Jurnal Ilmiah Peuradeun
The Indonesian Journal of the Social Sciences
Journal Homepage:
https://journal.scadindependent.org/index.php/jipeuradeun

Vol. 14, No. 1, January 2026	**Copyright © 2026, is licensed under a CC-BY-SA**
Pages: 413-438	**Publisher: SCAD Independent**
DOI: https://doi.org/10.26811/peuradeun.v14i1.2439	**P-ISSN: 2338-8617 / E-ISSN: 2443-2067**

Integrating Computational Thinking and Spirituality in Developing Students' Critical Thinking: A Comparative Study of Indonesia and Malaysia

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Received: June 30, 2025	**Accepted:** January 17, 2026	**Published:** January 30, 2026
Article Url: https://journal.scadindependent.org/index.php/jipeuradeun/article/view/2439		

Abstract

Global educational challenges demand the development of critical thinking through approaches that integrate cognitive and ethical dimensions. This study examines how computational thinking and spirituality contribute to the development of students' critical thinking skills in Indonesia and Malaysia. Using a quantitative design, data were collected from university students in both countries and analyzed through Partial Least Squares Structural Equation Modeling (PLS-SEM). The analysis reveals that computational thinking plays a more influential role in shaping students' critical thinking in Malaysia, reflecting the strong emphasis on analytical and digital reasoning in instructional practices. In contrast, spirituality makes a stronger contribution in the Indonesian context, underscoring the importance of moral and spiritual values in supporting reflective and ethical reasoning. These differences highlight the role of cultural and pedagogical contexts in shaping cognitive development. Ultimately, the study demonstrates that integrating computational thinking and spirituality provides a holistic framework for strengthening students' critical thinking, offering relevant implications for curriculum design and educational policy in higher education.

Keywords: *Computational Thinking; Critical Thinking; Spirituality; Higher Education; Cross-National Study.*

A. Introduction

The importance of critical thinking skills in educational contexts has been increasingly emphasized as global challenges grow in complexity. Regarding future workforce demands, the World Economic Forum highlights analytical and higher-order thinking skills as essential competencies for navigating rapid technological change, complex problem environments, and uncertain socio-economic conditions (Battista et al., 2023). This global demand is particularly evident in Southeast Asia; in Indonesia and Malaysia, projections indicate that by 2025, approximately 65% of jobs in Indonesia and 78% in Malaysia will require robust critical thinking skills. Despite these projections, empirical evidence consistently shows that students' performance in both countries remains below the global average when measured against Organization for Economic Co-operation and Development (OECD) benchmarks, revealing a persistent gap between global expectations and regional educational outcomes (Darmawan, 2020; Nob et al., 2025).

Consequently, critical thinking has been widely recognized not only as a core academic competence but also as a fundamental life skill essential for effective problem-solving and decision-making in everyday contexts (Cong & Ironsi, 2025; Hermita et al., 2025; So, 2025). However, scholars increasingly argue that developing these skills requires pedagogical strategies that transcend traditional instructional approaches by integrating diverse cognitive frameworks alongside the ethical and value-based dimensions of learning (Susilawati et al., 2025). Accordingly, critical thinking is now conceptualized as a multidimensional construct shaped by analytical reasoning, reflective judgment, ethical awareness, and contextual understanding.

Within this framework, the integration of computational thinking (CoT) has emerged as a strategic response to contemporary educational challenges (Åkerfeldt et al., 2024). CoT involves structured cognitive processes, such as problem decomposition, abstraction, and algorithmic reasoning, that are essential for addressing complex problems in digital societies. Empirical studies show that CoT enhances problem-solving abilities, particularly in STEM environments, and is widely recognized as a vital 21st-century skill (Dong et al., 2024; Hartawan et al., 2024). Nevertheless, an educational focus solely on analytical competencies risks neglecting the ethical and reflective dimensions necessary for sound critical judgment (Jones, 2025).

To address this limitation, spirituality is increasingly discussed as a complementary dimension in the development of critical thinking. In educational contexts, spirituality is associated with personal growth, moral development, and a sense of meaning that supports reflective and ethical reasoning (Chen et al., 2024; Ezzani & Brooks, 2022). Empirical evidence indicates that spirituality fosters critical thinking by encouraging reflection and ethical decision-making in complex situations (Gardner, 2024; Hay et al., 2024), while helping learners develop a deeper understanding of their role in a global society (Jirásek, 2023).

In Indonesia and Malaysia, both computational thinking and spirituality have begun to receive policy-level recognition within educational frameworks aimed at promoting holistic learning. However, a notable gap persists between this conceptual acknowledgment and its practical implementation, particularly in integrating cognitive skills such as computational thinking with the spiritual and ethical dimensions of learning (Alafnan, 2025). This implementation gap manifests differently across the two countries due to variations in curriculum orientation, teacher preparedness, institutional support, and cultural emphasis on values-based education. Research indicates that 58% of educators in Malaysia recognize the importance of integrating spiritual values alongside technical skills within the curriculum (Bhutto et al., 2024; Susilawati & Supriyatno, 2023). Additionally, empirical findings suggest that integrating computational thinking and spirituality in STEM education can enhance student engagement and critical thinking skills by up to 35% compared to traditional instructional approaches (Subramaniam et al., 2023).

