Online Learning in Educational Research
Volume 5, Issue 1, 9-24.
e_ISSN: 2798-2351
https://www.journal.foundae.com/index.php/oler/index
DOI: 10.58524/oler.v5i1.504

Enhancing Computational Thinking Skills through Digital Literacy and Blended Learning: The Mediating Role of Learning Motivation

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Article Info

Article history:

Received: December 2, 2024
Revised: January 29, 2025
Accepted: February 23, 2025
Published: June 15, 2025

Keywords:

Blended Learning;
Computational Thinking Skills;
Digital Literacy;
Learning Motivation.

Abstract

In the digital era, computational thinking becomes an essential skill to overcome technological challenges in 21st-century education. This study investigates the impact of digital literacy and blended learning on computational thinking skills, focusing on the mediating role of learning motivation. A total of 413 university students from blended learning environments participated, using a structured questionnaire with validated scales for digital literacy, computational thinking, and learning motivation. Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) to test direct and mediation relationships. The results showed that digital literacy and blended learning significantly influenced computational thinking, with learning motivation acting as a mediator that strengthened this relationship. Digital literacy showed a greater influence than blended learning. These findings highlight the importance of integrating digital literacy and motivational strategies into blended learning to optimize the development of computational thinking skills, as well as providing insights for learning design that is relevant to the needs of the 21st-century.

To cite this article: Nirmala, P., Suhardi, I., Kaswar, A. B., Surianto, D. F., B, M. F., S. Soeharto, & Z. Lavicza. (2025). Enhancing computational thinking skills through digital literacy and blended learning: The mediating role of learning motivation. *Online Learning in Educational Research, 5*(1), 9-24. https://doi.org/10.58524/oler.v5i1.504

INTRODUCTION

The digital transformation in education has revolutionized the way students learn and interact with technology, highlighting the importance of integrating Information and Communication Technologies (ICT) into the learning environment (Kurniawati et al., 2023; Pratiwi & Riyana, 2023; Yuangga, 2023). ICT not only increases the effectiveness and efficiency of learning, but also presents challenges in ensuring students can develop 21st-century skills, such as critical thinking, problem-solving, creativity, collaboration, and digital literacy (Aulia et al., 2023; Pratiwi & Riyana, 2023). These skills are essential to face the complexities of a technology-based world (Jufriadi et al., 2022). However, low motivation to learn and a lack of implementation of effective learning strategies often become obstacles to the maximum development of these skills (Iswadi & Karlina, 2021; Widayanti et al., 2021). This is in line with the findings of Siregar et al. (2024), who stated that when students do not feel interested in the methods used, they tend to lose motivation, which impacts their understanding of the material and the skills they develop.

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One of the most important cognitive skills to develop in the digital era is computational thinking ability (Widya et al., 2022). This ability includes expertise in analyzing problems, developing algorithmic steps for solving problems and using logic to find the right solution (Mardhatilah et al., 2022; Ramadhan et al., 2023). Unfortunately, low levels of digital literacy and the dominance of conventional learning approaches are often the main barriers to developing computational thinking skills (Putri et al., 2024; Zahra & Amaliyah, 2023). Low digital literacy makes students less able to use technology optimally to access information, evaluate data accuracy, and utilize this information in learning (Dimov, 2024; Halimah et al., 2020; Nurwahidah et al., 2021). This emphasizes the importance of a learning approach that can improve digital literacy and students' interest in learning, thereby supporting the development of computational thinking skills that are relevant to the needs of the digital era. One potential solution to bridge this gap is to integrate digital literacy and blended learning as an effective strategy in supporting the development of computational thinking skills. Digital literacy equips students with the ability to access, evaluate, and use technology-based information efficiently (A'yun, 2021; Kustini et al., 2021), while blended learning provides flexibility in combining face-to-face learning with immersive digital experiences (Kristiono et al., 2019; Martha & Zulherman, 2022; Purwanto et al., 2022; Riadi et al., 2024). Likewise, learning motivation plays an important role as a driver of student involvement in the learning process, both in the classroom and on digital platforms (Mahardika et al., 2022; Wafiqni et al., 2023).

