confidence in their mathematical capabilities demonstrated better higher-order reasoning when solving Pythagorean theorem problems. The positive structural coefficient and significant t-value indicate that students' beliefs regarding their capability to perform mathematical tasks contributed directly to their ability to analyse information, evaluate evidence, justify solution strategies, and formulate logical conclusions. This finding supports the proposition of Social Cognitive Theory, which argues that individuals' beliefs about their capabilities influence not only their behavioral persistence but also their cognitive engagement and performance during challenging tasks. Students with high mathematical self-efficacy are generally more willing to attempt unfamiliar mathematical problems, sustain effort after experiencing difficulties, evaluate alternative strategies, and regulate their own learning processes (Liu et al., 2025; Street et al., 2022). Such behaviours create favourable conditions for the development of critical thinking because students remain cognitively engaged throughout the problem-solving process instead of avoiding challenging situations. The present findings are consistent with previous studies demonstrating that mathematical self-efficacy contributes significantly to students' mathematical critical thinking and higher-order reasoning across different instructional settings (Marlena & Nugraheni, 2026; Nuryadi et al., 2025; Suhartini et al., 2025). Similar evidence has also been reported in large-scale educational studies showing that mathematical self-efficacy consistently predicts mathematics achievement even after controlling for individual and school characteristics (Grigg et al., 2018; Pitsia et al., 2017; Shone et al., 2024; Tanami & Tzuriel, 2026; Yang et al., 2024). Collectively, these findings indicate that mathematical self-efficacy functions as a proximal psychological determinant that directly supports students' analytical reasoning and critical thinking during mathematical problem solving. The present study therefore extends previous research by demonstrating that mathematical self-efficacy remains the strongest predictor of critical thinking even when learning motivation is estimated simultaneously within the same structural model. These findings reinforce the importance of strengthening students' mathematical confidence as an integral component of instructional practices aimed at improving higher-order thinking in mathematics education.

The measurement model further revealed that the strength dimension represented the strongest indicator of mathematical self-efficacy, followed by generality and level, suggesting that students' confidence was primarily reflected in their persistence when facing mathematical challenges rather than merely in their willingness to undertake tasks with different levels of difficulty. This finding implies that perseverance in confronting complex mathematical problems constitutes a more influential psychological characteristic than confidence associated solely with task difficulty (DiNapoli, 2023; Gabriel et al., 2020; Jiang et al., 2021; Voica et al., 2020; Zuo et al., 2024). Critical thinking rarely develops through immediate success because students are typically required to analyse information, evaluate evidence, revise incorrect assumptions, compare alternative strategies, and continuously reflect on the appropriateness of their reasoning before reaching valid conclusions. Under such circumstances, students with stronger self-beliefs are more likely to remain engaged in cognitive processing despite experiencing temporary failure or uncertainty. Conversely, students with weaker mathematical self-efficacy may discontinue problem-solving efforts prematurely because they perceive mathematical challenges as exceeding their capabilities. The relatively lower loading of the level dimension further indicates that students' confidence tends to decline as mathematical tasks become increasingly complex, even though they may still demonstrate persistence throughout the learning process. This pattern suggests that instructional practices should not only encourage students to participate actively in mathematics learning but should also provide graduated mastery experiences that progressively strengthen their confidence across varying levels of task difficulty. Previous intervention studies have likewise demonstrated that instructional approaches emphasizing guided practice, collaborative problem solving, constructive feedback, and authentic mastery experiences effectively strengthen students' mathematical self-efficacy while simultaneously improving higher-order thinking (Bachtiar et al., 2025; Bhatt, 2025; Sudiartini et al., 2025). Therefore, the present findings provide additional empirical evidence that strengthening students' persistence and confidence represents an effective pedagogical strategy for promoting critical thinking in mathematics classrooms. Taken together, these results support the view that mathematical self-efficacy should be regarded not merely as a positive personal belief but as a strategic psychological resource that enables students to sustain cognitive engagement throughout complex mathematical reasoning and critical problem-solving activities.