Despite these developments, existing studies have primarily examined computational thinking and spirituality as separate constructs. While research has explored the individual impact of spirituality on critical thinking (Zakaria et al., 2023), empirical evidence continues to show that students in Indonesia and Malaysia perform below international averages (Darmawan et al., 2025). This reflects a persistent global–regional disparity, where increasing demands for higher-order thinking skills remain misaligned with educational outcomes in Southeast Asia (Vázquez-Parra et al., 2025). Although cultural values and spirituality remain embedded within regional systems (Jensen, 2021), a significant research gap persists regarding the synergistic integration of computational thinking and spirituality as a unified framework for developing critical thinking.

In the context of rapid technological advancement and emerging ethical dilemmas, such integration has become a necessity rather than a pedagogical option.

Supporting this argument, a meta-analysis demonstrates that integrating cognitive and spiritual development can enhance students' critical thinking outcomes by up to 40%, highlighting the potential of holistic, solution-oriented educational models (Annunziata et al., 2023). However, comparative cross-national evidence examining how this integration operates, particularly in Indonesia and Malaysia, remains limited.

The significance of this study lies in its potential to bridge the gap between the theoretical recognition and practical implementation of critical thinking in higher education. Although computational thinking and spirituality are increasingly acknowledged at policy levels, their integrated application remains fragmented (Wahidmurni et al., 2025). By adopting a comparative perspective, this study examines how the integration of these dimensions influences students' critical thinking across diverse cultural and educational settings. The objective of this research is, therefore, to analyze the effects of integrating computational thinking and spirituality on students' critical thinking skills and to compare the strength of these relationships between Indonesia and Malaysia, providing empirical insights for curriculum development and evidence-based educational policy (Low, 2024; Rodríguez-Rojas et al., 2024).

B. Method

This study employs a quantitative approach with a survey design to analyze the influence of Computational Thinking (CoT) and spirituality on the critical thinking abilities of students in Indonesia and Malaysia. The study participants were students from the State Islamic University of Maulana Malik Ibrahim Malang and Universiti Teknologi Malaysia, selected based on comparable academic characteristics. Sampling was conducted using a stratified random sampling technique to ensure proportional representation from each institution, resulting in a sample of at least 136 respondents collected during the current academic year.

Data collection was carried out using a closed-ended Likert scale questionnaire measuring three primary constructs: Computational Thinking, spirituality, and critical thinking. Data were analyzed using Partial Least Squares–Structural Equation Modeling (PLS-SEM) to evaluate the measurement and structural models and to test the research hypotheses. The instrument's feasibility was established through validity and reliability tests, while the significance of relationships between variables was tested at a 95% confidence level. The research model is depicted in a chart to clearly describe the relationships among variables, as shown in Figure 1.

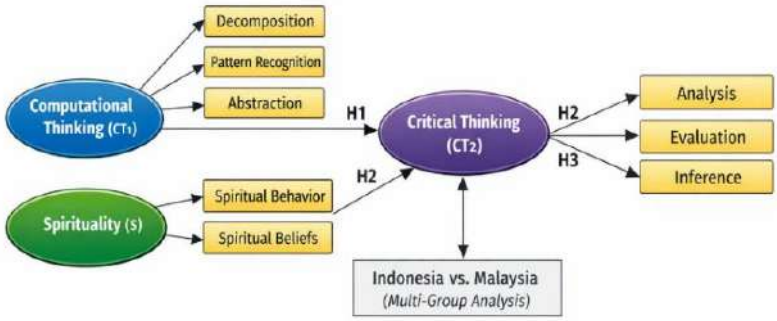

Figure 1. Research Variables Chart

All research procedures were conducted in compliance with ethical standards. Before data collection, the researchers obtained permission from the relevant university authorities and informed consent from all participants. The confidentiality and anonymity of participants were strictly maintained, and their involvement was entirely voluntary.

C. Results and Discussion

The integration of computational thinking and spirituality significantly enhances students' critical thinking skills. A comparative analysis of Indonesia and Malaysia reveals both similarities and differences in implementation patterns and pedagogical contexts, which in turn affect the effectiveness of critical thinking reinforcement. Data analysis indicates that this integrated approach positions students as active subjects who not only improve their analytical and problem-solving skills but also strengthen the reflective and ethical dimensions of their critical thinking.

1. Results

a. Measurement model

The measurement model was analyzed to evaluate the validity and reliability of the research construct, specifically regarding the influence of computational thinking and spirituality on critical thinking skills. Each variable was measured based on a specific set of indicators to ensure empirical accuracy.

In this study, Computational Thinking (CoT) comprises the dimensions shown in Table 1 (Åkerfeldt et al., 2024; Dong et al., 2024; Ezeamuzie et al., 2024; Gasaymeh & AlMohtadi, 2024).