Although digital literacy and blended learning have been widely discussed in educational contexts, previous research has more often focused on the individual impact of each strategy without highlighting the synergistic interaction between the two in supporting the development of computational thinking skills. Most studies emphasize the direct influence of digital literacy on learning outcomes or the effectiveness of blended learning in enhancing student motivation (Herlina et al., 2023). For example, research conducted by Patmanthara & Hidayat, (2018) shows that digital literacy can improve students' evaluative skills, while a study by Kusumawardani (2024) found that blended learning provides significant flexibility in the learning process. However, the study did not explore how these two elements can be integrated to have a greater impact on the development of computational thinking skills. In addition, Soraya et al. (2023) highlighted that digital literacy plays a role in motivating students, but the study did not discuss how blended learning can serve as a complementary framework to support digital literacy. By giving students the autonomy to explore digital materials at their own pace and needs, digital literacy can also encourage more active engagement and a sense of responsibility for their learning (Safitri, 2023; Syarifuddin et al., 2023). The integration of digital literacy into a blended learning framework provides an opportunity to create more relevant and meaningful learning experiences, which ultimately increases students' learning motivation, this is also supported by the Self-Determination theory (Deci & Ryan, 1985), which states that fulfilling students' psychological needs, such as competence and autonomy, is the key to increasing intrinsic motivation.

In the context of developing high-level thinking skills, such as computational thinking skills, synergy between technology and innovative learning strategies is the key (Ramadhan et al., 2023; Ribhan et al., 2024). Digital literacy, blended learning, and learning motivation have been identified as important factors that can support the development of these skills, but the synergistic interactions between the three are not fully understood. Research conducted by Putri et al. (2023) showed that the development of computational thinking skills requires the integration of technology with learning strategies that can increase active student engagement. However, their study did not specifically examine how digital literacy and blended learning can complement each other in supporting the development of these skills. In Addition, Riswan et al. (2024) emphasize that learning motivation acts as a bridge that strengthens the impact of digital literacy and blended learning on students' cognitive learning outcomes. However, this study is still limited to discussing the direct relationship without investigating the synergistic interaction between digital literacy, blended learning, and learning motivation in the context of computational thinking skills. This highlights a research gap that needs to be filled to understand how the three elements can integrated to improve the development of students' computational thinking skills.

Therefore, this study aims to explore the relationship between Digital Literacy (DL), Blended Learning (BL), and Computational Thinking (CT) Skills, highlighting the role of Learning Motivation

(LM) as a mediator. Specifically, this study aims to understand how DL and BL can jointly support the development of CT through enhancing learning motivation. Although digital literacy, blended learning, and computational thinking have been the focus of many studies, studies that integrate these three elements holistically are still limited. In addition, the role of LM as a connector in the interaction between DL, BL, and CT has not been widely explored, making this study a new contribution to the development of theory and practice in technology-based learning.

By exploring the interaction between digital literacy, blended learning, and computational thinking skills, as well as the role of learning motivation as a mediator, this study is expected to provide significant contributions to the literature on technology-based education. The results of this study are also expected to be a practical reference for educators, policymakers, and curriculum developers to design more relevant, inclusive, and adaptive learning models, to support the development of 21st-century skills in facing the challenges of an increasingly complex digital world. The formulation of the problems that will be discussed in this research: 1) How do Blended Learning and Digital Literacy have a direct and indirect influence on Computational Thinking through the mediating role of Learning Motivation?; 2) What is the direct effect of Learning Motivation on Computational Thinking?; 3) Does Learning Motivation significantly mediate the relationship between Blended Learning, Digital Literacy, and Computational Thinking?

METHOD

Study Design

This study uses quantitative methodology with a cross-sectional design (Creswell, 2014). to evaluate the relationship between digital literacy and blended learning on the development of computational thinking skills, with learning motivation as a mediating factor. This study was conducted at Makassar State University and Alauddin State Islamic University Makassar, involving students from various majors, both STEM and non-STEM, who were involved in blended learning. Data were collected through an online survey to ensure broad and effective access, taking into account the varying levels of participants' technological skills. Figure 1 illustrates the research design flow.

