The Role of Internal Factors in Physics Learning Achievement: A Conceptual Model of Self-Efficacy, Motivation, Self-Regulated Learning, and Critical Thinking Skills

Desnita*, Nadia Alfianeta, Venny Mulyana, and Muhammad Dhanil

Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Padang, Indonesia
Email: desnita@fmipa.unp.ac.id (D.); nadiaalfianetta18@gmail.com (N.A.); vennymulyhana10@gmail.com (V.M.); muhammaddhanil22@gmail.com (M.D.)
*Corresponding author
Manuscript received June 13, 2025; revised July 22, 2025; accepted August 18, 2025; published January 20, 2026

***Abstract*—This study aimed to develop and test a conceptual model that describes the direct and indirect relationships among self-efficacy, motivation, self-regulated learning, and critical thinking skills, as well as their effects on students' physics learning achievement. The research employed a quantitative survey approach with 319 upper secondary students. Data was analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) to examine causal relationships among variables, measure the validity and reliability of the instruments, and assess the strength and significance of the paths in the conceptual model. The findings indicated that the instruments used were valid and reliable. The developed conceptual model successfully explained significant relationships between self-efficacy, motivation, self-regulated learning, and critical thinking skills and their impacts on students' physics learning achievement. The research revealed that self-efficacy, self-regulated learning, motivation, and critical thinking skills significantly affected students' physics learning achievement. Other findings indicated a relationship among the various factors. Self-efficacy and motivation affect critical thinking skills, while motivation positively affects self-regulated learning. In general, these findings have important implications for educators and policymakers to consider the internal factors of students when designing more effective learning strategies to support the improvement of learning achievement.**

***Keywords*—conceptual learning models, critical thinking skills, physics learning, self-efficacy**

I. Introduction

As a branch of science, physics plays an important role in shaping students' scientific understanding. A solid command of physics education can support improving students' learning achievements. Furthermore, students with a good understanding of physics tend to possess higher logical and analytical skills [1]. This competency is essential for competing in a global era that demands problem-solving abilities and critical thinking [2]. Therefore, proficiency in physics is important for academic results and the development of 21st-century skills [3].

The results of measuring the learning achievement of Indonesian students in science, including physics, were still considered low on a global scale. The Programme for International Student Assessment (PISA) 2022 results indicated that the science skills of Indonesian students were below the threshold value, which was categorized as low [4]. These results indicated that students' mastery of concepts and skills in physics was not yet optimal. This low achievement reflected the lack of effectiveness of the teaching approaches that had been applied so far [5]. The weak mastery of physics certainly affects students' competitiveness in the international arena. This situation is a significant concern in the education sector, particularly in terms of improving the quality of science education. Therefore, further investigation into the factors influencing students' performance in physics is necessary.

Several previous studies have attempted to enhance students' mastery of physics by utilizing various strategies and learning media. These strategies included the use of e-modules [6], interactive media [7], and project-based learning methods [8]. However, the results of previous studies indicated that the learning achievement in physics of upper secondary students remains relatively low [9, 10]. Students' mastery of scientific skills in physics learning was still lacking in explaining, analyzing, investigating, and interpreting data [11]. This issue suggested that previous approaches were ineffective in addressing the problems. The discrepancies in results from various earlier studies also indicated the presence of other factors that had yet to be explored in depth. Therefore, there is a need for research that highlights the internal aspects of students as one of the causes of low learning achievement.

Learning achievement encompasses cognitive outcomes, such as exam scores and band. In physics learning, learning achievement reflects students' abilities to understand concepts, apply formulas, solve quantitative problems, and explain phenomena scientifically [12]. Enhancing academic achievement is a primary objective in designing effective learning strategies. This was particularly crucial in addressing the challenges of 21st-century education, which demands that students be more active, critical, and creative [2]. One way to achieve this is by understanding how psychological factors contribute to learning success. These internal factors include self-efficacy, self-regulated learning, motivation, and critical thinking skills.

Critical thinking skills are essential in understanding abstract concepts in physics and have been shown to enhance academic performance. At the same time, self-efficacy gives students the confidence to face academic challenges [13, 14]. Motivation was the primary driver of learning behaviour, encouraging students to be active and persistent in completing tasks [15, 16]. Motivation also serves as the foundation for the emergence of self-regulated learning skills, which involve goal setting, strategy selection, and self-reflection [17]. Students with self-regulated learning abilities tended to be more disciplined, critical, and responsible in their learning processes [18]. Therefore,

doi: 10.18178/ijiet.2026.16.1.2503

strengthening these psychological factors is crucial in improving overall academic performance in physics.

Many studies have examined the roles of self-efficacy and motivation separately in relation to learning achievement. A review of research on self-efficacy suggests that students' self-belief contributes to conceptual change in physics learning, thereby encouraging them to take an active role in improving their academic performance [19]. In addition, the integration of technology in instruction has been found to enhance students' motivation, which in turn positively affects their learning achievement [20, 21]. Strong self-efficacy among students also plays a key role in promoting better learning achievement, particularly in physics [22]. Both self-efficacy and motivation have shown significant effects on students' learning achievement. However, most previous studies have remained limited to examining these factors in isolation and have not comprehensively investigated the interconnections among the four internal factors: self-efficacy, motivation, self-regulated learning, and critical thinking skills. Thus, the integration of these four internal factors into a single conceptual model in the context of physics learning at upper secondary remains underexplored.

Therefore, this research contributes original findings by developing and testing a new conceptual model that is relevant to the challenges of 21st-century education by investigating the relationship between self-efficacy, motivation, self-regulated learning, and critical thinking skills on learning achievement, as illustrated in Fig. 1.

