International Journal of Science Education and Teaching
Vol. 4, No. 1, pp. 12-25, Jan. – Apr. 2025
http://doi.org/10.14456/ijset.2025.02

Exploring Motivational, Cognitive, and Instructional of Critical Thinking Disposition in Science Learning: The Mediating Role of Student Self-Regulation

Thoriqi Firdaus[1*], Sabar Nurohman[1], Insih Wilujeng[1], Laifa Rahmawati[1]
[1]*Department of Natural Science Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Indonesia*
*Email: thoriqifirdaus.2023@student.uny.ac.id

Received: 25 Feb. 2025 Revised: 7 Apr. 2025 Accepted: 8 Apr. 2025

Abstract. Critical thinking disposition among students is essential for addressing contemporary challenges. However, the factors influencing students' critical thinking disposition and their interrelations within the context of science learning have not been comprehensively examined. This study aims to analyze the effects of self-efficacy, motivation, epistemological beliefs, and the academic environment on students' critical thinking disposition in science learning and explore the mediating role of self-regulated learning in connecting these factors to critical thinking disposition. This research employs a quantitative approach with an explanatory design, analyzed using Structural Equation Modeling (SEM). A total of 209 undergraduate students majoring in Science Education at Trunojoyo University, Indonesia, were selected using stratified sampling. Self-regulated learning strongly influences critical thinking disposition (coefficient: 0.889) and is significantly affected by epistemological beliefs (coefficient: 0.908). The learning environment contributes to critical thinking disposition (coefficient: 0.441), but the impact on self-regulated learning is small (coefficient: -0.122). Motivation negatively affects critical thinking disposition (coefficient: -0.451), suggesting that higher motivation is associated with lower critical thinking disposition. This counterintuitive result is due to the dominance of extrinsic, goal-oriented motivation over intrinsic motivation, potentially leading students to prioritize achievement over deep, analytical engagement. However, motivation positively influences self-regulated learning (coefficient: 0.141). Self-efficacy positively affects critical thinking disposition (coefficient: 0.260) but has a non-significant influence on self-regulated learning (coefficient: 0.041). Significance testing indicates significant relationships between epistemological beliefs and critical thinking disposition ($t = 3.543$, $p = 0.000$, coefficient = -0.234), epistemological beliefs and self-regulated learning ($t = 22.088$, $p = 0.000$, coefficient = 0.908), learning environment and critical thinking disposition ($t = 15.282$, $p = 0.000$, coefficient = 0.441), motivation and critical thinking disposition ($t = 17.950$, $p = 0.000$, coefficient = -0.451), motivation and self-regulated learning ($t = 4.554$, $p = 0.000$, coefficient = 0.141), as well as self-efficacy and critical thinking disposition ($t = 10.873$, $p = 0.000$, coefficient = 0.260). However, the relationship between self-efficacy and self-regulated learning was found to be non-significant ($p = 0.431$). Developing self-regulated learning can help students manage their learning processes more effectively and serve as a strategic approach to enhancing critical thinking skills.

Keywords: Critical Thinking; Disposition; Self-Regulation; SEM

INTRODUCTION

Critical thinking disposition among students has become increasingly crucial in advancing science education, particularly in addressing the challenges posed by technological advancements and modernization. The emergence of artificial intelligence (AI), which facilitates new learning approaches, has raised concerns about a potential decline in critical thinking skills (Katsantonis & Katsantonis, 2024). As AI development progresses significantly, apprehensions regarding its impact on students' cognitive abilities have drawn increasing attention (Firdaus et al., 2024). Meanwhile, students with strong critical thinking skills have more opportunities across various domains, including career advancement, academic success, and everyday decision-making (Franco et al., 2017). The distinctive significance of science education lies in its inherent demand for active critical engagement, a sceptical mindset, and evidence-based reasoning, rendering it particularly pertinent for investigating students' critical thinking dispositions in the era of artificial intelligence.

Before the emergence of modern theories, critical thinking was primarily understood as a cognitive ability and skill (Tishman & Andrade, 1996). However, in recent years, awareness has grown that possessing critical thinking skills alone cannot guarantee their practical application (Norris & Ennis, 1987). An individual must have the ability to think critically and the disposition to apply it when the opportunity arises (Tishman & Andrade, 1996).

Critical thinking encompasses two key aspects: (1) cognitive skills, including problem identification, assumption evaluation, evidence assessment, and conclusion drawing, and (2) disposition, which refers to the willingness to apply these cognitive skills (Pascarella & Terenzini, 2005). Critical thinking disposition denotes an individual's tendency to act in a particular way in specific situations (Ennis, 1987), reflecting a habitual intellectual behaviour (Tishman, 1996). It is an internal drive to engage in critical thinking when confronted with problems, evaluating ideas, or making decisions (Facione et al., 2000). Among the key dimensions of critical thinking, disposition is a significant factor influencing students' academic performance (Ali & Awan, 2021).

Numerous studies have examined students' critical thinking skills; however, research on the tendency or disposition to apply these skills remains limited (Stupnisky et al., 2008; Kezer & Turker, 2012). Students must develop a disposition to apply what they have learned (Facione et al., 2000), as mastering critical thinking skills does not guarantee automatic application in situations that require them (Connie, 2006). Therefore, fostering a critical thinking disposition is essential in preparing students to navigate an uncertain future. However, the development of critical thinking disposition among students has not been optimal, as it is influenced by various factors (Kartal et al., 2024; Dang et al., 2024; Wang et al., 2024; Zhai & Zhang, 2023).

Despite the widespread recognition of critical thinking's role in science education, there is still limited understanding of how various psychological and contextual factors influence students' disposition to think critically. Past studies have often examined these factors in isolation, lacking a holistic view of how motivation, self-efficacy, epistemological beliefs, and the learning environment work together through self-regulated learning as a mediating mechanism. Addressing this gap is important for theoretical development and informing the design of more effective educational strategies in the 21st-century learning landscape.