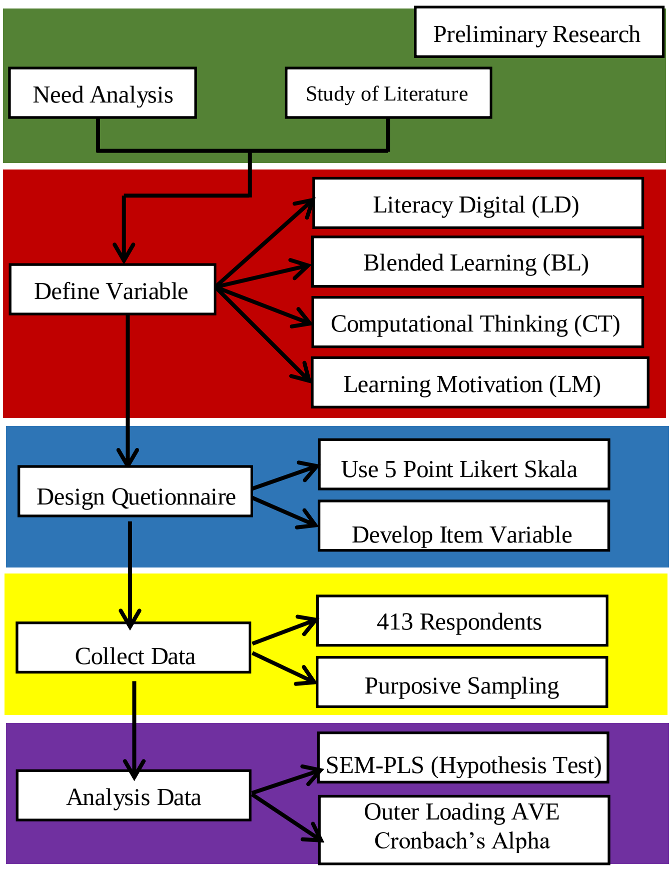

Figure 1. Research Design Flow

Collect Data

Participants in this study consisted of 413 undergraduate students actively engaged in a blended learning environment, selected using purposive sampling based on characteristics relevant to the study objectives (Hidayah et al., 2022). Respondents were 52% male and 48% female, with the majority aged 19 to 21 years. Most participants were in their third semester and were primarily enrolled in STEM-related fields such as Biology, Physics, Chemistry, and Engineering, as well as non-STEM fields such as Social Sciences, Humanities, and Education. Regarding computer literacy, 60% of respondents rated their skills as intermediate, 30% as beginner, and 10% as advanced. These demographic characteristics reflect a diverse and relevant participant profile, providing valuable insights into the relationship between digital literacy, blended learning, and computational thinking skills, with learning motivation as a mediating factor. Table 1 presents a general description of respondents.

Table 1. General Description of Respondents

Categories	Subcategories	Frequency	Percentage (%)
Gender	Male	181	43.82
	Female	232	56.17
Age	17	1	0.24
	18	47	11.38
	19	264	63.93
	20	82	19.85
	21	18	4.36
	22	1	0.24
Experience	Beginner	170	41.16
	Intermediate	226	54.72
	Advanced	17	4.12

Design Questionnaire

This study used a questionnaire as the main instrument to collect data related to the variables studied. The questionnaire was designed using a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree), which was chosen because of its ease of understanding and application, especially for the target population in the local context. The 5-point scale was also chosen because it can reduce the cognitive burden for respondents and produce reliable and valid data (Weijters et al., 2010).

The study explores the relationship between four primary variables: two independent variables, one mediating variable, and one dependent variable, focusing on how digital literacy and blended learning impact the enhancement of computational thinking skills, with learning motivation serving as a mediating factor. The first independent variable is Blended Learning (BL), which refers to the combination of face-to-face learning with digital technology-based learning to create a more flexible and adaptive learning experience (Eralita & Azzizzah, 2023). This variable is measured using five indicators, namely BL1, BL2, BL3, BL4, and BL5. The second independent variable is Digital Literacy (DL), which reflects students' ability to access, evaluate, and use technology-based information effectively to support the learning process (Hasanah et al., 2022). Digital literacy is measured through five indicators, namely DL1, DL2, DL3, DL4, and DL5. The mediating variable in this study is Learning Motivation (LM), which refers to students' internal drive to be actively involved in learning, both online and face-to-face (Nurfallah & Pradipta, 2021). Learning motivation is measured through five indicators, namely LM1, LM2, LM3, LM4, and LM5. The dependent variable that is the focus of this study is Computational Thinking Skills (CT), which includes students' abilities to analyze problems, compile algorithms, and use logic to find solutions (Syafril et al., 2022). These computational thinking skills are measured through four indicators, namely CT1, CT2, CT3, dan CT4.