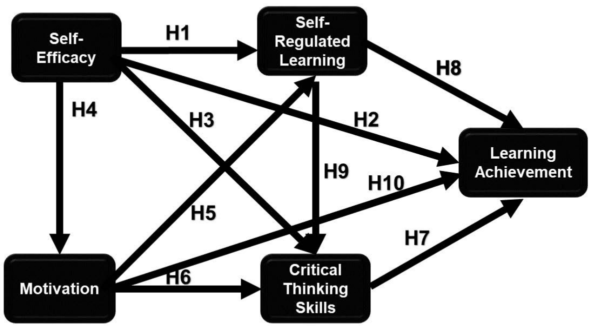

Fig. 1. Conceptual model.

This study aims to develop and test a conceptual model that describes the direct and indirect relationships among self-efficacy, motivation, self-regulated learning, and critical thinking skills, as well as their effects on students' physics learning achievement. This study was designed to answer the following research questions to focus the research according to its objectives.

RQ1: How does self-efficacy affect motivation, self-regulated learning, critical thinking skills, and physics learning achievement?

RQ2: How does motivation affect self-regulated learning, critical thinking skills, and physics learning achievement?

RQ3: How does self-regulated learning impact critical thinking skills and physics learning achievement?

RQ4: How do critical thinking skills influence physics learning achievement?

II. Literature Review

A. Self-Efficacy

Self-efficacy is an individual's perception of their capacity to organize and carry out the actions necessary to achieve a particular goal [13]. Self-efficacy plays an important role in shaping students' learning attitudes and behaviors, including in completing academic tasks [14]. Students who had high levels of self-efficacy tended to be more confident, more persistent in facing challenges, and did not give up easily when experiencing difficulties. Various studies revealed that self-efficacy has a direct effect on student learning achievement, as students with high self-efficacy usually exhibit more effective learning strategies, greater engagement in the learning process, and better academic performance [13]. In addition to its direct impact on learning achievement, self-efficacy was also closely related to various other psychological and cognitive factors that support learning success, such as self-regulated learning, motivation [23], and critical thinking skills. High self-efficacy encouraged students to take responsibility for their learning, set goals, monitor progress, and evaluate learning outcomes independently [13, 24]. In addition, belief in one's abilities was also known to be a strong driver of internal motivation. Students with high self-efficacy tend to have more consistent and achievement-oriented learning motivation [25].

On the other hand, in the context of critical thinking skills, self-efficacy allows students to be more confident in analyzing information, making inferences, and evaluating arguments, which are important skills in problem-solving [26]. Previous research revealed that self-efficacy has been studied in various contexts with mixed results. However, studies that specifically explore the relationship of self-efficacy with self-regulated learning, motivation, and critical thinking skills in physics learning are still limited. This gap is important to fill, considering that these three aspects play a major role in supporting the success of physics learning. Therefore, an empirical study is needed that investigates the contribution of self-efficacy as a predictor of self-regulated learning, motivation, and critical thinking skills in the context of physics learning. Thus, it is necessary to test the following hypotheses to understand the relationship between these variables better.

B. Motivation

Learning motivation is an internal factor that encourages individuals to actively engage in the learning process, maintain effort, and be oriented toward achieving academic goals. In the context of education, motivation was often considered the key to academic success because it acted as the main driver of student learning behavior [15]. Students who have a high level of motivation tend to show perseverance, focus, and seriousness in completing tasks and achieving optimal learning outcomes [16]. Some studies revealed that motivated students tend to have higher learning achievement compared to less motivated students because they tend to be more active in seeking information, participating in learning, and not giving up easily in facing challenges [25].

Motivation also contributed to students' ability to manage learning independently, known as self-regulated learning [17]. Students who had high intrinsic motivation were generally able to set learning goals, organize learning strategies, and monitor and evaluate their learning processes effectively [27]. In addition, strong motivation was also a foundation for developing critical thinking skills because motivated students will be more encouraged to explore concepts, question information, and engage in analysis and reflection on learning materials [28]. This makes motivation not only a supporting factor for academic success but also an important element in shaping the character of independent learners and higher-order thinking. Therefore, it is important to explore more deeply the effect of motivation on self-regulated learning and critical thinking skills as part of efforts to improve the quality of physics learning through testing the following hypotheses.

C. Self-Regulated Learning

Self-regulated learning is the ability of each individual to actively manage the learning process through planning, monitoring, and evaluation. Self-regulated learning includes important components such as goal setting, learning strategies, control over emotions, and self-reflection [18]. In the educational context, self-regulated learning made a significant contribution to academic achievement because students who were able to manage their learning process independently would be more disciplined, responsible, and consistent in completing learning tasks [29]. In addition, self-regulated learning played an important role in supporting the development of critical thinking skills. Students who are skilled in regulating their learning tend to be more active in analyzing information, questioning assumptions, and reflecting deeply on the concepts learned [30]. The process of self-regulated learning allows students to set higher standards of thinking, develop problem-solving strategies, and evaluate learning achievement independently.