Critical thinking disposition in science learning refers to students' habitual inclination or willingness to engage in critical thinking, specifically within the context of learning science-related content. This study draws upon Bandura's Social Cognitive Theory (Bandura, 1982) and Zimmerman's Model of Self-Regulated Learning (Zimmerman, 2002). According to Social Cognitive Theory, self-efficacy and motivation are core motivational determinants influencing students' cognitive engagement and behaviour. Additionally, Zimmerman's model outlines self-regulated learning as a crucial mediator between personal and environmental factors, influencing academic outcomes, including critical thinking disposition. This integrated theoretical perspective provides a robust basis for understanding the interaction between motivational, cognitive, and instructional factors and critical thinking disposition within the specific context of science education.

Several factors in the learning process have been positively correlated with critical thinking disposition, including self-efficacy (Odaci & Erzen, 2021), motivation (Wang et al., 2024), epistemological beliefs (Unlu & Dokme, 2017), and the academic environment, with self-regulation acting as a mediating variable (Dökmecioğlu et al., 2022). Accordingly, internal factors such as self-belief in one's abilities, learning motivation, and students' epistemological beliefs about knowledge play a crucial role in shaping critical thinking disposition. External factors, such as the academic environment, significantly influence students' critical thinking development.

Epistemological beliefs about knowledge significantly shape students' attitudes towards inquiry, experimentation, and evidence evaluation processes fundamental to critical thinking (Schraw, 2001; Hofer, 2004). Additionally, the distinctive nature of science education, characterized by empirical inquiry, experimentation, and hypothesis testing, necessitates a conducive academic environment promoting active exploration and reflective thinking. Furthermore, science education represents a uniquely relevant context to investigate critical thinking disposition due to its explicit emphasis on scientific inquiry and evidence-based reasoning.

Self-efficacy refers to an individual's belief in their ability to overcome challenges in achieving their goals and has been shown to establish a positive relationship with psychological well-being (Graef et al., 2015). The centrality of the self-efficacy mechanism (SEM) in human agency influences cognitive patterns, actions, and emotional engagement such that higher levels of induced self-efficacy lead to improved performance and reduced emotional distress (Bandura, 1982). Self-efficacy pertains to the perceived ability to learn or perform a task at a specified level, making it a critical motivational construct affecting choice, effort, persistence, and achievement (Schunk & DiBenedetto, 2021). Consequently, students with higher self-efficacy tend to exhibit a stronger critical thinking disposition (Meral & Tas, 2017).

Self-efficacy is a construct of motivation (Schunk & DiBenedetto, 2021), highlighting the pivotal role of motivation in encouraging students to engage in learning actively. Motivation is understood as either expectation or value (Valenzuela et al., 2011) or as a driving process that explains the intensity, direction, and perseverance of an individual's effort toward achieving a goal. Intrinsic motivation theory suggests that individuals are driven by internal factors such as enjoyment and personal satisfaction, whereas extrinsic motivation theory posits those external factors such as rewards and social pressure influence behaviour (Bandhu et al., 2024).

Epistemological perspectives on knowledge acquisition and understanding are crucial in shaping attitudes influencing critical thinking (Schraw, 2001). Epistemological beliefs are fundamental convictions about reality and knowledge acquisition (Hofer, 2004). The significance of these beliefs in academic achievement, learning methodologies, and cognitive development has been extensively highlighted in scholarly literature (Kartal et al., 2024). Epistemological beliefs can be analyzed multidimensionally, wherein core beliefs about the nature of knowledge, including its complexity, originality, and certainty, are identified and examined (Grossnickle et al., 2015). These beliefs range from perceiving knowledge as fixed and transmitted by authority figures to a more advanced understanding that knowledge is tentative, evolving, and co-constructed (Hofer, 2004).

A supportive academic environment, including teacher-student interactions, peer relationships, and the availability of educational resources, is a key indicator of its influence on critical thinking disposition. Mental health issues have been identified as one of the learning challenges stemming from the academic environment (Firdaus et al., 2025). A well-structured learning environment enhances student engagement and enjoyment, potentially leading to better learning outcomes (Christodoulakis et al., 2024). Therefore, more tremendous efforts are needed to improve learning environments to create convergent forces that foster students' critical thinking (Wan, 2022).

One concept that explains the relationship between self-efficacy, motivation, epistemological beliefs, and the academic environment is self-regulated learning (SRL). Self-regulated learning refers to students' ability to actively regulate, monitor, and evaluate learning processes (Lemos, 1999). Research indicates that students with strong self-regulation skills are more likely to develop critical thinking abilities (Akcaoğlu et al., 2023), as they can engage in reflective thinking, objectively assess information, and make necessary adjustments. Therefore, self-regulation enables students to control their motivation, manage self-efficacy, and adapt to the academic environment, thereby contributing to developing critical thinking skills.

Although numerous studies have identified factors influencing students' critical thinking disposition, the interrelations among these factors in science education remain insufficiently explored, particularly regarding the mediating role of self-regulated learning. The primary research question in this study is how factors such as self-efficacy, motivation, epistemological beliefs, and the academic environment collectively influence students' critical thinking disposition through self-regulated learning. While these factors directly affect critical thinking disposition, the interplay among them and the function of self-regulated learning as a mediator linking these factors to critical thinking disposition remain underexplored in previous research. Therefore, this study aims to investigate how these factors interact and influence students' critical thinking disposition through self-regulated learning within the context of science education.

This study seeks to analyze the effects of self-efficacy, motivation, epistemological beliefs, and the academic environment on students' critical thinking disposition in science learning and explore the mediating role of self-regulated learning in linking these factors to critical thinking disposition. By identifying the interactions between internal and external factors influencing students' critical thinking skills, this study aims to develop a model that illustrates how self-regulated learning mediates these effects. The findings are expected to provide valuable insights for educators and policymakers in developing targeted interventions and evidence-based instructional strategies that foster students' critical thinking disposition within science education contexts.