Table 1. Indicators of computational thinking

Dimension	Research Indicator
Abstraction	Identifying essential information and ignoring irrelevant details in problem-solving
Decomposition	Dividing complex problems into smaller, manageable sub-problems
Algorithmic Thinking	Constructing logical and systematic steps to solve problems
Evaluation	Assessing the effectiveness and accuracy of selected problem-solving strategies
Generalization	Recognizing patterns and applying solutions to similar problems in different contexts

Critical Thinking (CT) consists of two main dimensions, as presented in Table 2 (Rodríguez-Rojas et al., 2024)

Table 2. Indicators of critical thinking

Dimension	Research Indicator
Argumentative Ability	Understanding the main ideas and structure of arguments
	Evaluating the validity and relevance of arguments
	Assessing the credibility of information and sources
Analytical Ability	Analyzing information presented in written texts
	Interpreting data, facts, and evidence logically
	Drawing reasoned conclusions based on textual analysis

Meanwhile, Spirituality (S) comprises the two dimensions presented in Table 3 (Chen et al., 2024)

Table 3. Indicators of spirituality

Dimension	Research Indicator
Spiritual Behavior	Frequency of talking about spiritual or religious topics
	Frequency of meditation, prayer, or other spiritual practices
	Engagement in daily activities reflecting spiritual values
Spiritual Beliefs	Belief that spirituality provides meaning and purpose in life
	Belief that spirituality strengthens closeness to God
	Belief that spiritual values guide thoughts and behavior

Once the indicators for each variable were operationally defined, the measurement model was analyzed to assess the construct's convergent and discriminant validity. This analysis ensures that each indicator accurately measures its intended variable and that the constructs maintain an adequate degree of separation. Although the initial convergent validity test for the Indonesian sample met the requirements, with all indicators yielding a loading factor (LF) above 0.7 (Shrestha, 2021), the discriminant validity results revealed issues with several

indicators. Specifically, CT1, CT12, CT13, CT14, CoT9, CoT11, CoT12, and CoT14 exhibited higher factor loadings on unintended constructs than on their own, suggesting a conceptual overlap. This shows that while the indicators are reliable, the constructs themselves are not sufficiently distinct from one another. To ensure that constructs can be clearly distinguished, a second validity test was conducted by removing problematic indicators to evaluate whether the constructs are truly distinct and do not overlap.

Similarly, the results of the initial loading factor (LF) test for Malaysian students identified several indicators that failed to meet the threshold, specifically CT1 (0.677), CT10 (0.660), CT15 (0.643), CoT2 (0.365), CoT3 (0.674), CoT12 (0.576), and CoT16 (0.685). These low values indicate a weak relationship between the indicators and their respective constructs. In the second LF test, the CoT7 indicator (0.698) remained slightly below the requirement, while most other indicators showed improvement. By the third and fourth tests, previously problematic indicators such as CoT1 (0.729) and CoT10 (0.704) met the desired validity criteria. However, the CoT1 and CoT10 indicators were removed in the discriminant validity test to overcome overlap between constructs. Despite the loading factors meeting requirements in the final stages, issues with discriminant validity persisted, indicating that the constructs were not sufficiently distinct. Ultimately, a fourth validity test was conducted to eliminate all indicators that failed to meet discriminant validity standards (Rönkkö & Cho, 2020). The final validation results are presented in Table 4.

Table 4. Convergent validity

Indonesia					
Variables	**Indicators**	**LF**	**Cut-Off**	**AVE**	**Information**
CoT	CoT1	0.770	>0.7	0.682	Valid
	CoT10	0.771			Valid
	CoT13	0.723			Valid
	CoT15	0.756			Valid
	CoT16	0.854			Valid
	CoT17	0.827			Valid
	CoT18	0.861			Valid
	CoT19	0.828			Valid
	CoT2	0.826			Valid
	CoT3	0.898			Valid
	CoT4	0.777			Valid
	CoT5	0.854			Valid
	CoT6	0.808			Valid

Indonesia					
Variables	**Indicators**	**LF**	**Cut-Off**	**AVE**	**Information**
	CoT7	0.904			Valid
	CoT8	0.902			Valid
CT	CT10	0.798	>0.7	0.667	Valid
	CT11	0.859			Valid
	CT15	0.858			Valid
	CT16	0.756			Valid
	CT17	0.773			Valid
	CT2	0.819			Valid
	CT3	0.795			Valid
	CT4	0.791			Valid
	CT5	0.780			Valid
	CT6	0.837			Valid
	CT7	0.880			Valid
	CT8	0.767			Valid
	CT9	0.891			Valid
S	S10	0.747	>0.7	0.654	Valid
	S2	0.721			Valid
	S3	0.832			Valid
	S4	0.843			Valid
	S5	0.850			Valid
	S6	0.781			Valid
	S7	0.879			Valid
	S8	0.808			Valid
	S9	0.803			Valid
Malaysia					
Variables	**Indicators**	**LF**	**Cut-Off**	**AVE**	**Information**
CoT	CoT11	0.785	>0.7	0.625	Valid
	CoT13	0.799			Valid
	CoT14	0.811			Valid
	CoT15	0.819			Valid
	CoT18	0.826			Valid
	CoT19	0.792			Valid
	CoT4	0.816			Valid
	CoT5	0.784			Valid
	CoT8	0.708			Valid
	CoT9	0.761			Valid
CT	CT11	0.785		0.681	Valid
	CT12	0.860			Valid
	CT13	0.841			Valid
	CT14	0.752			Valid
	CT16	0.852			Valid
	CT17	0.855			Valid
S	S1	0.761		0.610	Valid
	S2	0.850			Valid