The questionnaire development process involved adapting scales that had been proven valid and reliable in previous research (Eralita & Azzizzah, 2023; Nurfallah & Pradipta, 2021; Syafril et al., 2022), with items modified for the relevance of this research context. The scale's convergent validity was confirmed, as all Outer Loading values exceeded 0.7, and the Average Variance

Extracted (AVE) values were greater than 0.5. Discriminant validity was assessed using the Fornell-Larcker criteria, while construct reliability was established through Composite Reliability and Cronbach's Alpha, both scoring above 0.7. Data collection was carried out via an online survey over a week, ensuring wide and efficient accessibility while considering participants' diverse levels of technological proficiency.

Analisis Data

PLS-SEM was chosen in this study because of its advantages in handling complex and non-normally distributed data, as well as its ability to handle models with multiple latent variables without requiring the assumption of normality, making it ideal for predictive and exploratory research (Wingdes, 2019). This method is used to analyze the relationship between digital literacy, blended learning, and computational thinking skills with learning motivation as a mediator. Convergent validity is tested through Outer Loading and AVE, discriminant validity using the Fornell-Larcker criteria, and reliability using Composite Reliability and Cronbach's Alpha, both of which are more than 0.7. All analyses were conducted using SmartPLS 3 to gain an in-depth understanding of the influence between variables. The analysis procedure involves two main phases: assessing the measurement model (outer model) to verify the validity and reliability of the indicators and examining the structural model (inner model) to evaluate the strength of the association between latent constructs (Hair et al., 2019).

Outer Model

The outer model evaluation in PLS-SEM aims to assess the validity and reliability of indicators representing latent variables (Al-Abdullatif, 2023; Teoh et al., 2022). Indicators refer to variables that can be measured directly, while latent variables describe concepts that cannot be measured directly (Aji & Ramadani, 2024). This assessment includes three main elements: convergent validity, discriminant validity, and construct reliability.

To evaluate the extent to which the reflective indicators represent the construct, convergent validity testing was carried out (Andrew & Junaidi, 2024; Yunizar & Wicaksono, 2023). In PLS-SEM, some metrics used to measure convergent validity include factor loading and Average Variance Extracted (AVE) (Nawawi et al., 2020). Factor loading indicates the strength of the relationship between the indicators and the latent construct (Faisaluddin et al., 2023), and a factor loading value greater than 0.7 indicates a significant contribution of the indicator to the measured construct (Adda et al., 2021). While AVE measures how much variance in the indicator is explained by the construct in question. An AVE value above 0.50 indicates that the construct can explain more than half of the variance in the indicator (Khalil et al., 2023).

To assess whether different constructs are not highly correlated with each other, discriminant validity is tested (Ratna et al., 2023). Evaluation of discriminant validity is carried out using the Fornell-Larcker criterion, which requires the square root of the AVE of a construct to be greater than its correlation with other constructs (Memon et al., 2021).

Construct reliability refers to the consistency and stability of construct measurement in this study (Limarus & Pamungkas, 2023). In PLS-SEM, construct reliability is measured by metrics such as Composite Reliability (CR) and Cronbach’s Alpha. CR is used to evaluate the internal consistency of indicators in measuring a particular construct (Al Ayubi et al., 2023). CR value of more than 0.70 indicates good construct reliability. Cronbach's Alpha is also used to measure internal consistency, with values greater than 0.7 indicating acceptable construct reliability (Arovah & Heesch, 2020).

Inner Model

The inner model in PLS-SEM is used to test the relationship between latent constructs according to the research hypothesis (Farrukh et al., 2020). The evaluation was carried out using the coefficient of determination (R^2) to measure the ability of the independent variable to predict the dependent variable, with an R^2 value of more than 0.25 indicating significant strength (Kurniawan et al., 2023). Next, path coefficients were analyzed to determine the strength and direction of the relationship between constructs, with a p-value of less than 0.05 indicating significance. Effect size (f^2) measures the influence of each construct, with $f^2 > 0.02$ considered small, $f^2 > 0.15$ moderate, and $f^2 > 0.35$ substantial (He & Ismail, 2023). This model describes the relationships between latent constructs, including mediation or moderation roles that are consistent with the research hypotheses. Figure 2 presents the PLS Algorithm Model, which illustrates the stages and processes used in Partial Least Squares (PLS) analysis.