D. Critical Thinking Skills

Critical thinking skills are one of the core competencies in 21st-century learning that have a significant impact on student academic achievement. Critical thinking skills include the ability to analyze information, evaluate arguments, make logical inferences, and make decisions based on relevant evidence [31]. Critical thinking skills encompass a range of dimensions, including interpretation, analysis, evaluation, and inference [32]. Strong critical thinking skills enhance students' capacity to interpret scientific data. Moreover, these skills are closely related to the ability to assess and logically draw conclusions from information, as well as to evaluate the validity of experimental results [33]. Analytical ability plays a crucial role in critical thinking, particularly in formulating arguments needed to distinguish between facts and opinions [34]. Such critical thinking skills are highly relevant in physics education, as learning physics typically involves interpreting data, analyzing phenomena, and drawing scientific conclusions from observed events [35].

In the context of physics learning, this ability was particularly important because it helped students understand complex concepts, evaluate experimental data, and solve quantitative problems systematically [36]. Various studies have revealed that students with good critical thinking skills tend to have higher learning achievement, as they are able to integrate information more effectively, learn more reflectively, and demonstrate deeper conceptual understanding [37, 38].

III. Materials and Methods

A. Research Design

This research is included in the quantitative research category with a survey approach. This design was chosen to measure and analyze the relationship between several latent variables based on data collected from a large sample. The survey method allowed researchers to collect data efficiently through structured questionnaires distributed to participants. This study collected data using questionnaires representing five main constructs: self-efficacy, motivation, self-regulated learning, critical thinking skills, and learning achievement. The collected data were analyzed based on the conceptual model presented in Fig. 1, with a focus on the relationships among the five main constructs. Subsequently, hypothesis testing was conducted to address the ten proposed hypotheses (H), which are formulated as follows:

H1: Self-efficacy has a significant positive effect on students' learning achievement in physics.

H2: Self-efficacy has a significant positive effect on students' self-regulated learning in physics.

H3: Self-efficacy has a significant positive effect on students' motivation in physics.

H4: Self-efficacy has a significant positive effect on students' critical thinking skills in physics.

H5: Motivation has a significant positive effect on students' learning achievement in physics.

H6: Motivation has a significant positive effect on students' self-regulated learning in physics.

H7: Motivation has a significant positive effect on students' critical thinking skills in physics.

H8: Self-regulated learning has a significant positive effect on students' learning achievement in physics.

H9: Self-regulated learning has a significant positive effect on students' critical thinking skills in physics.

H10: Critical thinking skills significantly positively affect students' learning achievement in physics.

B. Implementation

The procedures in this study were carried out through several stages, leading to the final results and conclusions. The research process began with a literature review to gather relevant sources for developing the conceptual model. The conceptual model, constructed based on previous studies, was then formulated into a set of hypotheses. To test these hypotheses, research instruments were developed based on the literature review and the constructs identified in the conceptual model. These instruments were used to measure the variables related to the proposed hypotheses. The variables included critical thinking skills, motivation, learning achievement, self-efficacy, and self-regulated learning. Data were collected by distributing questionnaires to 319 students. The collected data were then analyzed using the Structural Equation Modeling approach based on Partial Least Squares (SEM-PLS), with the assistance of the SmartPLS software. This analysis was conducted to examine the model and test the formulated hypotheses. Based on the results of the analysis, interpretations were made, and conclusions were drawn. The overall research procedure is visually presented in Fig. 2.

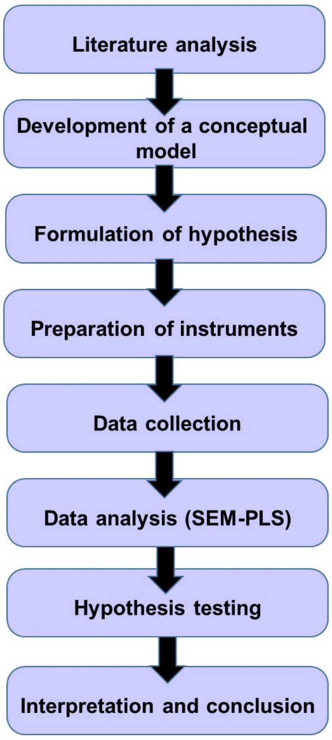

Fig. 2. Research procedures.

C. Participants

All upper secondary students spread across six schools in Sungai Penuh City, Jambi Province, Indonesia, comprised the population in this study. The sample selection was conducted using the stratified random sampling technique, which considers strata as schools of origin. The final sample selected in this study amounted to 319 students, consisting of 194 female students and 125 male students, who were in the age range of 15 to 16 years. This study was approved by the Ethics Committee of the Physics Education Study Program, Universitas Negeri Padang. All participants were informed about the purpose, procedures, and confidentiality of the research. Participation was entirely voluntary, and written informed consent was obtained from all respondents prior to data collection.

D. Data Collection

Research data were obtained through distributing questionnaires. The questionnaire instrument consists of 26 question items that have been compiled based on the indicators of each variable. The questionnaire instrument used a Likert scale with five assessment levels from 1 (strongly disagree) to 5 (strongly agree) to measure each statement. Student participation in filling out the questionnaire was voluntary without coercion. Details of the survey instrument are shown in Table 1.