Indonesia					
Variables	**Indicators**	**LF**	**Cut-Off**	**AVE**	**Information**
	S3	0.721			Valid
	S4	0.805			Valid
	S5	0.803			Valid
	S6	0.749			Valid
	S7	0.766			Valid
	S8	0.796			Valid
	S9	0.773			Valid

Based on the validity test results, all indicators for each research variable were declared valid. This is evidenced by loading factor values that meet the minimum required threshold, as well as average variance extracted (AVE) values that confirm the fulfillment of convergent validity. Additionally, the results of the discriminant validity test indicate that each construct maintains adequate separation. Consequently, the measurement model meets the required validity criteria, and the study can proceed to structural model analysis.

Table 5 presents the results of the discriminant validity analysis for the constructs of Computational Thinking (CoT), Critical Thinking (CT), and Spirituality (S) across the Indonesian and Malaysian samples. Discriminant validity was assessed to ensure that each construct is empirically distinct and captures a unique concept within the measurement model. The analysis indicates that the indicators are more strongly associated with their respective constructs than with others, confirming that the measurement model adequately differentiates between CoT, CT, and Spirituality in both national contexts. These results demonstrate the robustness of the constructs and support the suitability of the measurement model for subsequent structural analysis.

Table 5. Discriminant validity

Indonesia				
Indicators	**CoT**	**CT**	**S**	**Information**
CT10	0.709	0.798	0.522	Valid
CT11	0.771	0.859	0.762	Valid
CT15	0.841	0.858	0.696	Valid
CT16	0.740	0.756	0.647	Valid
CT17	0.747	0.773	0.631	Valid
CT2	0.771	0.819	0.731	Valid
CT3	0.681	0.795	0.594	Valid
CT4	0.682	0.791	0.615	Valid
CT5	0.701	0.780	0.670	Valid
CT6	0.754	0.837	0.623	Valid

Indonesia				
Indicators	**CoT**	**CT**	**S**	**Information**
CT7	0.766	0.880	0.671	Valid
CT8	0.614	0.767	0.518	Valid
CT9	0.816	0.891	0.736	Valid
CoT1	0.770	0.698	0.711	Valid
CoT10	0.771	0.738	0.697	Valid
CoT13	0.723	0.674	0.626	Valid
CoT15	0.756	0.709	0.604	Valid
CoT16	0.854	0.817	0.670	Valid
CoT17	0.827	0.793	0.683	Valid
CoT18	0.861	0.802	0.762	Valid
CoT19	0.828	0.787	0.673	Valid
CoT2	0.826	0.693	0.705	Valid
CoT3	0.898	0.790	0.801	Valid
CoT4	0.777	0.667	0.694	Valid
CoT5	0.854	0.705	0.763	Valid
CoT6	0.808	0.743	0.728	Valid
CoT7	0.904	0.793	0.814	Valid
CoT8	0.902	0.825	0.809	Valid
S10	0.642	0.680	0.747	Valid
S2	0.654	0.604	0.721	Valid
S3	0.741	0.610	0.832	Valid
S4	0.722	0.695	0.843	Valid
S5	0.766	0.685	0.850	Valid
S6	0.699	0.658	0.781	Valid
S7	0.772	0.692	0.879	Valid
S8	0.614	0.584	0.808	Valid
S9	0.708	0.613	0.803	Valid
Malaysia				
Indicators	**CoT**	**CT**	**S**	**Information**
CT11	0.709	0.785	0.602	Valid
CT12	0.702	0.860	0.754	Valid
CT13	0.717	0.841	0.767	Valid
CT14	0.644	0.752	0.584	Valid
CT16	0.604	0.852	0.706	Valid
CT17	0.603	0.855	0.714	Valid
CoT11	0.785	0.728	0.711	Valid
CoT13	0.799	0.681	0.702	Valid
CoT14	0.811	0.632	0.664	Valid
CoT15	0.819	0.595	0.752	Valid
CoT18	0.826	0.581	0.658	Valid
CoT19	0.792	0.615	0.613	Valid
CoT4	0.816	0.660	0.698	Valid
CoT5	0.784	0.702	0.662	Valid
CoT8	0.708	0.507	0.607	Valid

Indonesia				
Indicators	**CoT**	**CT**	**S**	**Information**
CoT9	0.761	0.624	0.663	Valid
S1	0.689	0.708	0.761	Valid
S2	0.690	0.752	0.850	Valid
S3	0.568	0.503	0.721	Valid
S4	0.670	0.629	0.805	Valid
S5	0.777	0.648	0.803	Valid
S6	0.716	0.680	0.749	Valid
S7	0.595	0.658	0.766	Valid
S8	0.639	0.629	0.796	Valid
S9	0.627	0.660	0.773	Valid

Based on the results of the discriminant validity test presented in the table, all indicators for each construct were declared valid. The results show that each indicator has a higher correlation to its intended construct than to any other construct, ensuring there is no overlap between them. With the fulfillment of these discriminant validity criteria, it can be concluded that each construct in the research model maintains an adequate degree of separation. These findings confirm that the measurement model meets all necessary quality requirements.