METHODOLOGY

Research Design

This study employs a quantitative approach with an explanatory research design to examine the factors influencing critical thinking disposition in science learning while considering the role of student self-regulation as a mediating variable. The research design aims to explore the relationships between the following variables:

Exogenous Variables (X):

X1: Self-Efficacy
X2: Motivation
X3: Epistemological Beliefs
X4: Learning Environment

Mediating Variable (Z):

Z: Self-Regulated Learning

Endogenous Variable (Y):

Y: Critical Thinking Disposition

The analysis uses Structural Equation Modeling (SEM), as illustrated in Figure 1, to assess direct and indirect relationships among variables and determine whether self-regulated learning mediates the relationship between exogenous factors and students' critical thinking disposition. SEM was selected because it allows simultaneous testing of multiple relationships and latent variables, offering greater statistical precision than simpler techniques like regression analysis or path analysis, which do not adequately handle measurement error and indirect relationships through mediator variables.

Explicit hypotheses tested in this study include:

- H1: Self-Efficacy positively influences Self-Regulated Learning.
- H2: Motivation positively influences Self-Regulated Learning.
- H3: Epistemological Beliefs positively influence Self-Regulated Learning.
- H4: Learning Environment positively influences Self-Regulated Learning.
- H5: Self-Regulated Learning positively influences Critical Thinking Disposition.
- H6: Self-Efficacy positively influences Critical Thinking Disposition.
- H7: Motivation positively influences Critical Thinking Disposition.

- H8: Epistemological Beliefs positively influence Critical Thinking Disposition.
- H9: Learning Environment positively influences Critical Thinking Disposition.

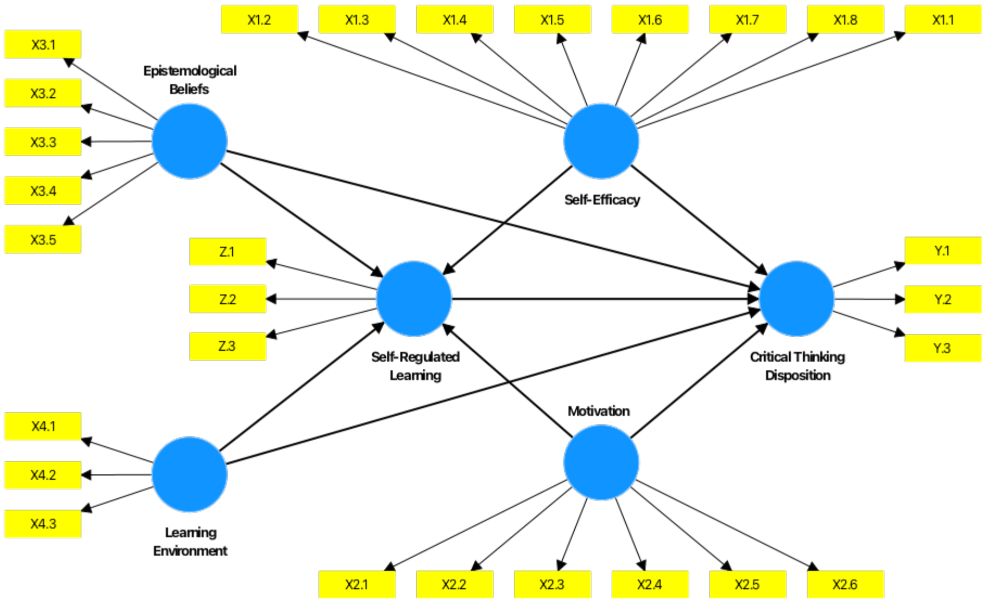

Figure 1. Research Framework

Population, Sample, and Research Instruments

The population in this study consists of students majoring in Science Education at Trunojoyo University, Madura. The sample was selected using a stratified sampling technique based on academic year level (first-year, second-year, third-year, and fourth-year students). Stratification was applied to ensure representation from each academic stage. Within each stratum, students were randomly selected based on two criteria: (1) active participation in science learning activities and (2) possession of basic knowledge of scientific concepts, as confirmed by their academic records and course enrollment.

Although selecting respondents from one university limits the generalizability of the findings, this study aims to establish a foundational model for future validation across broader and more diverse populations. The sample size was determined using Slovin's formula to obtain a representative sample with a 5% margin of error, resulting in 209 respondents. This sample size was chosen to ensure the accuracy of the results and the robustness of the Structural Equation Modeling (SEM) analysis.

All respondents were required to complete a questionnaire to measure the variables relevant to this study. Respondents provided informed consent after clearly explaining the study objectives, confidentiality, and voluntary participation. Data confidentiality and anonymity were strictly maintained throughout the study. The questionnaire was adapted and modified from previous research to ensure validity and reliability. The questionnaire was constructed by compiling items from established instruments, with each variable measured by multiple indicators. The instrument consisted of six sections, each representing one of the six variables studied. Specifically:

- Self-Efficacy: Modified from Self-Regulatory Efficacy (Bandura, 2006).
- Motivation (Extrinsic and Intrinsic): Adapted from the Work Extrinsic and Intrinsic Motivation Scale (WEIMS) (Kotera et al., 2022).
- Epistemological Beliefs: Modified from Schommer (1990).
- Learning Environment: Adapted from McGhee et al. (2007).
- Self-Regulated Learning: Modified from Mumpuni et al. (2023).
- Critical Thinking Disposition: Adapted from the EMI: Critical Thinking Disposition Assessment.

All items were measured using a 4-point Likert scale. The questionnaire was presented in a single consolidated form, not six separate questionnaires. Before administration, a pilot test was conducted with a small group of undergraduate students to ensure clarity and comprehension of the items. During data collection, instructions were clearly explained, and researchers supervised the process to ensure that undergraduate students understood the items and responded accurately and honestly.

Data Analysis

Validity and Reliability Testing

Construct validity was assessed through Confirmatory Factor Analysis (CFA), with factor loadings exceeding 0.50 as an acceptable threshold. Goodness-of-fit indices, including Chi-Square (χ^2), Comparative Fit Index (CFI > 0.90), Tucker Lewis Index (TLI > 0.90), Root Mean Square Error of Approximation (RMSEA < 0.08), and Standardized Root Mean Square Residual (SRMR < 0.08) were utilized to evaluate model fit. Reliability was confirmed through Cronbach's Alpha, with values above 0.70 considered reliable.