The findings of this study provide important theoretical and pedagogical implications by clarifying the distinct roles of learning motivation and mathematical self-efficacy in explaining students' critical thinking skills in mathematics. The results indicate that mathematical self-efficacy functions as a more proximal psychological determinant of higher-order thinking, whereas learning motivation primarily initiates students' engagement in learning activities before cognitive processes are activated. This distinction supports the perspective of Social Cognitive Theory, which emphasizes that students' beliefs about their capabilities directly influence cognitive engagement, persistence, and performance during challenging learning tasks. Consequently, the development of students' critical thinking should be understood as the outcome of interactions between motivational processes and beliefs about mathematical competence rather than as the product of learning motivation alone. From a pedagogical perspective, mathematics instruction should extend beyond fostering students' interest in learning by systematically strengthening their mathematical self-efficacy through authentic mastery experiences, graduated instructional support, constructive feedback, collaborative learning, and reflective problem-solving activities. Such instructional practices are expected to improve not only students' confidence but also their analytical reasoning, metacognitive regulation, and persistence when solving complex mathematical problems. These implications are consistent with previous studies demonstrating that contextual and problem-based learning simultaneously enhance mathematical self-efficacy and critical thinking by providing meaningful opportunities for reasoning and reflection (Cahyani & Setyaningsih, 2024; Masitoh & Fitriyani, 2018; Yulianto et al., 2024). Nevertheless, the findings should be interpreted cautiously because the relatively small sample size and the presence of a standardized coefficient exceeding the recommended threshold suggest the possibility of suppression effects or multicollinearity within the structural model. Future studies involving larger and more diverse samples are therefore needed to validate the stability of the proposed model and examine whether the observed relationships remain consistent across different mathematical topics and educational contexts. Overall, this study contributes to the growing body of mathematics education research by providing empirical evidence that strengthening students' mathematical self-efficacy represents a more effective pathway for fostering critical thinking than focusing solely on increasing learning motivation.

Implications

This study provides both theoretical and practical implications for mathematics education. Theoretically, the findings reinforce the perspective that mathematical self-efficacy is a more proximal predictor of students' critical thinking skills than learning motivation. Although motivation encourages students to engage in learning activities, confidence in one's mathematical ability appears to play a more decisive role in sustaining analytical reasoning and problem-solving processes. These findings contribute to the literature by demonstrating the comparative influence of two affective constructs within a single structural model, thereby extending previous studies that primarily examined each construct independently. Practically, the findings suggest that mathematics instruction should not only aim to increase students' learning motivation but should also intentionally strengthen their mathematical self- efficacy. Teachers are encouraged to design learning experiences that provide achievable challenges, constructive feedback, opportunities for successful problem solving, and reflective activities that enhance students' confidence in their mathematical abilities. Such learning environments are expected to foster higher levels of critical thinking when students encounter complex mathematical problems.

Limitations and Suggestions for Future Research

This study has several limitations that should be considered when interpreting its findings. First, the study involved a relatively small sample from a single junior high school, which limits the generalizability of the results to broader educational contexts. Second, the research focused exclusively on the Pythagorean theorem, and the identified structural relationships may differ when applied to other mathematical topics with different cognitive characteristics. Third, the cross-sectional design only captures relationships among variables at one point in time and therefore does not explain causal or developmental changes in students' critical thinking. In addition, although the structural model achieved acceptable goodness-of-fit, there is still room for improving the model by refining its specification and incorporating additional explanatory variables. Future studies are encouraged to involve larger and more diverse samples from different educational levels and school settings to improve the robustness and generalizability of the findings. Longitudinal or experimental research designs are also recommended to examine the causal development of critical thinking and the long-term influence of mathematical self-efficacy and learning motivation. Furthermore, future research should incorporate additional psychological and instructional variables, such as self-regulated learning, metacognitive awareness, mathematics anxiety, cognitive engagement, and classroom learning environment, to develop a more comprehensive explanatory model. Alternative analytical approaches may also be considered to validate the consistency and stability of the proposed structural relationships. From a practical perspective, mathematics teachers should design learning experiences that emphasize meaningful problem solving, guided practice, reflective activities, and constructive feedback to strengthen students' mathematical self-efficacy. Such instructional strategies are expected to enhance students' confidence while simultaneously fostering stronger critical thinking skills and more effective mathematical reasoning.