Table 1. Questionnaire items

Latent Variables	Code Item	Description Item
Critical Thinking Skills (CTS)	CTS1	I can express opinions about given physics problems.
	CTS2	I have the skill to ask questions about physics topics.
	CTS3	I can answer physics questions logically.
	CTS4	I can analyze and understand problems in physics questions.
	CTS5	I can conclude from physics learning results.
	CTS6	I have the skill to evaluate and assess results from physics observations or experiments.
Motivation (M)	M1	I have the desire and willingness to learn physics.
	M2	I have hopes and aspirations related to my physics learning.
	M3	I am persistent in doing physics assignments.
	M4	I am resilient in facing difficulties when learning physics.
	M5	I can defend my opinion during physics discussions.
	M6	I enjoy working independently on physics tasks.
	M7	I enjoy solving and exploring physics problems.
Learning Achievement (LA)	LA1	I have achieved academic success in physics learning at school.
Self-Efficacy (SE)	SE1	I am confident that I can complete tasks in physics learning.
	SE2	I am confident that I can motivate myself to take the necessary actions to complete physics tasks.
	SE3	I believe I can work hard, persistently, and diligently in learning physics.
	SE4	I believe I can endure challenges and difficulties in studying physics.
	SE5	I am confident that I can complete both broad and specific physics tasks.
Self-Regulated Learning (SRL)	SRL1	I take the initiative in learning physics.
	SRL2	I take responsibility for my physics learning.
	SRL3	I can organize my study plan for physics, including time, pace, and goals.
	SRL4	I am disciplined and diligent in studying physics.
	SRL5	I enjoy learning physics and have a high level of curiosity.
	SRL6	I do not depend on others to understand physics material.

E. Data Analysis

Data were analyzed using the SEM-PLS approach with the help of SmartPLS software version 3.2.8. This approach simultaneously models the path relationship between latent variables, including the measurement and structural models [39]. The analysis stage began by assessing the conceptual model in terms of structure. The conceptual model described the relationship between constructs and their measuring indicators. In contrast, the structural model explains direct and indirect causal relationships between constructs that cannot be observed directly [39].

Composite reliability (CR), Cronbach's alpha, and Average Variance Extracted (AVE) were used to test reliability and validity in evaluating the measurement model. The AVE value was considered qualified if it exceeded the 0.50 threshold, indicating that the construct explained more than 50% of the indicator variance [40]. Meanwhile, the CR value was considered adequate if it was more than 0.60, as it indicates the internal consistency of the latent construct [41]. The reliability of each indicator was also evaluated based on the extent to which the indicator represented the construct being measured. Indicators were reliable if the latent construct explained at least 50% of the indicator variance, equivalent to a loading factor value $\geq$ 0.707. Construct validity was tested through convergent and discriminant validity. After the constructs were declared valid, the evaluation continued to the structural model, which was analyzed based on the predictive or causal relationship between constructs [42]. This study's assessment of the structural model focused on three main indicators: the

R-squared (R^2) value to see the variance explained, the path coefficient, and the significance level to test the strength and meaning of the relationship between constructs.

In addition, analyses of the Standardized Root Mean Square Residual (SRMR) and the Normed Fit Index (NFI) were conducted to assess the overall fit of the conceptual model. A model is considered to have a good fit when the SRMR value is less than 0.08 and the NFI exceeds 0.90 [39]. The significance level of each variable in every hypothesis (H) was interpreted based on the t-value, where a value of $t > 1.96$ or $t < -1.96$ (for $\alpha = 0.05$) indicates that the hypothesis is supported. Meanwhile, the effect size (f^2) was interpreted based on its magnitude, with the following criteria: $f^2 < 0.02$ indicates a very small effect, $0.02 \leq f^2 < 0.15$ indicates a small effect, $0.15 \leq f^2 < 0.35$ indicates a medium effect, and $f^2 \geq 0.35$ indicates a large effect [43].

IV. Results

The results of the analysis of latent variables consisting of critical thinking skills, motivation, learning achievement, self-efficacy, and self-regulated learning were obtained from 26 question items. Testing was carried out based on the conceptual model that had been designed previously. Evaluation of construct reliability is done through AVE and CR values. In addition, the loading factor value on each item was also analyzed to assess the contribution of each indicator to the construct. The results of AVE, CR, and indicator variable loading tests are presented in Table 2.

Table 2. AVE, CR, and loading of manifest variables

Latent Variables	Code Item	Loading Factor	α	CR	AVE
Critical Thinking Skills (CTS)	CTS1	0.733	0.867	0.900	0.601
	CTS2	0.798			
	CTS3	0.807			
	CTS4	0.705			
	CTS5	0.777			
	CTS6	0.826			
Motivation (M)	M1	0.839	0.933	0.946	0.715
	M2	0.842			
	M3	0.854			
	M4	0.911			
	M5	0.876			
	M6	0.874			
	M7	0.711			
Learning Achievement (LA)	LA1	1.000	1.00	1.00	1.00
Self-Efficacy (SE)	SE1	0.850	0.966	0.974	0.881
	SE2	0.922			
	SE3	0.964			
	SE4	0.974			
	SE5	0.977			
Self-Regulated Learning (SRL)	SRL1	0.869	0.962	0.969	0.840
	SRL2	0.891			
	SRL3	0.897			
	SRL4	0.916			
	SRL5	0.967			
	SRL6	0.955			

Table 2 presents the complete loading factor and cross-loading results for each indicator. The analysis revealed that all indicators had the highest correlation with the measured construct compared to other constructs. Indicators in the self-efficacy construct had a higher loading value on self-efficacy compared to their correlation value with other constructs, and the same thing also happens with the constructs of learning motivation, self-regulated learning, critical thinking skills, and physics learning achievement. This finding revealed that each construct could predict indicators within its block better than indicators from other construct blocks, so discriminant validity is met. Further analysis was conducted to test discriminant validity. The results of the analysis are shown in Table 3.