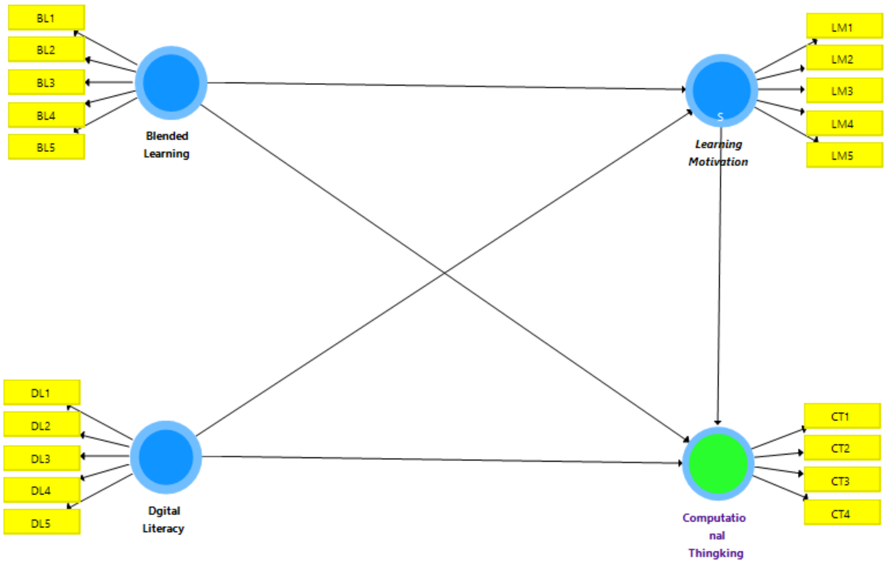

Figure 2. PLS Algorithm Model

H1: Blended Learning and Digital Literacy have a significant positive influence on Computational Thinking through Learning Motivation.
- H1a: Blended Learning has a direct and positive influence on Learning Motivation.
- H1b: Digital Literacy has a direct and positive influence on Learning Motivation.
- H1c: Blended Learning has a direct and positive influence on Computational Thinking Skills.
- H1d: Digital Literacy has a direct and positive influence on Computational Thinking Skills.

H2: Learning Motivation has a significant positive influence on Computational Thinking.
- H2a: Learning Motivation has a direct and positive influence on Computational Thinking Skills.

H3: Learning Motivation mediates the relationship between Blended Learning, Digital Literacy, and Computational Thinking.
- H3a: Learning Motivation mediates the relationship between Blended Learning and Computational Thinking Skills.
- H3b: Learning Motivation mediates the relationship between Digital Literacy and Computational Thinking Skills.

RESULTS AND DISCUSSION

Outer Model

The measurement model was assessed by examining the convergent validity and construct reliability of the constructs, including Blended Learning, Computational Thinking, Digital Literacy, and Learning Motivation. Convergent validity was determined through Outer Loading values and Average Variance Extracted (AVE), while reliability was measured using Cronbach's Alpha and Composite Reliability (CR). A summary of the results is presented in Table 2.

Table 2. Results of Reliability Evaluation of Constructs

Construct	Item	Outer Loading	Cronbanch's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Blended Learning	BL1	0.785	0.890	0.919	0.695
	BL2	0.837			
	BL3	0,879			
	BL4	0,841			
	BL5	0,823			

Construct	Item	Outer Loading	Cronbanch's Alpha	Composite Reliability	Average Variance Extracted (AVE)
Computational Thinking	CT1	0,856	0.868	0.910	0.716
	CT2	0,832			
	CT3	0,848			
	CT4	0,849			
Digital Literacy	DL1	0,860	0.909	0.932	0.733
	DL2	0,848			
	DL3	0,839			
	DL4	0,876			
	DL5	0,856			
Learning Motivation	LM1	0,892	0.911	0.934	0.739
	LM2	0,846			
	LM3	0,818			
	LM4	0,879			
	LM5	0,862			

The Outer Model verifies that the indicators effectively and reliably represent the latent constructs being measured. The reliability of the constructs is evaluated using Cronbach's Alpha (values above 0.7 signify good internal consistency), Composite Reliability (CR) (values exceeding 0.7 indicate strong consistency), and Average Variance Extracted (AVE) (values greater than 0.5 demonstrate that constructs capture more variance from indicators than error). The evaluation of the measurement model confirmed that all constructs satisfied the criteria for convergent validity and construct reliability. Outer loading values for all items surpassed the threshold of 0.7, signifying that the indicators adequately represented their constructs. Additionally, Cronbach's Alpha values for all constructs were above 0.7, indicating robust internal consistency. Similarly, Composite Reliability (CR) values exceeded 0.7 for all constructs, affirming the reliability of the measurement items.