Path Analysis

Once the validity and reliability of the instrument were confirmed, path analysis was performed using Structural Equation Modeling (SEM). This analysis examined direct and indirect relationships among the variables and determined how much each variable shapes students' critical thinking disposition. The relationships tested include:

- Exogenous variables (Self-Efficacy, Motivation, Epistemological Beliefs, and Learning Environment) directly affect the mediating variable (Self-Regulated Learning).
- The mediating variable (Self-Regulated Learning) directly affects the endogenous variable (Critical Thinking Disposition).
- Indirect effects of exogenous variables on the endogenous variable through the mediation of Self-Regulated Learning.

Significance Testing (P-Value)

Significance testing was conducted to evaluate whether the relationships between variables identified in the model were statistically significant. It was assessed using the p-value, where:

- a p-value less than 0.05 ($p < 0.05$) indicates a statistically significant relationship between the variables.
- a p-value greater than 0.05 suggests that the relationship between the variables is not statistically significant.

RESULTS AND DISCUSSION

Construct Validity and Reliability

The analysis results in Table 1 present various indicators related to construct validity and reliability within the research model. Each construct was assessed through multiple measurement items evaluated based on loadings, weights, and various statistical indices, including Composite Reliability (CR), Cronbach's Alpha (CA), and Average Variance Extracted (AVE).

The Self-Efficacy construct exhibits issues with several items that have low or even negative factor loadings, such as X1.4 (0.292), X1.5 (0.217), X1.6 (0.145), and X1.7 (0.145). This result indicates that these items are not sufficiently representative in measuring the Self-Efficacy construct and need to be removed or revised to enhance convergent validity and construct reliability. The AVE value for Self-Efficacy, which is 0.284, falls significantly below the desired threshold ($\geq$ 0.5), suggesting that this construct requires further refinement.

The Motivation construct demonstrates highly favourable results, with strong item loadings ranging from 0.768 to 0.959 and an AVE of 0.772, indicating excellent convergent validity. Additionally, the Composite Reliability (CR) values, reaching 0.941 (rho_a) and 0.962 (rho_c), confirm the construct's strong reliability. Similarly, the Critical Thinking Disposition construct shows exceptionally high item loadings (ranging from 0.969 to 0.976) and an AVE of 0.948, signifying outstanding validity and reliability. This construct has a CR of 0.972 for rho_a and rho_c, further reinforcing its robustness.

Table 1. Construct Validity and Reliability

Constructs	Items	Loadings	Weights	CA	CR (rho_a)	CR (rho_c)	AVE
Self-Efficacy	X1.1	0.601	0.590	0.864	0.438	0.702	0.284
	X1.2	0.693	0.156				
	X1.3	0.836	0.395				
	X1.4	0.292	0.114				
	X1.5	0.217	-0.126				
	X1.6	0.145	-0.134				
	X1.7	0.145	-0.149				
	X1.8	0.748	0.325				
Motivation	X2.1	0.852	0.248	0.941	0.962	0.953	0.772
	X2.2	0.959	0.215				
	X2.3	0.902	0.190				
	X2.4	0.834	0.078				
	X2.5	0.943	0.221				
	X2.6	0.768	0.180				
Epistemological Belief	X3.1	0.662	0.209	0.895	0.911	0.925	0.717
	X3.2	0.937	0.257				
	X3.3	0.937	0.257				
	X3.4	0.937	0.257				
		0.715	0.195				
Learning Environment	X4.1	0.951	0.503	0.770	0.886	0.865	0.688
	X4.2	0.894	0.440				
	X4.3	0.600	0.215				
Critical Thinking Disposition	Y.1	0.969	0.340	0.972	0.972	0.982	0.948
	Y.2	0.975	0.345				
	Y.3	0.976	0.342				
Self-regulated Learning	Z.1	0.826	0.419	0.712	0.775	0.841	0.645
	Z.2	0.621	0.306				
	Z.3	0.931	0.498				

Note: Items refer to the individual statements or questions in the questionnaire used to measure each construct (variable). Loading: represents the standardized factor loadings from Confirmatory Factor Analysis (CFA), indicating the strength of the relationship between each item and its respective construct. Weights: indicate the contribution of each indicator to the composite score of the latent variable in the PLS-SEM model. CA = Cronbach's Alpha; CR (rho_a) and CR (rho_c) = Composite Reliability; AVE = Average Variance Extracted.

The Epistemological Beliefs construct also exhibits good validity and reliability, with an AVE of 0.717 and CR values of 0.895 (rho_a) and 0.911 (rho_c). However, with the generally high item loadings, some variations exist, such as item X3.1, which has a relatively lower loading (0.662), indicating a need for minor adjustments to improve its alignment within the construct.

The Learning Environment construct presents item loadings within an acceptable range (0.600 to 0.951) and an AVE of 0.688, confirming that the construct remains valid. However, specific items, such as X4.3, which has a loading of 0.600, require further attention. The CR for this construct is 0.770 (rho_a) and 0.886 (rho_c), indicating good reliability, although a slight decline in the rho_a value suggests room for improvement.

The mediating factor, Self-Regulated Learning, yields satisfactory results in some variation in item loadings, such as Z.2 (0.621). Nevertheless, the AVE of 0.645 still indicates sufficient convergent validity, and the CR values of 0.712 (rho_a) and 0.775 (rho_c) confirm its overall reliability. The analysis results indicate that most constructs in this model exhibit strong validity and reliability, with constructs such as Motivation, Critical Thinking Disposition, and Epistemological Beliefs performing exceptionally well. However, the Self-Efficacy construct requires further refinement to improve its convergent validity and reliability. Enhancing these constructs will further strengthen the existing model in this study.