Table 3. Item cross-loading

Code Item	CTS	M	A	SE	SRL
CTS1	**0.733**	0.030	0.252	0.051	0.040
CTS2	**0.798**	0.017	0.285	0.041	0.021
CTS3	**0.807**	0.055	0.248	0.096	0.019
CTS4	**0.705**	0.014	0.189	0.092	0.047
CTS5	**0.777**	−0.048	0.242	0.018	−0.019
CTS6	**0.826**	0.011	0.311	0.059	0.018
M1	−0.022	**0.839**	0.443	0.735	0.434
M2	0.019	**0.842**	0.459	0.676	0.407
M3	0.030	**0.854**	0.447	0.766	0.399
M4	0.041	**0.911**	0.499	0.776	0.407
M5	−0.003	**0.876**	0.497	0.768	0.385
M6	0.026	**0.874**	0.505	0.775	0.416
M7	0.005	**0.711**	0.446	0.828	0.346
A1	0.331	0.559	**1.000**	0.568	0.347
SE 1	0.037	0.669	0.405	**0.850**	0.334
SE 2	0.053	0.927	0.555	**0.922**	0.424
SE 3	0.074	0.891	0.567	**0.964**	0.422
SE 4	0.089	0.856	0.559	**0.974**	0.439
SE 5	0.094	0.861	0.555	**0.977**	0.438
SRL 1	0.035	0.473	0.307	0.392	**0.869**
SRL 2	0.030	0.423	0.338	0.390	**0.891**
SRL 3	0.080	0.358	0.300	0.387	**0.897**
SRL 4	−0.019	0.429	0.298	0.390	**0.916**
SRL 5	0.025	0.478	0.337	0.447	**0.967**
SRL6	−0.004	0.423	0.325	0.414	**0.955**

Table 3 presents the complete loading factor and cross-loading results for each indicator. The factor loading results, as shown in the cross-loading table, reveal that each indicator exhibits the highest loading on its corresponding construct, thereby providing evidence for discriminant validity. The analysis revealed that all indicators had the highest correlation with the measured construct compared to other constructs. Indicators in the self-efficacy construct had a higher loading value on self-efficacy compared to their correlation value with other constructs, and the same thing also happens with the constructs of learning motivation, self-regulated learning, critical thinking skills, and physics learning achievement. This finding revealed that each construct could predict indicators within its block better than indicators from other construct blocks, so discriminant validity was met. Further analysis was conducted to test discriminant validity. The results of the analysis are shown in Table 4.

Table 4. Discriminant validity

Variable	CTS	M	LA	SE	SRL
Critical Thinking Skills (CTS)	**0.775**				
Motivation (M)	0.017	**0.846**			
Achievement (LA)	0.331	0.559	**1.000**		
Self-Efficacy (SE)	0.075	0.903	0.568	**0.938**	
Self-Regulated Learning (SRL)	0.026	0.473	0.347	0.441	**0.916**

Table 4 shows that all constructs have adequate discriminant validity by the criteria of Fornell and Larcker (1981). Discriminant validity was achieved when the AVE square root value (shown in bold diagonal) was higher than the correlation between other constructs (non-diagonal values in the same row/column). The AVE root value for the self-efficacy construct (0.938) is higher than its correlation with other constructs, such as motivation (0.903) and learning achievement (0.568). Similarly, the self-regulated learning construct has a root AVE value of 0.916, greater than its correlation with other constructs, such as motivation (0.473) and learning achievement (0.347). This revealed that each construct in the model truly represented a different concept and did not overlap with the other, so the model could be said to fulfill overall discriminant validity.

The structural model was evaluated to measure the predictive relationships between constructs [29]. The PLS algorithm in SmartPLS was used to calculate the R² value, with $R^2 \geq 0.67$ (substantial), $R^2 \geq 0.33$ (moderate), and $R^2 \geq 0.19$ (weak). The analysis results showed R² of Motivation 0.815 (substantial), Learning achievement 0.434 (moderate), self-regulated learning 0.224 (weak), and Critical Thinking Skills 0.020 (very weak). This indicated a different level of predictive power between constructs in the model.

The R² values for several variables fall within the weak to very weak category, indicating limitations in the variables used in this study. This suggests the possible existence of other relevant variables not included in the model that may influence the results. This limitation has been acknowledged and reported as part of the study's limitations. Nevertheless, the overall findings still meet the required statistical criteria in terms of both reliability and model validity. In addition, SRMR and NFI analyses were conducted to assess the overall fit of the conceptual model. SRMR measures the average difference between the observed and predicted correlations, while NFI evaluates the extent to which the specified structural model improves upon the baseline model with no relationships among variables. The results showed an SRMR value of 0.067 and an NFI value of 0.915, indicating that the model demonstrates a good fit with the data. The SRMR value falls below the threshold of 0.08, placing it within the "good fit" category, and the NFI exceeds the minimum acceptable value of 0.90, suggesting that the model provides a substantially better fit than the null model [41]. Having met the required model fit standards, the conceptual model was then subjected to hypothesis testing.

Based on these relationships, hypothesis testing was conducted to determine whether these relationships were statistically significant. Conclusions were drawn by referring to the path coefficient value and its significance level. The complete results of the path coefficients and hypothesis testing are presented in Fig. 3 and Table 5.

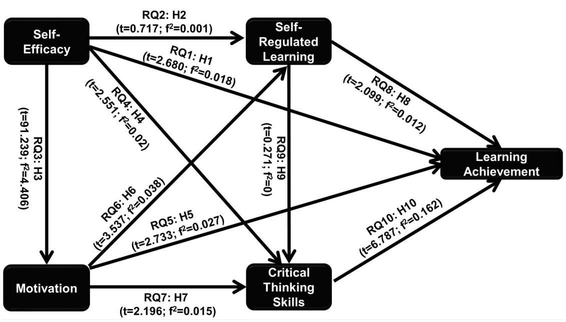

Fig. 3. Results of path coefficients.