Table 6 shows the results of the construct reliability tests for the variables Computational Thinking (CoT), Critical Thinking (CT), and Spirituality (S) in the Indonesian and Malaysian samples. Construct reliability was evaluated using Cronbach's Alpha (CA), rho_A, and Composite Reliability (CR) to ensure internal consistency before performing the structural analysis.

Table 6. Construct Reliability

Indonesia			
Variables	**CA**	**rho_A**	**CR**
CoT	0.966	0.968	0.970
CT	0.958	0.961	0.963
S	0.933	0.936	0.944
Malaysia			
Variables	**CA**	**rho_A**	**CR**
CoT	0.933	0.935	0.943
CT	0.906	0.913	0.927
S	0.920	0.922	0.934

The results of the construct reliability test showed that the composite reliability and Cronbach's alpha values for all constructs exceeded the required minimum

threshold (≥ 0.70), indicating the internal consistency of the indicators in measuring latent constructs. This combination of discriminant validity and construct reliability confirms that the measurement model meets the quality criteria for the SEM-PLS approach and is suitable for structural model testing.

b. Structural model

After the measurement model was confirmed to meet the criteria for validity and reliability, the analysis proceeded to the structural model to evaluate the causal relationships between latent constructs and the model's ability to explain endogenous variables. The evaluation of the structural model in the SEM-PLS approach was conducted by examining the coefficient of determination (R^2) to assess the model's predictive power and the effect size (F^2) to measure the magnitude of influence exerted by each exogenous construct on the endogenous construct. The results of the R Square (R^2) and F Square (F^2) tests are presented to illustrate the model's explanatory strength and the variations in influence between the Indonesian and Malaysian contexts.

The results of the R Square (R^2) and F Square (F^2) analyses indicate that the model used to measure the construct of Spirituality (S) in Indonesia and Malaysia has strong explanatory power. In Indonesia, the R Square for Spirituality is 0.760, meaning that the model explains 76% of the variation in Spirituality, with an Adjusted R Square of 0.753. In Malaysia, the R Square is 0.796, indicating that the model explains 79.6% of the variation, an the Adjusted R Square is 0.790, suggesting slightly higher explanatory power than the Indonesian model. Regarding F^2, in Indonesia, Computational Thinking (CoT) has a significant influence on Spirituality ($F^2 = 0.495$), while Critical Thinking (CT) has a negligible influence ($F^2 = 0.002$). In Malaysia, CoT exerts a significant influence ($F^2 = 0.450$), whereas CT shows a moderate influence ($F^2 = 0.330$), highlighting a distinct difference in the relationships between these variables across the two countries.

In terms of Goodness of Fit, the models in both countries show favorable results, although notable differences exist. For Indonesia, the SRMR is 0.072, indicating a very good fit as it falls below the 0.08 threshold. While d_ULS (3.611) and d_G (6.525) suggest a sound model, the NFI value of 0.583 indicates a poor overall fit. In Malaysia, the SRMR of 0.078 remains within the acceptable limit, while d_ULS

(1.972) and d_G (1.795) are lower than in Indonesia, suggesting a better fit to the data. However, the Malaysian NFI value of 0.675 also indicates a poor fit, as it falls below the standard threshold of NFI > 0.90. Overall, while the Malaysian model performs better across certain metrics, the low NFI values in both countries suggest that the model could be further improved (Shadfar & Malekmohammadi, 2013).

Table 7 presents the results of the structural model evaluation for Indonesian and Malaysian samples, as indicated by the determination coefficients (R^2 and R^2 adjusted) and the effect size (F^2). The R^2 value is utilized to assess the predictive ability of exogenous constructs in explaining the variance of endogenous variables. At the same time, F^2 indicates the magnitude of each construct's contribution to the R^2 values. This analysis is essential for understanding the strength of the structural relationships and the practical relevance of the proposed model.

Table 7. Output of R2 Results

	Variable	R2	R2 Adjusted	Countries
R2		0.76	0.753	Indonesia
		0.796	0.79	Malaysia
F2	S	**CoT**	**CT**	**Countries**
		0.495	0.002	Indonesia
		0.45	0.33	Malaysia

Based on the analysis of R Square (R^2) and F Square (F^2) presented in Table 7, the structural model shows strong clarity in explaining the construct of Spirituality in the Indonesian and Malaysian contexts. The R^2 value for Spirituality in Indonesia is 0.760, with an Adjusted R^2 of 0.753, indicating that the model explains 76% of the variation in the construct. Meanwhile, the R^2 value in Malaysia is 0.796, with an Adjusted R^2 of 0.790, showing that the model's explanatory ability is slightly higher than in Indonesia.