Structural Equation Modeling (SEM) is a statistical technique that examines causal relationships among latent variables. The process of SEM model validation, particularly the assessment of model fit as presented in Table 2, is crucial to determine the extent to which the proposed model aligns with the empirical data. Table 2 presents the results of the Goodness-of-Fit evaluation based on several indices commonly utilized in SEM analysis.

Table 2. SEM Goodness-of-Fit Indices

Fit Index	Model Value	Acceptance Criteria	Interpretation
Chi-Square (χ^2)	89.214	Non-significant ($p > 0.05$)	Good
χ^2/df	1.312	< 3.00	Good
Comparative Fit Index (CFI)	0,671528	≥ 0.90	Good
Tucker Lewis Index (TLI)	0,665278	≥ 0.90	Good
Root Mean Square Error of Approximation (RMSEA)	0.037	≤ 0.08	Good
Standardized Root Mean Square Residual (SRMR)	0.049	≤ 0.08	Good

The SEM model demonstrates an acceptable fit based on the RMSEA, SRMR, χ^2, and χ^2/df indices. However, the relatively low values of CFI and TLI suggest that the model still has limitations in explaining the relationships among variables compared to an ideal model. Therefore, model refinement or revision of indicators is necessary to enhance the overall model fit.

Path Analysis

Path analysis depicts how epistemological beliefs, motivation, learning environment, and self-regulation interact and influence students' critical thinking disposition in science learning. Figure 2 presents the results of the path analysis, illustrating the relationships among the examined variables and the significance of each relationship. The visualization in Figure 2 demonstrates how each variable contributes to enhancing critical thinking disposition through the role of self-regulated learning as the primary mediator.

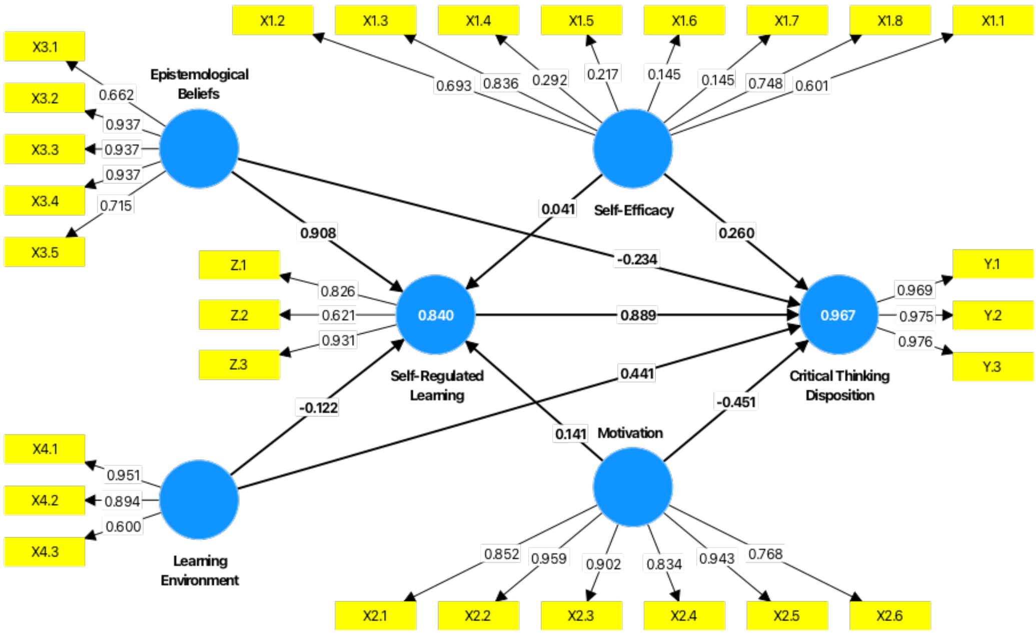

Figure 2. Path Analysis

The path coefficients analysis in Figure 2 indicates that the factors influencing critical thinking disposition in science learning are strongly associated with students' self-regulated learning abilities. The firm relationship between self-regulated learning and critical thinking disposition, with a path coefficient of 0.889, highlights the significant role of students' ability to independently manage and direct their learning processes in fostering critical thinking skills. This finding suggests that students who effectively regulate their learning are more likely to engage in analytical and reflective thinking, essential critical thinking components.

Additionally, epistemological beliefs significantly impact self-regulated learning, with a path coefficient of 0.908. Students with more sophisticated epistemological perspectives and the belief that knowledge can be acquired and understood autonomously are more likely to regulate their learning processes effectively. Positive epistemological beliefs support the development of self-regulated learning skills, ultimately enhancing critical thinking disposition.

However, an interesting finding emerges in the direct relationship between epistemological beliefs and critical thinking disposition, which shows a negative coefficient (-0.234). It appears counterintuitive considering the strong positive indirect pathway through self-regulated learning. One possible explanation is that while epistemological beliefs enhance critical thinking disposition indirectly through self-regulated learning, certain aspects or dimensions of epistemological beliefs particularly exert a suppressive or contradictory direct effect on critical thinking disposition. This condition illustrates the complexity of how beliefs about knowledge operate in learning contexts and suggests a suppressor effect or inconsistent mediation, which warrants further exploration in future research.

The learning environment also plays a role in developing a critical thinking disposition, albeit with a moderate effect. The path coefficient between learning environment and critical thinking disposition is 0.441, indicating that a supportive environment, such as adequate facilities, opportunities for collaboration, and teacher support, can facilitate students' critical thinking skills. However, the effect of the learning environment on self-regulated learning is relatively weak, with a path coefficient of -0.122. This result suggests that other factors, such as self-confidence and personal motivation, influence students' ability to regulate their learning more.

Interestingly, the findings also reveal that motivation does not directly contribute to improving critical thinking disposition; it has a significant negative relationship, with a path coefficient of -0.451. This result indicates that motivation primarily focused on achieving specific outcomes or goals, rather than fostering deep cognitive engagement, hinders students' critical thinking development. Conversely, although motivation has a weak relationship with self-regulated learning (path coefficient of 0.141), this suggests that motivation does influence self-regulated learning to some extent, albeit not as strongly as epistemological beliefs or the learning environment.