Fig. 3 illustrates the results of the hypothesis testing regarding the relationships among variables within the conceptual framework. Each path represented the direction of influence from one variable to another, which was measured through the original sample (O) values, t-statistics, and effect size (f^2), as presented in Table 5. The interpretation of the results for each hypothesis is presented as follows.

Table 5. Hypothesis testing results

Hypothesis (H)	Original Sample (O)	t	Effect Size (f²)
H1: Self-efficacy has a significant positive effect on students' learning achievement in physics.	0.267	2.680	0.018
H2: Self-efficacy has a significant positive effect on students' self-regulated learning in physics.	0.079	0.717	0.001
H3: Self-efficacy has a significant positive effect on students' motivation in physics.	0.903	91.239	4.406
H4: Self-efficacy has a significant positive effect on students' critical thinking skills in physics.	0.323	2.551	0.02
H5: Motivation has a significant positive effect on students' learning achievement in physics.	0.292	2.733	0.027
H6: Motivation has a significant positive effect on students' self-regulated learning in physics.	0.401	3.537	0.038
H7: Motivation has a significant positive effect on students' critical thinking skills in physics.	−0.283	2.196	0.015
H8: Self-regulated learning has a significant positive effect on students' learning achievement in physics.	0.097	2.099	0.012
H9: Self-regulated learning has a significant positive effect on students' critical thinking skills in physics.	0.017	0.271	0
H10: Critical thinking skills significantly positively affect students' learning achievement in physics.	0.285	6.787	0.162

A. The Effect of Self-Efficacy on Motivation, Self-Regulated Learning, Critical Thinking Skills, and Physics Learning Achievement

The analysis revealed that self-efficacy had a very strong influence on motivation (H3), with ($O = 0.903$; $t = 91.239$; $f^2 = 4.406$). This large effect confirms that students' belief in their own abilities is a key factor in fostering motivation to learn physics. In addition, self-efficacy had a positive and significant effect on critical thinking skills (H4), although the magnitude of the effect was small ($O = 0.323$; $t = 2.551$; $f^2 = 0.02$). This implies that students with higher self-efficacy tend to possess better reflective and logical thinking abilities, even though the contribution is not dominant. Regarding learning achievement (H1), self-efficacy showed a significant positive effect, but the effect size was very small ($O = 0.267$; $t = 2.680$; $f^2 = 0.018$). This finding suggests that the direct influence of self-efficacy on academic achievement is limited and may be more effectively exerted through indirect pathways. Meanwhile, the effect of self-efficacy on self-regulated learning (H2) was not statistically significant and had a nearly negligible effect size ($O = 0.079$; $t = 0.717$; $f^2 = 0.001$). This indicates that confidence alone is not sufficient to drive students to manage their own learning processes, and additional support—such as explicit learning strategies or external guidance—may be necessary.

B. The Effect of Motivation on Self-Regulated Learning, Critical Thinking Skills, and Physics Learning Achievement

The hypothesis test results indicated that motivation had a significant positive effect on academic achievement (H5), with ($O = 0.292$; $t = 2.733$; $f^2 = 0.027$). This finding suggests that higher levels of motivation were associated with better performance in physics, albeit with a small effect size.

Motivation also showed a significant negative effect on critical thinking skills (H7), as reflected in (O = –0.283; t = 2.196; f^2 = 0.015). Although statistically significant, the negative direction of the relationship indicates a complex association possibly influenced by the dominance of extrinsic motivation, which may hinder the development of critical thinking. This result warrants further investigation to examine the role of motivational types in shaping students' higher-order thinking skills.

The results of this study indicate that motivation has a significant negative effect on students' critical thinking skills. This finding contradicts many previous studies, which typically report a positive relationship between the two variables. One possible explanation is the suppression effect, in which motivation is intertwined with other constructs such as self-efficacy or self-regulated learning, thereby influencing the direction and strength of the relationship in the model [44–46].

Moreover, it should be noted that motivation is not a single construct. The type of motivation, whether intrinsic or extrinsic, determines the direction of its influence. According to Deci and Ryan [47] in their Self-Determination Theory, extrinsic motivation that becomes overly dominant tends to drive students to pursue end results rather than the learning process itself. This can hinder the development of critical thinking, which requires deep reflection, evaluation of alternatives, and logical reasoning [48]. Therefore, this result highlights that the impact of motivation on higher-order cognitive skills is highly contextual and requires further exploration by distinguishing types of motivation and identifying relevant mediating variables [49, 50]. Thus, distinguishing the types of motivation and examining the influence of other variables are limitations of the present study and serve as recommendations for future researchers to investigate other possible variables.

Furthermore, motivation had a significant positive effect on self-regulated learning (H6), with (O = 0.401; t = 3.537; f^2 = 0.038). This small-to-moderate effect size indicates that students with higher motivation were more capable of managing their own learning processes effectively. Taken together with its effects on academic achievement and critical thinking, these findings highlight that motivation plays a pivotal role in shaping both cognitive and metacognitive outcomes. Therefore, fostering students' motivation should be a central focus in efforts to enhance learning achievement in physics education.