For convergent validity, the Average Variance Extracted (AVE) values for all constructs exceed 0.5, demonstrating that each construct accounts for more than 50% of the variance in its associated indicators. Specifically, Blended Learning exhibits outstanding reliability, reflected in a Cronbach's Alpha of 0.890, a Composite Reliability (CR) of 0.919, and an AVE of 0.695. Similarly, Computational Thinking demonstrates high reliability and validity, with a Cronbach's Alpha of 0.868, a CR of 0.910, and an AVE of 0.716. Digital Literacy also achieves excellent internal consistency, supported by a Cronbach's Alpha of 0.909, a CR of 0.932, and an AVE of 0.733. Lastly, Learning Motivation stands out with the highest reliability metrics, evidenced by a Cronbach's Alpha of 0.911, a CR of 0.934, and an AVE of 0.739. Table 3 presents the results of the Fornell-Lacker criterion validity test, which evaluates the discriminant validity by comparing the square root of the average variance extracted (AVE) with the correlations between constructs.

Table 3. Results of the Fornell-Lacker Criterion Validity Test

Construct	Blended Learning	Computational Thinking	Digital Literacy	Learning Motivation
Blended Learning	$\sqrt{AVE^{BL}}$ = 0,834			
Computational Thinking	0,706	$\sqrt{AVE^{CT}} = 0,846$		
Digital Literacy	0,787	0,751	$\sqrt{AVE^{DL}} = 0,856$	
Learning Motivation	0,719	0,736	0,843	$\sqrt{AVE^{LM}} = 0,860$

The validity test results using the Fornell-Larcker Criterion validated that all constructs satisfied the requirements for discriminant validity, confirming that each construct was distinct from the others. The square root of the Average Variance Extracted (AVE) for each construct exceeded its correlations with other constructs, demonstrating robust discriminant validity. For instance, Blended Learning had an √AVE of 0.834, surpassing its correlations with Computational Thinking (0.706), Digital Literacy (0.787), and Learning Motivation (0.719). Similarly, Computational Thinking displayed an √AVE of 0.846, which was higher than its correlations with Blended Learning (0.706), Digital Literacy (0.751), and Learning Motivation (0.736). Digital Literacy also exhibited strong discriminant validity, with an √AVE of 0.856 exceeding its correlations with Blended Learning (0.787), Computational Thinking (0.751), and Learning Motivation (0.843). Lastly, Learning Motivation achieved an √AVE of 0.860, higher than its correlations with Blended Learning (0.719), Computational Thinking (0.736), and Digital Literacy (0.843). These findings confirm the conceptual uniqueness of the constructs, reinforcing the robustness of the measurement model. These results confirm that each construct can be well distinguished from the other constructs, which meets the requirements of discriminant validity in PLS-SEM analysis. Discriminant validity is important in this context to ensure that each construct measures a different aspect of the research framework and is not overly influenced by other constructs. This validation provides confidence that the observed relationships among constructs reflect true theoretical associations, rather than methodological overlap or redundancy.

Inner Model

Table 4 presents the results of the effect size analysis, which provides insights into the magnitude of the observed effects in this study.

Table 4. Result Effect Size

Construct	Computational Thinking	Learning Motivation
Blended Learning	0,030	0,066
Digital Literacy	0,050	0.716
Learning Motivation	0,071	

The results of the effect size (f^2) analysis show the contribution of each construct to the dependent variable in the research model. Digital Literacy has the largest contribution to Learning Motivation, with an f^2 value of 0.716, which is included in the large category according to Cohen's criteria ($f^2 \geq 0.35$). This confirms the importance of digital literacy in increasing student confidence and engagement in the learning process. Blended Learning shows a small but significant contribution to Learning Motivation with an f^2 of 0.066 and Computational Thinking Skills with an f^2 of 0.030, both of which are in the small category ($f^2 \geq 0.02$). Despite its small contribution, these results indicate that blended learning strategies remain relevant in supporting student engagement and the development of computational skills. Digital Literacy also has a small contribution to Computational Thinking Skills with an f^2 of 0.050, indicating that although digital literacy plays an important role, its contribution to the development of computational thinking requires support from other factors. Meanwhile, Learning Motivation has an f^2 of 0.071 on Computational Thinking Skills, which is also in the small category. This indicates that learning motivation supports the development of computational skills, although the impact is not too large directly. This classification of effect size values helps to understand the magnitude of the influence of each construct in the model, where small f^2 values range from ≥ 0.02, medium ≥ 0.15, and large ≥ 0.35, in accordance. Table 5 presents the model fit indices.