In terms of effect size (F^2), within the Indonesian context, the Computational Thinking (CoT) has a considerable influence on Spirituality with an F^2 value of 0.495, while Critical Thinking (CT) shows a negligible influence (0.002). In contrast, in the Malaysian context, CoT still demonstrates a significant influence (F^2 = 0.450), whereas CT has a moderate influence (F^2 = 0.330). These findings highlight a distinct difference in the influence patterns between the two countries within this research model.

Table 8 presents the results of the Goodness of Fit evaluation for the Indonesian and Malaysian samples. The assessment was conducted using several model fit indices,

including the Standardized Root Mean Square Residual (SRMR), d_ULS, d_G, Chi-Square, and Normed Fit Index (NFI), for both the saturated and estimated models. This evaluation ensures that the proposed model achieves an adequate level of compatibility with the empirical data before interpreting the hypothesis-testing results.

Table 8. Goodness of Fit (GoF)

	Saturated Model		Estimated Model	
SRMR	0.072	0.078	0.072	0.078
d_ULS	3.611	1.972	3.611	1.972
d_G	6.525	1.795	6.525	1.795
Chi-Square	1564.333	544.834	1564.333	544.834
NFI	0.583	0.675	0.583	0.675
	Indonesia	Malaysia	Indonesia	Malaysia

Based on Table 8, the results demonstrate an acceptable level of fit in both the Indonesian and Malaysian contexts. The Standardized Root Mean Square Residual (SRMR) values in Indonesia and Malaysia were 0.072 and 0.078 in the estimated models for Indonesia and Malaysia, respectively; both values remain within the recommended tolerance limit of < 0.08. Furthermore, the d_ULS and d_G values in the estimated models were lower than those in the saturated models, indicating an improvement in model fit following the estimation process. The Chi-Square value also decreased significantly from the saturated to the estimated model, suggesting a more efficient representation of the data. Additionally, the Normed Fit Index (NFI) in the estimated model is higher than in the saturated model, although it remains in the moderate range. Overall, these results indicate that the estimated model possesses an adequate level of fit and is suitable for further analysis.

c. Hypothesis testing

Once the structural model was confirmed to have an adequate fit, the next stage was hypothesis testing to identify the direction, strength, and significance of the relationships among the constructs in the research model. This testing was conducted to compare the influence of Computational Thinking (CoT) and Critical Thinking (CT) on Spirituality (S) within the Indonesian and Malaysian contexts.

Table 9 presents the results of the comparative analysis testing the differences in influence between variables in the Indonesian and Malaysian samples. This table

displays the Original Sample, Sample Mean, Standard Deviation, T-Statistics, and P-Values for each tested structural relationship. These metrics allow identification of differences in the strength and significance of influences across constructs in the two national contexts. This presentation provides an empirical basis for comparing the patterns of relationships between variables and understanding the variations in model characteristics in each country.

Table 9. Hypotheses

Relation	Original Sample	Sample Mean	Standard Deviation	T Statistics	P Values	Countries
CoT -> S	0.82	0.81	0.181	4.535	0.000	Indonesia
CoT -> S	0.506	0.547	0.18	2.809	0.005	Malaysia
CT -> S	0.057	0.069	0.199	0.286	0.775	Indonesia
CT -> S	0.433	0.399	0.181	2.401	0.017	Malaysia

Table 9 shows a significant difference between Indonesia and Malaysia regarding the influence of Computational Thinking (CoT) and Critical Thinking (CT) on Spirituality (S). In Indonesia, CoT exerts a powerful influence on Spirituality, evidenced by a very low P Value (0.000) and high T Statistics (4.535). In contrast, CT does not show a significant influence with a very high P Value (0.775) and low T Statistics (0.286). In contrast, in Malaysia, CT shows a substantial influence on Spirituality, with P Values of 0.005 and 0.017, respectively, and higher T Statistics (2.809 and 2.401), indicating that CT is more influential in Malaysia than in Indonesia. This suggests that in Indonesia, Critical Thinking plays a greater role in influencing Spirituality, while in Malaysia, Computational Thinking also has a significant influence.

2. Discussion

This study provides important insights into the development of critical thinking in higher education by demonstrating that such abilities are shaped not only by cognitive and technical skills, but also by ethical and value-based dimensions, such as spirituality. The findings confirm that computational thinking and spirituality jointly contribute to students' critical thinking skills, although their relative influence differs between Indonesia and Malaysia. This variation highlights the contextual nature of critical thinking development and underscores the importance of integrating cognitive and ethical dimensions in accordance with national educational cultures.

From a conceptual perspective, spiritual attitude plays a significant role in shaping individual character through actions grounded in personal values and moral awareness. Spirituality contributes to the development of mental quality by guiding individuals to act based on faith, ethical principles, and reflective judgment. As indicated in this study, spiritual attitudes tend to strengthen alongside the development of critical thinking skills, suggesting that higher levels of reflective reasoning may reinforce ethical awareness and moral responsibility. This relationship is particularly relevant in educational contexts, where students are expected not only to think analytically but also to apply their reasoning skills in ways that uphold ethical conduct and social responsibility (Baizhuma et al., 2025).