C. The Effect of Self-Regulated Learning on Critical Thinking Skills and Physics Learning Achievement

The hypothesis test results indicated that self-regulated learning had a positive and significant effect on learning achievement, with a t-value of 2.099 and a path coefficient (O) of 0.097, meaning that the better students' self-regulated learning abilities were, the higher their physics learning achievement. However, the impact of self-regulated learning on critical thinking skills was insignificant, with a t-value of only 0.271 and an O of 0.017, indicating that self-regulated learning was not sufficiently strong to influence students' critical thinking abilities. The results of this study indicate that the relationship between the two variables was not significant. This may be attributed to the types of self-regulated learning strategies employed by the students, which tend to be procedural and task-oriented rather than focused on deep idea exploration. In learning contexts that emphasize grades or examination performance, students might be able to manage their learning processes independently, but do not engage in evaluative, reflective, or analytical processes that are central to critical thinking [51]. Moreover, the low quality of SRL strategies used, such as merely scheduling or recording tasks without accompanying reflection on understanding, may also contribute to the underdevelopment of critical thinking skills. Contextual factors, such as a learning culture that emphasizes memorization or compliance with instructions, might also hinder the effective integration of SRL and critical thinking.

D. The Effect of Critical Thinking Skills on Physics Learning Achievement

The hypothesis test results showed that critical thinking skills had a positive and significant effect on students' learning achievement in physics (H10), with (O = 0.285; t = 6.787; f^2 = 0.162). This moderate effect size suggests that students with stronger critical thinking abilities tend to achieve better academic outcomes. These findings underscore the critical role of analytical, evaluative, and problem-solving skills in supporting physics learning. Students who can reason logically and reflectively are better equipped to grasp complex concepts and apply them effectively. Therefore, developing critical thinking skills should be prioritized as a key strategy in improving student performance in physics education.

The quantitative findings presented in the previous section have revealed several important relationships among the main variables, particularly regarding how self-efficacy, motivation, self-regulated learning, and critical thinking skills contribute to students' physics learning achievement. The results demonstrate both consistencies and divergences when compared to prior studies and are linked to relevant theoretical perspectives. This study has also generated new insights that extend the existing body of literature. To gain a deeper understanding of the implications of these findings, the following discussion section will explore them in greater depth by connecting the results to relevant theories and previous empirical research.

V. DISCUSSION

Based on the results of data analysis, the conceptual model developed in this study was found to be valid and reliable in terms of construct measurement. This is supported by the SRMR value of 0.067 and the NFI value of 0.915. An SRMR below the 0.08 threshold and an NFI exceeding the recommended minimum of 0.90 indicate that the model demonstrates a good fit to the empirical data [39]. These results suggest that the structural relationships among the variables in the model adequately represent the observed data and provide a sound basis for drawing conclusions about causal relationships among the constructs.

The results of this study revealed that almost all of the proposed hypotheses were accepted, except for two, namely the relationship between self-efficacy and self-regulated learning and self-regulated learning and critical thinking skills. The analysis results of this study revealed that self-efficacy, motivation, self-regulated learning, and critical thinking skills directly affected the physics learning achievement of upper secondary students. Furthermore, the research findings also indicated that these factors mutually affect one another. Self-efficacy and motivation positively affect critical thinking skills, while motivation also positively affects self-regulated learning. However, self-efficacy did not significantly impact self-regulated learning, and self-regulated learning did not significantly affect critical thinking skills. These findings highlight the key factors that directly affect students' physics learning achievement and how the interrelationships among these factors contribute to the dynamics of students' learning processes.

This finding reinforces most previous findings that revealed a positive relationship between students' psychological and academic variables. The results revealed that critical thinking skills significantly affected learning achievement in line with previous research **(H10)**. Research revealed that critical thinking skills improved concept understanding and complex problem-solving, especially in science subjects such as physics [52–54]. Students who can analyze, evaluate, and make logical decisions would be better prepared to face academic challenges [55]. This confirmed that critical thinking was a learning outcome and an important predictor of student learning achievement [37, 38, 56]. However, the research results show deeper findings regarding the relationship between one factor and another in providing an effect.

In addition, motivation was revealed to positively affect critical thinking skills (**H7**), self-regulated learning (**H6**), and learning achievement (**H5**), consistent with the theory of motivation. Pintrich & De Groot [51] state that internal motivation encouraged students to be more cognitively and metacognitively engaged. Other research also supported this finding that motivated students have a higher tendency to learn independently, ask questions, and evaluate their understanding [57], all of which were directly related to critical thinking ability and better learning achievement [28]. Furthermore, self-efficacy significantly affected motivation, learning achievement, and critical thinking skills. These results aligned with previous findings that self-belief in the ability to complete tasks would increase students' initiative, perseverance, and resilience in facing academic challenges [17, 58]. Self-efficacy was a determining factor in student success, both from cognitive, motivational, and affective aspects [13, 59]. Although previous studies have consistently shown that motivation has a strong positive impact on various aspects of learning, the findings of the present study indicated that the effect of motivation was relatively small. Specifically, motivation exerted a small effect on critical thinking skills ($f^2 = 0.015$), self-regulated learning ($f^2 = 0.038$), and learning achievement ($f^2 = 0.027$). While these relationships were statistically significant, the small effect sizes suggested that the contribution of motivation to these three variables was still limited. Therefore, it is important to consider other factors that may play a more dominant role in influencing students' critical thinking ability, self-regulated learning, and learning achievement.

Self-efficacy directly influenced students' learning achievement (H1) and critical thinking skills (H4) in physics learning, although the magnitudes of these effects were categorized as small ($f^2 = 0.018$ and $f^2 = 0.02$, respectively). In contrast, the effect of self-efficacy on motivation (H3) was found to be very large ($f^2 = 4.406$). These findings suggested that self-efficacy contributed positively to both students' learning achievement and motivation. Students with high levels of self-efficacy tend to feel more confident in facing learning challenges, which in turn enhances their motivational drive [60]. This increase in motivation may subsequently lead to better learning achievement. Students' belief in their own abilities plays a critical role in fostering effort, persistence, and optimal academic achievement [19].