CONCLUSION

This study investigated the structural relationships among learning motivation, mathematical self- efficacy, and students' critical thinking skills in solving Pythagorean mathematics problems using. Structural Equation Modeling (SEM). Overall, the measurement model demonstrated generally acceptable psychometric properties. The results indicated adequate sampling adequacy and satisfactory construct reliability across the three latent constructs. Convergent validity was fully supported for the Mathematical Self-Efficacy and Critical Thinking constructs, whereas the Learning. Motivation construct exhibited acceptable reliability but a slightly lower Average Variance Extracted (AVE) than the recommended threshold. Considering the relatively small sample size and the model re-specification based on theoretically justified modification indices, these findings should be interpreted with appropriate caution. Nevertheless, the measurement model provides sufficient empirical support for subsequent structural model analysis. After model reanalysis, the structural model achieved acceptable goodness-of-fit, indicating that the proposed model was sufficiently supported by the empirical data. The findings reveal that mathematical self-efficacy is a significant predictor of students' critical thinking skills, whereas learning motivation does not contribute positively when analyzed simultaneously with mathematical self-efficacy in the structural model. These findings indicate that students' confidence in their mathematical capabilities plays a more immediate role in fostering critical thinking than their general willingness to learn. Students who believe they are capable of solving mathematical problems tend to demonstrate greater persistence, analytical reasoning, and reflective thinking when confronting complex mathematical tasks. The main contribution of this study lies in demonstrating the relative influence of learning motivation and mathematical self-efficacy within a single structural model. Unlike previous studies that primarily examined these variables independently, this study provides empirical evidence that mathematical self-efficacy represents the more proximal affective factor associated with students' critical thinking skills. These findings enrich the theoretical understanding of affective factors in mathematics education and suggest that efforts to improve students' critical thinking should prioritize strengthening mathematical self-efficacy alongside maintaining students' learning motivation.

AUTHOR CONTRIBUTIONS STATEMENT

Nanang Khuzaini contributed to the conceptualization of the study, research design, instrument development, data collection, data analysis using Structural Equation Modeling (SEM), interpretation of the findings, and manuscript drafting. Nuryadi contributed to the methodological framework, statistical analysis, interpretation of the SEM results, and critical revision of the manuscript. Muhammad Irfan Rumasoreng contributed to the theoretical framework, validation of the research instruments, interpretation of the findings, and manuscript review. Muhammad Farid Nasrulloh contributed to data validation, literature review, interpretation of the results, and manuscript editing. Arie Purwanto contributed to research supervision, methodological guidance, critical review of the manuscript, and final approval of the version to be published. All authors have read and approved the final manuscript and agree to be accountable for all aspects of the work.

REFERENCES

Abdulla, H. M., & Ibrahim, M. A. (2023). The impact of urban spatial plan on land value: An approach system to relating space syntax premises to the land price. *Sustainability*, *15(9).* https://doi.org/10.3390/su15097239

Agusman, A., Purwanto, P., & Rahardi, R. (2025). An exploration of critical thinking stages of junior high school students in solving contradictory mathematical problems. *JRAMathEdu (Journal of Research and Advances in Mathematics Education)*, *10*(3), 200–217. https://doi.org/10.23917/jramathedu.v10i3.8911

Alotaibi, S. S. (2020). Identifying the relationship between academic self-motivation and the mathematical thinking: A case study of secondary school students. *Universal Journal of Educational Research*, *8*(12A), 7239–7245. https://doi.org/10.13189/ujer.2020.082506

Bachtiar, A. H., Pribadi, N. W., & Khasanah, F. (2025). Exploring the impact of discovery learning and self-efficacy on students' critical thinking skills. *AL-ISHLAH: Jurnal Pendidikan*, *17*(4), 5950–5961. https://doi.org/10.35445/alishlah.v17i4.7134

Bhatt, B. S. (2025). Teaching methods and learning environments as catalysts for critical thinking: A social cognitive approach in Japanese junior high schools. *American Journal of STEM Education*, *12*, 47–66. https://doi.org/10.32674/m84k6807