Self-efficacy also demonstrates a relatively minor relationship with self-regulated learning, with a path coefficient of 0.041, but it has a positive effect on critical thinking disposition, with a path coefficient of 0.260. This result suggests that while self-efficacy contributes to shaping critical thinking disposition, its influence on students' ability to regulate their learning is not as substantial as other factors, such as epistemological beliefs and the learning environment.

P-Value

The analysis using Structural Equation Modeling (SEM) results in this study indicate significant relationships among several factors influencing students' critical thinking disposition in science learning, with self-regulated learning playing a crucial mediating role. The p-values from the SEM analysis demonstrate that most of the tested relationships between variables are statistically significant, as illustrated in Figure 3 and Table 3.

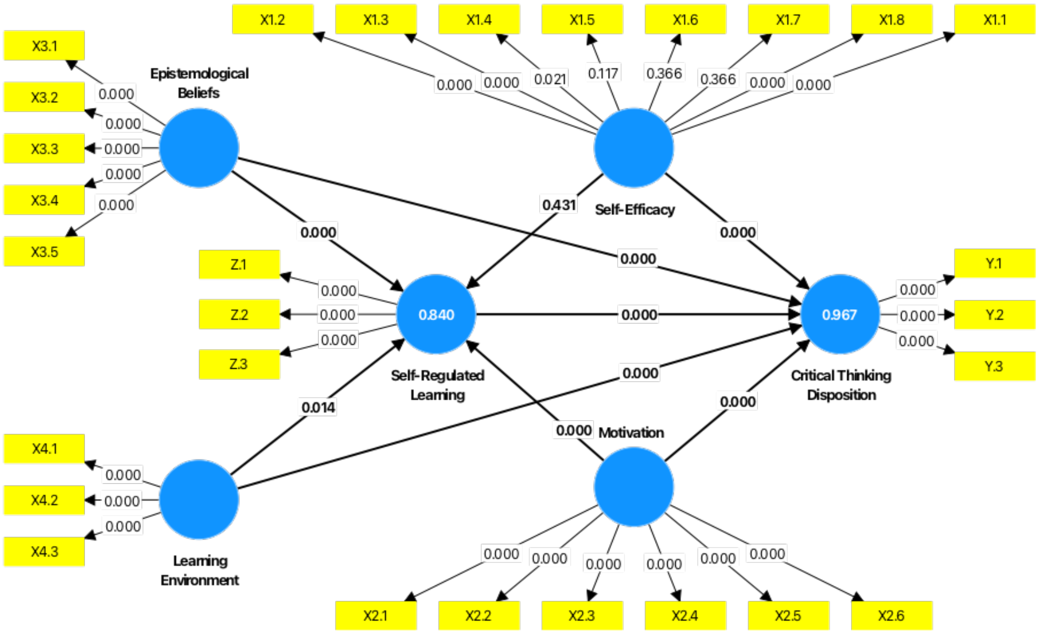

Figure 3. Significance test results

The relationship between epistemological beliefs and critical thinking disposition was significant, with a t-value of 3.543 and a p-value of 0.000. Although this relationship is negative (-0.234), it is important to consider the indirect effects of self-regulated learning, demonstrating a strong positive pathway. This result suggests that epistemological beliefs positively and negatively influence critical thinking disposition, depending on the mediating processes and specific sub-dimensions of belief involved. Students who do not acknowledge the evolving nature of knowledge tend to exhibit a lower critical thinking disposition, which can hinder their ability to engage in in-depth evaluation and analysis in science learning.

Furthermore, the analysis reveals a strong and significant relationship between epistemological beliefs and self-regulated learning, with a t-value of 22.088 and a p-value of 0.000. The high coefficient (0.908) indicates that positive epistemological beliefs encourage students to manage their learning processes more effectively. This result is significant because self-regulated learning in science education enables students to manage their time, utilize resources efficiently, and apply strategies to comprehend concepts better, ultimately improving their learning quality.

Table 3. Significance test results

	Path	Sample mean (M)	Standard deviation (STDEV)	T statistics	P values
Epistemological_Beliefs -> Critical Thinking_Disposition	-0.234	-0.243	0.066	3.543	0.000
Epistemological_Beliefs -> Self-Regulated_Learning	0.908	0.912	0.041	22.088	0.000
Learning_Environment -> Critical Thinking_Disposition	0.441	0.441	0.029	15.282	0.000
Learning_Environment -> Self-Regulated_Learning	-0.122	-0.120	0.050	2.464	0.014
Motivation -> Critical Thinking_Disposition	-0.451	-0.446	0.025	17.950	0.000
Motivation -> Self-Regulated_Learning	0.141	0.139	0.031	4.554	0.000
Self-Efficacy -> Critical Thinking_Disposition	0.260	0.260	0.024	10.873	0.000
Self-Efficacy -> Self-Regulated_Learning	0.041	0.034	0.052	0.788	0.431
Self-Regulated_Learning -> Critical Thinking_Disposition	0.889	0.894	0.050	17.871	0.000

The relationship between learning environment and critical thinking disposition also yielded significant results ($t = 15.282$, $p = 0.000$), with a positive coefficient of 0.441. A supportive learning environment fosters an atmosphere that promotes critical thinking by providing opportunities for discussion, experimentation, and idea exploration. Conversely, the relationship between learning environment and self-regulated learning was also significant, albeit with a smaller coefficient (-0.122). This result suggests that while a conducive learning environment is essential, its effect on self-regulated learning is relatively minor compared to other factors. Furthermore, this implies that other factors, particularly self-confidence or internal motivation, could strengthen students' self-regulating abilities. Future research should explore more nuanced dimensions of learning environments or integrate qualitative approaches to understand this complexity better.