However, the results revealed that the relationship between self-efficacy and self-regulated learning was insignificant compared to previous findings **(H2)**. A similar pattern was also observed in the relationship between self-regulated learning and critical thinking skills, which was found to be non-significant (H9). Schunk [60] stated that self-efficacy was the main driver of self-regulated learning behavior. This difference can be caused by the learning context of students who have not fully provided space for self-regulated learning or due to learning culture factors emphasizing dependence on teachers [30]. Similarly, the relationship between self-regulated learning and critical thinking skills was insignificant. This contradicts the findings of several studies, such as Wolters [61], which suggested that students with high self-regulated learning abilities tend to have better analysis and evaluation skills.

The non-significant relationship between self-efficacy and self-regulated learning suggested that although students may feel confident in their abilities, this does not necessarily translate into the planned and controlled use of learning strategies. Therefore, efforts to enhance self-efficacy should be accompanied by training in self-regulated learning skills, enabling students to manage their learning processes more effectively. This difference in findings suggested that students' self-regulated learning strategies were not fully directed towards higher-order thinking activities but were still limited to time and task management.

Overall, the findings indicated that most of the examined variables, self-efficacy, motivation, self-regulated learning, and critical thinking skills, were positively and significantly associated with learning achievement. However, two non-significant relationships were identified: the effect of self-efficacy on self-regulated learning and that of self-regulated learning on critical thinking skills. These results highlight the importance of strengthening variables that demonstrated significant contributions, while also calling for a reevaluation of instructional approaches that did not yield effective outcomes.

The implications of this study extend beyond the context of physics education and may be applied to other STEM disciplines, including biology, chemistry, mathematics, and technology. This is because critical thinking and self-directed learning are cross-disciplinary competencies essential for scientific problem-solving. In science education more broadly, students are expected to formulate hypotheses, evaluate data, and draw logical conclusions, all of which require motivational drive as well as the capacity to manage their own learning strategically and reflectively. Accordingly, these findings offer a foundation for designing instructional models across STEM fields that not only emphasize content mastery but also promote metacognitive and affective skills that foster deeper critical thinking. The application of such models can be tailored to subject matter and student characteristics within each discipline.

Taken together, the results underscore the pivotal role of self-efficacy in enhancing learning achievement, motivation, and critical thinking skills. Hence, curriculum development should incorporate learning activities that build students' confidence, such as project-based assessment, self-reflection, and scaffolded learning challenges. Moreover, since learning motivation was shown to support achievement and structured learning behaviors, instructional strategies such as inquiry-based learning or problem-based learning could be integrated to foster students' intrinsic motivation. The finding that critical thinking skills directly contributed to learning outcomes also emphasizes the need to prioritize learning objectives that cultivate analytical, evaluative, and argumentative abilities. Although self-regulated learning did not exhibit a strong link to critical thinking, it still contributed to learning achievement, thus supporting the inclusion of independent learning programs or training in effective study strategies as part of broader educational policy, even beyond the core curriculum.

VI. Conclusions and Implications

The results of the analysis indicated that several factors had a direct effect on learning achievement. Research findings revealed that self-efficacy, self-regulated learning, motivation, and critical thinking skills significantly affected students' physics achievement. Analyzing the relationship between these factors shows that there is an indirect relationship between these variables. Self-efficacy and motivation were shown to impact critical thinking skills, while motivation also positively affected self-regulated learning. However, self-efficacy did not have a significant effect on self-regulated learning, and self-regulated learning also did not have a significant effect on critical thinking skills. Overall, these findings have important implications for educators and policymakers to consider the internal factors of students when designing more effective learning strategies to support enhancing academic achievement, particularly in physics education at the upper secondary level.

The researchers acknowledge that this study has several limitations. First, the analysis was restricted to five main variables: critical thinking skills, motivation, learning achievement, self-efficacy, and self-regulated learning. While other potential moderating variables, such as gender, teaching practices, and cultural context, may have influenced the outcomes and contributed to variance in the data, this study deliberately focused on these five constructs in order to meet the primary research objective: to investigate the factors influenced by these key variables.

In addition, the study employed a cross-sectional design, which limits the ability to establish temporal or causal relationships among the variables. Consequently, future research is recommended to adopt a longitudinal approach in order to track changes over time and strengthen the causal inferences that can be drawn from the model. Another limitation concerns the relatively small sample size, which may affect the generalizability of the findings. Future studies with larger and more diverse samples are needed to validate the current findings and explore potential interactions with other contextual factors.

Therefore, future research is recommended to explore other factors that may have an impact and to use a larger sample size to make the findings more representative. Nevertheless, the results of this research contribute to filling the gap in the study of internal factors that need to be considered by teachers and educational policymakers in efforts to improve student learning outcomes. These findings are expected to serve as a basis for developing strategies, approaches, and methods, and using more appropriate and effective learning media to enhance the quality of education.

Conflict of Interest

The authors declare no conflict of interest

Author Contributions

D.D. contributed to developing the research idea, designing the study, writing the manuscript, collecting data, and validating the research findings. N. A contributed to validating the research, conducting the study, and collecting data. V.M. contributed to data collection and manuscript writing. M.D contributed to processing and presenting the results, as well as writing the manuscript. All authors had approved the final version.

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