Cahyani, V. F., & Setyaningsih, R. (2024). The implementation of problem-based learning to enhance critical thinking skills in solving contextual mathematics problems. *DIDAKTIKA : Jurnal Penelitian Tindakan Kelas*, *2*(2), 51–56. https://doi.org/10.63757/jptk.v2i2.29

Chan, C. T., Eu, L. K., & Zulnaidi, H. (2022). Measurement model and adaptation of self-efficacy toward mathematics reasoning among university students. *Asian Social Science and Humanities Research Journal (ASHREJ)*, *4*(1), 37–43. https://doi.org/10.37698/ashrej.v4i1.114

Chiu, M.-S., Lin, F.-L., Yang, K.-L., Hasumi, T., Wu, T.-J., & Lin, P.-S. (2022). The interplay of affect and cognition in the mathematics grounding activity: Forming an affective teaching model. *Eurasia Journal of Mathematics, Science and Technology Education*, 18(12), em2187. https://doi.org/10.29333/ejmste/12579

Dai, L., Jin, W., Zhu, B., Liao, R., Xu, G., Jiang, H., & Guan, J. (2025). Exploring the role of social media in mathematics learning: Effects on self-efficacy, interest, and self-regulation. *BMC Psychology*, *13*(1), 829. https://doi.org/10.1186/s40359-025-03192-z

Daniel, K., Msambwa, M. M., Antony, F., & Wan, X. (2024). Motivate students for better academic achievement: A systematic review of blended innovative teaching and its impact on learning. *Computer Applications in Engineering Education*, *32*(4), e22733. https://doi.org/10.1002/cae.22733

DiNapoli, J. (2023). Distinguishing between grit, persistence, and perseverance for learning mathematics with understanding. *Education Sciences*, *13(4).* https://doi.org/10.3390/educsci13040402

Dulun, Ö., & Lane, J. F. (2023). Supporting critical thinking skills needed for the International Baccalaureate Diploma Programme: A content analysis of a national and two international education programs in Turkey. *Thinking Skills and Creativity*, *47*, 101211. https://doi.org/10.1016/j.tsc.2022.101211

Gabriel, F., Buckley, S., & Barthakur, A. (2020). The impact of mathematics anxiety on self-regulated learning and mathematical literacy. *Australian Journal of Education*, *64*(3), 227–242. https://doi.org/10.1177/0004944120947881

Granello, F., Cuder, A., Doz, E., Pellizzoni, S., & Passolunghi, M. C. (2026). "I can do math!": A self-regulated learning intervention to enhance math-related motivational factors and performance in middle school. *British Journal of Educational Psychology*, *96*(2), 501–521. https://doi.org/10.1111/bjep.70034

Grigg, S., Perera, H. N., McIlveen, P., & Svetleff, Z. (2018). Relations among math self efficacy, interest, intentions, and achievement: A social cognitive perspective. *Contemporary Educational Psychology*, *53*, 73–86. https://doi.org/10.1016/j.cedpsych.2018.01.007

Hellín, C. J., Calles-Esteban, F., Valledor, A., Gómez, J., Otón-Tortosa, S., & Tayebi, A. (2023). Enhancing student motivation and engagement through a gamified learning environment. *Sustainability*, *15(19).* https://doi.org/10.3390/su151914119

Huang, X., Mayer, R. E., & Usher, E. L. (2020). Better together: Effects of four self-efficacy-building strategies on online statistical learning. *Contemporary Educational Psychology*, *63*, 101924. https://doi.org/10.1016/j.cedpsych.2020.101924

Ismail, I., Jamaluddin, A. B., Muis, A., Pratiwi, A. C., Palennari, M., & Adnan, A. (2026). Cultivating innovation readiness in biology education: The mediating roles of plant attitudes and scientific argumentation in deep learning and cognitive flexibility. *Qubahan Academic Journal*, *6*(2), 157–176. https://doi.org/10.48161/qaj.v6n2a2429

Jiang, R., Liu, R., Star, J., Zhen, R., Wang, J., Hong, W., Jiang, S., Sun, Y., & Fu, X. (2021). How mathematics anxiety affects students' inflexible perseverance in mathematics problem-solving: Examining the mediating role of cognitive reflection. *British Journal of Educational Psychology*, *91*(1), e12364. https://doi.org/10.1111/bjep.12364