Table 5. Model Fit

	Model Saturated	Estimation Model
SRMR	0,056	0,056
NFI	0,879	0,879

The analysis of model fit reveals that the research framework demonstrates an adequate fit, as evidenced by the SRMR (Standardized Root Mean Square Residual) and NFI (Normed Fit Index) values. The SRMR for both the Saturated Model and the Estimation Model is reported at 0.056, well below the maximum threshold of 0.08. This low value indicates a minimal discrepancy between the observed and predicted covariance matrices, suggesting that the model effectively captures the relationships among the variables. Additionally, the NFI for both models is calculated at 0.879, which, although slightly below the ideal threshold of 0.90, still reflects a reasonably good capacity of the model to explain the data in comparison to the null (baseline) model. Collectively, these findings confirm that the proposed research model aligns sufficiently with the analyzed data, thereby supporting the validity of its structural representation. Table 6 presents the path coefficients, T-statistics, and P-values.

Table 6. Path Coef, T-Statistik and P Value

	Hypothesis	Path Coeffisient	T Statistic	P Values	Finding
H1a	BL -> LM	0.148	2.980	0.003	Significant
H1b	DL -> LM	0.727	15.911	0.000	Significant
H1c	BL -> CT	0.257	3.973	0.000	Significant
H1d	DL -> CT	0.289	3.216	0.001	Significant
H2a	LM -> CT	0.307	4.196	0.000	Significant
H3a	BL -> LM -> CT	0.045	2.351	0.019	Significant
H3b	DL -> LM -> CT	0.223	4.159	0.000	Significant

The results of the hypothesis testing obtained through PLS-SEM analysis show that Blended Learning has a direct and positive effect on Learning Motivation, with a path coefficient of 0.148, a T-statistic of 2.98, and a P value of 0.003. These findings indicate that blended learning strategies significantly contribute to improving students' learning motivation, which is supported by research by Al-Ghoweri et al. (2021). Their research highlights the importance of a combination of flexible and interactive face-to-face and online learning in creating a learning environment that supports student engagement. In addition, this approach allows students to manage their time more effectively while providing opportunities for collaboration and knowledge exploration. The effect size (f^2) of Blended Learning on Learning Motivation is 0.030, which is included in the small category. Although its contribution is small, this still confirms the relevance of blended learning strategies in encouraging increased student learning motivation. In line with these findings, Monoarfa (2023) shows that blended learning not only enhances students' intrinsic motivation but also provides benefits in terms of their sense of responsibility and active participation in learning activities. Thus, these results emphasize the importance of blended learning as a relevant educational strategy in the context of modern learning, where the diversity of teaching methods can directly affect students' learning motivation. This strategy makes an important contribution to creating a holistic and meaningful learning experience.

Furthermore, the results of the analysis show that Digital Literacy has a significant direct effect on Learning Motivation, with a path coefficient of 0.727, a T-statistic of 15.91, and a P value of 0.000. This finding confirms that the higher the digital literacy possessed by students, the more likely they are to be actively involved in the learning process. Digital literacy allows students to utilize technology more optimally, search for information, collaborate, and solve problems in the context of learning. The effect size (f^2) of Digital Literacy on Learning Motivation is 0.716, which is included in the large category, indicating a very significant contribution of digital literacy in encouraging student motivation. Research conducted by Jaya & Nurqamarani, (2023) supports these findings by highlighting that good digital literacy not only equips students with technical skills but also increases their confidence in utilizing technology to achieve learning goals. In Addition, research conducted by Mariani et al. (2022) revealed that digital literacy also plays an important role in boosting students' intrinsic motivation, as they feel more confident in managing digital tools that support their academic success. In the context of modern learning, the ability to navigate digital technology effectively is one of the key elements in creating interactive and meaningful learning experiences (Ganicheva et al., 2019). Therefore, improving digital literacy not only enriches students' learning experiences but also strengthens their motivation to engage more deeply in the educational process.