The findings further show that computational thinking contributes substantially to the development of analytical and argumentative reasoning skills. Consistent with previous studies, computational thinking enhances students' ability to approach problems systematically, decompose complex issues, and apply structured reasoning in decision making. Dong et al., (2024) demonstrated that the development of computational thinking improves students' systematic problem-solving abilities; this aligns with the current study's results, which show a strong relationship between computational thinking and critical thinking, particularly in the Malaysian context. The more pronounced influence of computational thinking in Malaysia may be attributed to a curriculum orientation and pedagogical practices that place greater emphasis on technical, analytical, and technology-driven competencies (Haseski et al., 2018; Fauzi et al., 2025).

In contrast, spirituality emerged as a more influential factor in strengthening critical thinking skills in Indonesia. This finding reflects cultural and institutional differences in how spiritual values are embedded within educational practices. In Indonesian higher education, particularly in Islamic universities, spirituality is more explicitly integrated into students' academic and social lives, shaping their perspectives on knowledge, ethics, and responsibility (Hayadin et al., 2025). Tirri (2023) emphasizes that spirituality in the Indonesian context is closely intertwined with students' daily experiences and value systems, enabling moral and ethical considerations to enrich cognitive processes. Similarly, Ezzani and Brooks (2022) argue that spirituality provides a reflective dimension that supports wiser, more ethical decision-making, which is essential for the development of holistic critical thinking.

These findings are consistent with Gardner (2024), who highlights the role of spirituality in fostering deep ethical reflection within higher education. Spiritual reflection

allows students to evaluate arguments not only in terms of logical validity but also in terms of their moral implications and social consequences. Annunziata et al., (2023) further support this integrative perspective by demonstrating that educational approaches combining cognitive and spiritual development can significantly enhance critical thinking outcomes. The present study extends this argument by providing empirical evidence from a comparative cross-national context, showing that integrating computational thinking and spirituality offers more comprehensive support for the development of critical thinking than approaches that emphasize cognitive skills alone.

At the theoretical level, this study's results reinforce and extend existing models of critical thinking by affirming the importance of non-cognitive dimensions. Mahmud et al. (2024) emphasize that critical thinking involves not only analytical reasoning but also reflection, ethical judgment, and responsibility. The findings of this study support this view by demonstrating that spirituality enriches the reflective and ethical components of critical thinking, enabling learners to engage in deeper self-examination, moral discernment, and value-oriented decision-making. This aligns with research highlighting the role of affective and personal dimensions in intellectual development, such as the formation of a positive self-concept and reflective awareness as foundations of professional and cognitive growth (Nurwahyuni & Tabrani ZA, 2025). In this sense, spirituality functions as an inner regulatory framework that shapes how reasoning is guided by meaning, responsibility, and ethical sensitivity, thereby extending conventional cognitively driven models of critical thinking.

At the same time, this study shows that computational thinking complements spirituality by strengthening the analytical, structural, and problem-solving dimensions of critical thinking. Prior studies have demonstrated that computational thinking enhances learners' abilities to decompose problems, recognize patterns, and apply logical procedures systematically, particularly within digital and technology-mediated learning environments (Ngandoh, 2022). When integrated with pedagogical innovations such as interactive digital resources, computational thinking further supports differentiated and meaningful learning processes (Ziaurrahman et al., 2024). The present findings suggest that when these analytical capacities are combined with spiritual and ethical orientations, critical thinking becomes more holistic and balanced. This integrated model resonates with educational practices that emphasize disciplined cognition alongside moral and spiritual formation, as seen in faith-based

learning contexts that cultivate focus, self-regulation, and ethical commitment (Khafidah et al., 2020). Collectively, the results point toward a comprehensive model of critical thinking that responds more effectively to the complex intellectual, ethical, and technological demands of contemporary education.

Furthermore, the study supports the conceptualization of computational thinking as a cross-disciplinary foundational skill, as proposed by Merino-Armero et al., (2022) and Yeni et al., (2024). However, it also extends this perspective by showing that computational thinking alone is insufficient to explain the development of critical thinking fully. Instead, its integration with affective and value-based constructs such as spirituality provides a more robust explanatory framework. This integrative approach is consistent with the findings of Almulla and Al-Rahmi (2023) and Teng and Yue (2023), who argue that educational models combining cognitive and affective dimensions yield stronger explanatory power in understanding students' higher-order thinking skills.

The comparative findings between Indonesia and Malaysia further confirm that critical thinking development is context-dependent. Differences in curriculum orientation, pedagogical strategies, and cultural values shape how computational thinking and spirituality influence students' reasoning processes. In Malaysia, where technology integration and problem-based learning are more strongly emphasized, computational thinking plays a dominant role in strengthening analytical and evidence-based reasoning. In Indonesia, where spiritual and moral education is more deeply embedded within institutional practices, spirituality exerts a more substantial influence on reflective and ethical aspects of critical thinking. These differences illustrate that there is no single universal pathway to the development of critical thinking; instead, effective strategies must be aligned with local educational contexts.