Kholid, M. N., Mahmudah, M. H., Ishartono, N., Putra, F. G., & Forthmann, B. (2024). Classification of students' creative thinking for non-routine mathematical problems. *Cogent Education*, *11*(1), 2394738. https://doi.org/10.1080/2331186X.2024.2394738

Kitsantas, A., Cleary, T. J., Whitehead, A., & Cheema, J. (2021). Relations among classroom context, student motivation, and mathematics literacy: A social cognitive perspective. *Metacognition and Learning*, *16*(2), 255–273. https://doi.org/10.1007/s11409-020-09249-1

Kurniawan, H., Darmono, P. B., Mursalin, M., Shang, Y., Weinhandl, R., & Sharm, R. (2022). Describe mathematical creative thinking skills and problem-solving strategies by prospective teacher students on non-routine problems. *International Journal of Trends in Mathematics Education Research*, *5*(2), 119–124. https://doi.org/10.33122/ijtmer.v5i2.140

Li, Y., Li, X., Zhu, D., & Guo, H. (2020). Cultivation of the students' critical thinking ability in numerical control machining course based on the virtual simulation system teaching method. *IEEE Access*, *8*, 173584–173598. https://doi.org/10.1109/ACCESS.2020.3025079

Liu, Z., Guo, H., Zhou, Z., Ma, F., & Zeng, Y. (2025). How creative self-efficacy influences problem-solving skills in engineering education: The dual mediating role of critical thinking and metacognition. *BMC Psychology*, *13*(1), 1278. https://doi.org/10.1186/s40359-025-03630-y

Lugosi, E., & Uribe, G. (2022). Active learning strategies with positive effects on students' achievements in undergraduate mathematics education. *International Journal of Mathematical Education in Science and Technology*, *53*(2), 403–424. https://doi.org/10.1080/0020739X.2020.1773555

Lyu, B., Li, C., Li, H., & Xing, W. (2025). The effects of text-based conversational teachable agents' communicative features on student math learning: Tone style and emoji use. *Journal of Research on Technology in Education*, *0*(0), 1–23. https://doi.org/10.1080/15391523.2025.2511313

Marlena, L., & Nugraheni, E. A. (2026). The correlation between self-efficacy and critical thinking skills of senior high school students on the Pythagorean Theorem material. *Mandalika Mathematics and Educations Journal*, *8*(1), 590–597. https://doi.org/10.29303/jm.v8i1.11587

Masitoh, L. F., & Fitriyani, H. (2018). Improving students mathematics self-efficacy through problem based learning. *Malikussaleh Journal of Mathematics Learning (MJML)*, *1*(1), 26–30. https://doi.org/10.29103/mjml.v1i1.679

Meng, Q., & Zhang, Q. (2023). The influence of academic self-efficacy on university students' academic performance: The mediating effect of academic engagement. *Sustainability*, *15(7).* https://doi.org/10.3390/su15075767

Namono, R., Hojops, O. J. P., & Tanui, S. (2024). Self-efficacy: Implications for university employees' innovativeness. *International Journal of Innovation Science*, *17*(5), 1235–1252. https://doi.org/10.1108/IJIS-05-2023-0106

Nuryadi, N., Sukestiyarno, Y. L., Suyitno, H., & Kharisudin, I. (2025). Self-efficacy, reflective thinking, and critical thinking: A structural equation modeling study among adolescents. *Islamic Guidance and Counseling Journal*, *8(2).* https://doi.org/10.25217/0020258684000

Okolie, U. C., Igwe, P. A., Mong, I. K., Nwosu, H. E., Kanu, C., & Ojemuyide, C. C. (2022). Enhancing students' critical thinking skills through engagement with innovative pedagogical practices in Global South. *Higher Education Research & Development*, *41*(4), 1184–1198. https://doi.org/10.1080/07294360.2021.1896482

Owens, D. C., Sadler, T. D., Barlow, A. T., & Smith-Walters, C. (2020). Student motivation from and resistance to active learning rooted in essential science practices. *Research in Science Education*, *50*(1), 253–277. https://doi.org/10.1007/s11165-017-9688-1