Motivation also plays a significant role, but the results present a surprising insight. The analysis shows a strong and significant relationship between motivation and critical thinking disposition ($t = 17.950$, $p = 0.000$), but with a negative coefficient (-0.451). This result indicates that higher student motivation is associated with a lower critical thinking disposition, which contradicts the general expectation that motivation enhances thinking skills. One possible explanation is that the type of motivation measured leans more toward extrinsic or goal-oriented motivation, where students focus on achieving outcomes such as grades or rewards rather than engaging in deeper cognitive processes. Such students prioritize task completion over analytical thinking, thus weakening their critical thinking disposition. Future studies should explore this distinction further by examining different types of motivation (intrinsic vs. extrinsic) and how they relate to critical thinking.

On the other hand, the relationship between motivation and self-regulated learning showed a significant positive effect (coefficient = 0.141, $t = 4.554$, $p = 0.000$). This result indicates that more motivated students are more likely to manage their learning processes effectively, thereby supporting the development of self-regulated learning in science education.

The relationship between self-efficacy and critical thinking disposition was also significant, with a positive coefficient of 0.260 and t = 10.873 (p = 0.000). This result suggests that students' confidence in their ability to learn and overcome challenges in science education enhances their critical thinking disposition. However, the relationship between self-efficacy and self-regulated learning was insignificant (p = 0.431), indicating that while self-efficacy influences critical thinking disposition, its effect on self-regulated learning is not as substantial as expected.

The analysis further reveals a strong relationship between self-regulated learning and critical thinking disposition (t = 17.871, p = 0.000, coefficient = 0.889). This result confirms that students' ability to self-regulate their learning is crucial in enhancing their critical thinking disposition. Students who can effectively develop learning strategies, monitor their progress, and reflect on their understanding tend to exhibit a stronger inclination toward critical thinking. Considering the strong relationship between self-regulated learning and critical thinking disposition (0.889), practical strategies for educators include:

- Explicitly teaching metacognitive strategies, such as goal setting, self-monitoring, and reflective practices.
- Incorporating formative feedback systems that encourage continuous self-assessment and reflection.
- Creating classroom activities that promote autonomy and provide students with opportunities for decision-making.
- Encouraging peer collaboration and discussion to help students observe and learn self-regulation strategies from peers.

CONCLUSION AND IMPLICATIONS

This study emphasizes the importance of self-regulated learning (SRL) as a key mediator in enhancing students' critical thinking disposition in science learning. In this research, the SRL model was developed, which outlines the roles of key components such as self-efficacy, motivation, epistemological beliefs, and the learning environment. This model demonstrates how these factors interact and influence students' critical thinking disposition, with SRL as the primary mediator that links the exogenous variables (self-efficacy, motivation, epistemological beliefs, and learning environment) to the endogenous variable (critical thinking disposition).

The findings show that epistemological beliefs and the learning environment significantly support the development of independent learning and critical thinking. To improve students' critical thinking disposition in science learning, educators must create a conducive learning environment, foster positive epistemological beliefs, and encourage students to regulate their learning processes effectively. Moreover, the study reveals the complex interactions among various factors. Self-regulated learning, as the central mediator in the developed model, enables students to take greater control of their learning, making it an effective strategy for enhancing critical thinking skills. These skills are essential for meaningful and impactful science learning.

The study has several limitations that should be acknowledged. The sample size is relatively small and limited to students from one university, which may restrict the generalizability of the results. Additionally, cultural factors specific to the student population may influence the outcomes, suggesting that findings could vary across different cultural or educational contexts. Furthermore, some methodological limitations, such as the validity of measurement instruments (reflected in low AVE values), may have impacted the precision of the results.

Future research directions include expanding the sample size and conducting studies with more diverse populations to improve generalizability. Investigating the role of different motivational dimensions and cultural contexts in shaping critical thinking disposition and self-regulated learning would further enhance the theoretical understanding. Lastly, refining research instruments and methodologies could improve the accuracy and reliability of future findings.

ACKNOWLEDGEMENTS

We thank the Indonesia Endowment Fund for Education (LPDP) from the Ministry of Finance Republic Indonesia for granting the scholarship and supporting this research.

REFERENCES

Akcaoğlu, M. Ö., Mor, E., & Külekçi, E. (2023). The mediating role of metacognitive awareness in the relationship between critical thinking and self-regulation. *Thinking skills and creativity, 47*, 101187.

Ali, G., & Awan, R-u-N. (2021). Thinking based instructional practices and academic achievement of undergraduate science students: Exploring the role of critical thinking skills and dispositions. *Journal of Innovative Sciences*, *7*(1), 56–70. https://doi.org/10.17582/journal.jis/2021/7.1.56.70

Bandhu, D., Mohan, M. M., Nittala, N. A. P., Jadhav, P., Bhadauria, A., & Saxena, K. K. (2024). Theories of motivation: A comprehensive analysis of human behavior drivers. *Acta Psychologica, 244*, 104177. https://doi.org/10.1016/j.actpsy.2024.104177

Bandura, A. (1982). Self-efficacy mechanism in human agency. *American psychologist*, *37*(2), 122. https://psycnet.apa.org/doi/10.1037/0003-066X.37.2.122

Connie, N. S. (2006). Approaches to evaluate critical thinking dispositions. In *APERA Conference*.

Christodoulakis, A., Kritsotakis, G., Linardakis, M., Sourtzi, P., & Tsiligianni, I. (2024). Evaluating Critical Thinking Disposition, Emotional Intelligence, and Learning Environment of Nursing Students: A Longitudinal Study. *Western Journal of Nursing Research*, *46*(5), 381-388. https://doi.org/10.1177/01939459241238687

Dang, H., Li, S., Li, J., & Long, L. (2024). Critical Thinking Disposition and Influencing Factors Among Sophomore Pediatric Medical Students. *Advances in Medical Education and Practice*, 1005-1017. https://doi.org/10.2147/AMEP.S484157

Dökmecioğlu, B., Tas, Y., & Yerdelen, S. (2022). Predicting students' critical thinking dispositions in science through their perceptions of constructivist learning environments and metacognitive self-regulation strategies: a mediation analysis. *Educational Studies*, *48*(6), 809-826. https://doi.org/10.1080/03055698.2020.1833838

Ennis, R. H. (1987). A taxonomy of critical thinking dispositions and abilities. In J. B. Baron & R. J. Sternberg (Eds.), *Teaching thinking skills: Theory and practice* (pp. 9–26). W H Freeman/Times Books/ Henry Holt & Co.