From a practical perspective, the findings suggest that higher education institutions should adopt context-sensitive strategies for developing students' critical thinking skills. In Indonesia, strengthening spirituality through reflective learning activities, value-based case studies, and interdisciplinary approaches can deepen students' ethical awareness and meaningful reasoning. In Malaysia, enhancing computational thinking through problem-based learning, systematic reasoning exercises, and the use of digital technologies can further strengthen analytical competence and rational decision-making. An integrative pedagogical framework that combines computational thinking and spirituality, as suggested by

Arslantaş (2024), offers a more complete approach to preparing students for complex intellectual and ethical challenges.

The study also responds to ongoing debates regarding the conceptual clarity of critical thinking in education. Bowen (2022) notes that despite widespread recognition of critical thinking as an educational goal, its conceptualization remains contested. The present findings contribute to this debate by demonstrating that critical thinking should be understood as a multidimensional construct encompassing analytical, reflective, and ethical dimensions. Smith (2021) further argues that integrating computational thinking and spirituality in learning can foster more holistic individuals who are capable of critical reasoning that is both technically sound and ethically grounded. The results of this study provide empirical support for this integrative perspective.

In addition, the assessment of critical thinking in educational contexts should extend beyond purely cognitive measures to include ethical and argumentative dimensions influenced by spiritual values (Hariyanto, 2025; Nurwahyuni & Tabrani ZA, 2025; Hashi, 2024). The stronger influence of spirituality on critical thinkifng in Indonesia reinforces the argument that multidimensional educational approaches integrating both computational thinking and spirituality are more effective in developing students who are not only intellectually competent but also morally responsible (Yuan et al., 2021; Zamroni & Supriyanto, 2024). Higher education institutions, therefore, play a crucial role in shaping students' intellectual and moral character, thereby contributing to the formation of graduates with strong critical thinking skills and high ethical standards.

Despite its contributions, this study has several limitations that should be acknowledged. First, the focus on higher education institutions in Indonesia and Malaysia limits the generalizability of the findings to other educational and cultural contexts. Second, the use of a cross-sectional survey design restricts the ability to observe changes in students' critical thinking, computational thinking, and spirituality over time, and precludes strong causal inferences. Third, the reliance on self-report measures, particularly in assessing spirituality, may be influenced by subjective perceptions and culturally shaped responses. Consequently, these findings should be interpreted with appropriate caution.

D. Conclusion

This study concludes that the development of students' critical thinking skills in higher education is shaped by the interaction between cognitive and ethical dimensions,

specifically computational thinking and spirituality. The findings demonstrate that both computational thinking and spirituality contribute positively to critical thinking, though their relative influence varies across national contexts. In Malaysia, computational thinking plays a more dominant role, reflecting the strong emphasis on analytical reasoning, technological integration, and systematic problem-solving within the educational curriculum. In contrast, spirituality exerts a more substantial influence in Indonesia, underscoring the importance of moral reflection, value-based reasoning, and ethical awareness in shaping students' critical thinking.

From a theoretical perspective, this study contributes to advancing critical thinking frameworks by affirming that critical thinking should be understood as a multidimensional construct that extends beyond purely technical or cognitive competencies. By empirically demonstrating the complementary roles of computational thinking and spirituality, this research strengthens integrative models of critical thinking that incorporate analytical, reflective, and ethical dimensions. The comparative findings further underscore that critical thinking development is context-sensitive and influenced by curriculum orientation, pedagogical approaches, and cultural values.

Practically, the results suggest that higher education institutions should adopt context-responsive strategies in fostering critical thinking. Educational practices that integrate computational thinking with spirituality offer a more holistic pedagogical framework, enabling students to develop not only analytical competence but also ethical judgment and reflective awareness. Such an approach is particularly relevant for addressing the intellectual and moral challenges of the digital era.

Despite its contributions, this study acknowledges several limitations, including its focus on higher education institutions in Indonesia and Malaysia, its use of a cross-sectional survey design, and its reliance on self-reported measures of spirituality. To address these limitations, future research is encouraged to expand the institutional and cultural scope of analysis, employ longitudinal or mixed-methods designs, and incorporate more diverse measurement approaches to capture changes in critical thinking, computational thinking, and spirituality over time.

Finally, this study highlights that integrating computational thinking and spirituality provides a more comprehensive foundation for developing students' critical thinking skills. A balanced integration of cognitive and ethical dimensions is

essential for preparing graduates who are not only intellectually capable but also ethically responsible, offering a clear take-home message for higher education in the twenty-first century.

Declaration of Competing Interest

The authors declare that they have no known competing financial or non-financial interests that could have influenced the work reported in this paper.

Declaration of Generative AI

During the preparation of this manuscript, the authors used a generative AI tool to improve the clarity and readability of the text. All AI-generated outputs were carefully reviewed and edited by the authors. The authors take full responsibility for the content, interpretation, and conclusions presented in this article.

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