Pajares, F., & Miller, M. D. (1995). Mathematics self-efficacy and mathematics performances: The need for specificity of assessment. *Journal of Counseling Psychology*, *42*(2), 190–198. https://doi.org/10.1037/0022-0167.42.2.190

Paudel, K. C., & Ghimire, S. P. (2024). Mathematics self-efficacy among secondary level students. *Pragyaratna प्रज्ञारत्न*, *6*(1), 123–130. https://doi.org/10.3126/pragyaratna.v6i1.64544

Peng, R., & Fu, R. (2021). The effect of Chinese EFL students' learning motivation on learning outcomes within a blended learning environment. *Australasian Journal of Educational Technology*, *37*(6), 61–74. https://doi.org/10.14742/ajet.6235

Pitsia, V., Biggart, A., & Karakolidis, A. (2017). The role of students' self-beliefs, motivation and attitudes in predicting mathematics achievement: A multilevel analysis of the programme for international student assessment data. *Learning and Individual Differences*, *55*, 163–173. https://doi.org/10.1016/j.lindif.2017.03.014

Raes, A., Vanneste, P., Pieters, M., Windey, I., Van Den Noortgate, W., & Depaepe, F. (2020). Learning and instruction in the hybrid virtual classroom: An investigation of students' engagement and the effect of quizzes. *Computers & Education*, *143*, 103682. https://doi.org/10.1016/j.compedu.2019.103682

Rahmatin, T., Dahlan, J. A., & Jupri, A. (2025). Students' mathematical creative thinking and learning obstacles in solving ill-structured exponential problems. *Jurnal Didaktik Matematika*, *12*(1), 53–74. https://doi.org/10.24815/jdm.v12i1.43834

Robinson, K. A. (2023). Motivational climate theory: Disentangling definitions and roles of classroom motivational support, climate, and microclimates. *Educational Psychologist*, *58*(2), 92–110. https://doi.org/10.1080/00461520.2023.2198011

Sachdeva, S., & Eggen, P.-O. (2021). Learners' critical thinking about learning mathematics. *International Electronic Journal of Mathematics Education*, *16*(3), em0644. https://doi.org/10.29333/iejme/11003

Schunk, D. H., & DiBenedetto, M. K. (2021). Self-regulation, self-efficacy, and learning disabilities. In S. Misciagna (Ed.), *Learning disabilities—Neurobiology, assessment, clinical features and treatments*. IntechOpen. https://doi.org/10.5772/intechopen.99570

Shanta, S., & Wells, J. G. (2022). Zzprot9zz design based learning: Assessing student critical thinking and problem solving abilities. *International Journal of Technology and Design Education*, *32*(1), 267–285. https://doi.org/10.1007/s10798–020–09608–8

Shone, E. T., Weldemeskel, F. M., & Worku, B. N. (2024). The role of students' mathematics perception and self-efficacy toward their mathematics achievement. *Psychology in the Schools*, *61*(1), 103–122. https://doi.org/10.1002/pits.23033

Shwartz, H., & Fuchs, A. (2025). The cognitive distinctions between mathematical problem-solving and problem-posing processes. *Gaia*, *1*(1), 37.

Street, K. E. S., Malmberg, L.-E., & Stylianides, G. J. (2022). Changes in students' self-efficacy when learning a new topic in mathematics: A micro-longitudinal study. *Educational Studies in Mathematics*, *111*(3), 515–541. https://doi.org/10.1007/s10649–022–10165–1

Sudiartini, N. P., Suastika, I. N., & Parmiti, D. P. (2025). How does self-efficacy moderate the effect of guided inquiry learning on sixth-grade students' critical thinking skills in science? psychology, evaluation, and technology in educational research, 7(2), 292–302. https://doi.org/10.33292/petier.v7i2.304

Suhartini, T., Hendriana, H., & Putra, H. D. (2025). How students' self-efficacy can affect their mathematical critical thinking ability? (jiml) journal of innovative mathematics learning, 8(3), 503–509. https://doi.org/10.22460/jiml.v8i3.26650

Supriadi, N., Jamaluddin Z, W., & Suherman, S. (2024). The role of learning anxiety and mathematical reasoning as predictor of promoting learning motivation: The mediating role of mathematical problem solving. *Thinking Skills and Creativity*, *52*, 101497. https://doi.org/10.1016/j.tsc.2024.101497