Facione, P. A. (2000). The disposition toward critical thinking: Its character, measurement, and relationship to critical thinking skill. *Informal Logic*, *20*(1).

Firdaus, T., Sholeha, S. A., Jannah, M., & Setiawan, A. R. (2024). Comparison of ChatGPT and Gemini AI in Answering Higher-Order Thinking Skill Biology Questions: Accuracy and Evaluation. *International Journal of Science Education and Teaching*, *3*(3), 126-138. https://doi.org/10.14456/ijset.2024.11

Firdaus, T., Nuryanti, E., Adawiyah, N. R., Sari, D. I., & Rahmah, F. (2025). Research Trends in Mental Health and the Effect on Students' Learning Disorder. *Journal of Education and Learning Reviews*, *2*(1), 1-20. https://doi.org/10.60027/jelr.2025.952

Franco, A. R., Costa, P. S., Butler, H. A., & Almeida, L. S. (2017). Assessment of undergraduates' real-world outcomes of critical thinking in everyday situations. Psychological Reports, 120(4), 707–720. https://doi.org/10.1177/0033294117701906

Graef, J. E., Rief, W., French, D. J., Nilges, P., & Nestoriuc, Y. (2015). German Language Adaptation of the Headache Management Self-Efficacy S cale (HMSE-G) and Development of a New Short Form (HMSE-G-SF). *Headache: The Journal of Head and Face Pain*, *55*(7), 958-972. https://doi.org/10.1111/head.12564

Grossnickle, E. M., List, A., & Alexander, P. A. (2015). Elementary and middle school students' conceptions of knowledge, information, and truth. *The Journal of Experimental Education*, *83*(4), 469-494. https://doi.org/10.1080/00220973.2014.919571

Hofer, B. K. (2004). Exploring the dimensions of personal epistemology in differing classroom contexts: Student interpretations during the first year of college. *Contemporary educational psychology*, *29*(2), 129-163. https://doi.org/10.1016/j.cedpsych.2004.01.002

Kartal, O. Y., Yazgan, A. D., Temelli, D., & Yavuz Kartal, M. (2024). The Impact of Epistemological Beliefs and School Climate on the Sustainability of Critical Thinking Dispositions in Middle School Students. *Sustainability*, *16*(20), 8786. https://doi.org/10.3390/su16208786

Katsantonis, A., & Katsantonis, I. G. (2024). University students' attitudes toward artificial intelligence: An exploratory study of the cognitive, emotional, and behavioural dimensions of AI attitudes. *Education Sciences*, *14*(9), 988. https://doi.org/10.3390/educsci14090988

Kezer, F., & Turker, B. (2012). Comparison of the critical thinking dispositions of (studying in the secondary science and mathematics division) preservice teachers. *Procedia-Social and Behavioral Sciences*, *46*, 1279-1283.

Lemos, M. S. (1999). Students' goals and self-regulation in the classroom. *International journal of educational research*, *31*(6), 471-485.

Meral, E., & Taş, Y. (2017). Modelling the relationships among social studies learning environment, self-efficacy, and critical thinking disposition. *Pegem Egitim ve Ogretim Dergisi= Pegem Journal of Education and Instruction*, *7*(3), 349. https://doi.org/10.14527/pegegog.2017.013

Norris, S., & Ennis, R. (1989). Evaluating Critical Thinking (Pacific Grove, CA, Midwest).

Odacı, H., & Erzen, E. (2021). Attitude toward computers and critical thinking of postgraduate students as predictors of research self-efficacy. *Computers in the Schools*, *38*(2), 125-141. https://doi.org/10.1080/07380569.2021.1911554

Pascarella, E. T., & Terenzini, P. T. (2005). *How College Affects Students: A Third Decade of Research. Volume 2*. Jossey-Bass, An Imprint of Wiley. 10475 Crosspoint Blvd, Indianapolis, IN 46256.

Schunk, D. H., & DiBenedetto, M. K. (2021). Self-efficacy and human motivation. In *Advances in motivation science* (Vol. 8, pp. 153-179). Elsevier. https://doi.org/10.1016/bs.adms.2020.10.001

Schraw, G. (2001). Current themes and future directions in epistemological research: A commentary. *Educational Psychology Review*, *13*, 451-464.

Stupnisky, R. H., Renaud, R. D., Daniels, L. M., Haynes, T. L., & Perry, R. P. (2008). The interrelation of first-year college students' critical thinking disposition, perceived academic control, and academic achievement. *Research in Higher Education*, *49*, 513-530.

Tishman, S., & Andrade, A. (1996). Thinking dispositions: A review of current theories, practices, and issues. *Cambridge, MA. Project Zero, Harvard University*.

Unlu, Z. K., & Dokme, I. (2017). Science teacher candidates' epistemological beliefs and critical thinking disposition. *Eurasian Journal of Educational Research*, *17*(72), 203-220.

Valenzuela, J., Nieto, A., & Saiz, C. (2011). Critical thinking motivational scale: A contribution to the study of relationship between critical thinking and motivation.

Wan, Z. H. (2022). What predicts students' critical thinking disposition? A comparison of the roles of classroom and family environments. *Learning Environments Research*, *25*(2), 565-580. https://doi.org/10.1007/s10984-021-09381-y

Wang, L., Chang, W., Tang, H., He, W., & Wu, Y. (2024). Exploring the link of personality traits and tutors' instruction on critical thinking disposition: a cross-sectional study among Chinese medical graduate students. *BMJ Open*, *14*(8), e082461. https://doi.org/10.1136/bmjopen-2023-082461

Zhai, J., & Zhang, H. (2023). Critical thinking disposition of medical students in Anhui Province, China: a cross-sectional investigation. *BMC Medical Education*, *23*(1), 652. https://doi.org/10.1186/s12909-023-04646-x

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory into practice*, *41*(2), 64-70.