Szabo, Z. K., Körtesi, P., Guncaga, J., Szabo, D., & Neag, R. (2020). Examples of problem-solving strategies in mathematics education supporting the sustainability of 21st-century skills. *Sustainability*, *12(23).* https://doi.org/10.3390/su122310113

Tanami, Y., & Tzuriel, D. (2026). Prediction of math achievements by executive functions and math self-efficacy among grade 12 students in three study levels. *Frontiers in Education*, *11.* https://doi.org/10.3389/feduc.2026.1696182

Tay, L. Y., Chan, M., Chong, S. K., Tan, J. Y., & Aiyoob, T. B. (2024). Learning of mathematics: A metacognitive experiences perspective. *International Journal of Science and Mathematics Education*, *22*(3), 561–583. https://doi.org/10.1007/s10763–023–10385–8

Tee, K. N., Leong, K. E., & Abdul Rahim, S. S. (2021). A self-regulation model of mathematics achievement for eleventh-grade students. *International Journal of Science and Mathematics Education*, *19*(3), 619–637. https://doi.org/10.1007/s10763–020–10076–8

Voica, C., Singer, F. M., & Stan, E. (2020). How are motivation and self-efficacy interacting in problem-solving and problem-posing? educational studies in mathematics, 105(3), 487–517. https://doi.org/10.1007/s10649–020–10005–0

Wu, M., Liu, Y., Guo, J., & Talib, O. (2026). Why does feedback work? unpacking the serial mediation of emotion regulation and discourse skills in mathematics. *Frontiers in Psychology*, *17.* https://doi.org/10.3389/fpsyg.2026.1854668

Yang, Y., Maeda, Y., & Gentry, M. (2024). The relationship between mathematics self-efficacy and mathematics achievement: Multilevel analysis with NAEP 2019. *Large-Scale Assessments in Education*, *12*(1), 16. https://doi.org/10.1186/s40536–024–00204-z

Yulianto, D., Umami, M. R., & Mony, R. S. (2024). Fostering critical thinking and self-efficacy in mathematics students: Exploring the impact of contextual learning and problem-based learning as well as direct instruction. *Union: Jurnal Ilmiah Pendidikan Matematika*, *12*(1), 116–133. https://doi.org/10.30738/union.v12i1.16900

Yuliyanto, A., Turmudi, T., Putri, H. E., Muqodas, I., & Rahayu, P. (2021). The mathematical self-efficacy instruments for elementary school students. *Journal of Physics: Conference Series*, *1987*(1), 012023. https://doi.org/10.1088/1742–6596/1987/1/012023

Zakariya, Y. F. (2022). Improving students' mathematics self-efficacy: A systematic review of intervention studies. *Frontiers in Psychology*, *13.* https://doi.org/10.3389/fpsyg.2022.986622

Zhu, Y., Zhang, J. H., Au, W., & Yates, G. (2020). University students' online learning attitudes and continuous intention to undertake online courses: A self-regulated learning perspective. *Educational Technology Research and Development*, *68*(3), 1485–1519. https://doi.org/10.1007/s11423–020–09753-w

Zlatkin-Troitschanskaia, O., Beck, K., Fischer, J., Braunheim, D., Schmidt, S., & Shavelson, R. J. (2020). The role of students' beliefs when critically reasoning from multiple contradictory sources of information in performance assessments. *Frontiers in Psychology*, *11.* https://doi.org/10.3389/fpsyg.2020.02192

Zou, L., Zhang, Z., Mavilidi, M., Chen, Y., Herold, F., Ouwehand, K., & Paas, F. (2025). The synergy of embodied cognition and cognitive load theory for optimized learning. *Nature Human Behaviour*, *9*(5), 877–885. https://doi.org/10.1038/s41562–025–02152–2

Zuo, S., Huang, Q., & Qi, C. (2024). The relationship between cognitive activation and mathematics achievement: Mediating roles of self-efficacy and mathematics anxiety. *Current Psychology*, *43*(39), 30794–30805. https://doi.org/10.1007/s12144–024–06700–3