Blended Learning was also shown to have a direct positive effect on Computational Thinking Skills, with a path coefficient of 0.257, a T-statistic of 3.97, and a P-value of 0.000. These findings confirm that the blended learning approach significantly supports the development of students' computational thinking skills through learning activities that focus on problem-solving. The effect size (f^2) of Blended Learning on Computational Thinking Skills of 0.066, which is included in the small category, indicates that although its contribution is relatively small, blended learning is still relevant in supporting the development of student's abilities to think computationally. By combining elements of face-to-face and online learning, blended learning creates a flexible and interactive learning environment, allowing students to develop analytical and systematic abilities. Research conducted by Oktarianto et al. (2023) supports these results by highlighting that the flipped classroom model in blended learning provides students with the opportunity to learn the basic material independently before the face-to-face session, which is then focused on collaborative discussion and application of concepts in problem-solving. This approach not only increases student engagement but also strengthens their ability to apply computational thinking in real-world situations. Thus, these results emphasize the role of blended learning as an effective strategy to foster the mastery of 21st-century skills, including computational thinking, which is highly relevant in the modern educational context.

Similarly, Digital Literacy showed a significant direct effect on Computational Thinking Skills, with a path coefficient of 0.289, a T-statistic of 3.22, and a P-value of 0.001. These findings indicate that digital literacy is not only important as a basic skill but also has a direct impact on student's ability to think computationally. The effect size (f^2) of Digital Literacy on Computational Thinking Skills of 0.050, which is included in the small category, indicates that although its contribution is limited, digital literacy remains an important factor in supporting the development of students' computational thinking skills. Digital literacy allows students to understand and analyze patterns, construct algorithms, and utilize technology to solve complex problems. Research conducted by Kristiyanto et al. (2023) supports these results by asserting that students with good digital literacy are better able to apply algorithmic concepts in various learning contexts. In addition, other studies have also shown that digital literacy contributes to the development of higher-order cognitive abilities, such as problem-solving and data analysis, which are at the heart of computational thinking skills. Thus, improving students' digital literacy not only enriches their learning experience but also strengthens their foundation for mastering computational skills relevant to educational and employment needs in the digital age.

Learning Motivation showed a significant effect on Computational Thinking Skills, with a path coefficient of 0.307, a T-statistic of 4.20, and a P value of 0.000. This finding underlines the crucial role of motivation in enhancing students' engagement and performance in computational tasks. The effect size (f^2) of Learning Motivation on Computational Thinking Skills of 0.071, which is included in the small category, indicates that although the impact is not large, learning motivation remains an important element that supports the development of computational skills. Motivated students tend to be more enthusiastic about exploring, understanding, and applying computational concepts in various learning contexts. Research conducted by Soraya et al. (2023) supports these results by showing that high learning motivation encourages students to be more active in the learning process, including in solving problems that require systematic and algorithmic thinking. Motivation not only increases students' efforts in understanding the material but also builds their mental resilience in facing complex challenges. In addition, other studies indicate that strong intrinsic motivation can accelerate the mastery of higher-order thinking skills, including computational thinking, which is very relevant in today's digital education era (Stewart et al., 2021). Therefore, fostering learning motivation among students is an important step in creating a learning environment that supports the development of computational skills effectively.

Furthermore, Learning Motivation was shown to mediate the relationship between Blended Learning and Computational Thinking, with a path coefficient of 0.045, a T-statistic of 2.35, and a P-value of 0.019. These findings indicate that blended learning not only has a direct effect on computational thinking skills but also indirectly through increasing students' learning motivation. In this context, blended learning strategies, which combine online and face-to-face elements, create a more varied and interactive learning experience, thus encouraging students to be more motivated in completing computationally challenging tasks Research conducted by Monoarfa (2023) supports these results by asserting that the blended learning approach increases students' engagement and sense of responsibility, which ultimately strengthens their motivation to actively participate in the learning process. This is in line with findings by Sukkamart et al. (2025) blended learning allows students to access educational resources more flexibly, which helps them utilize their learning time effectively and maximize their potential in solving computational problems. For the implementation of educational policies, educators can be given special training to design blended learning-based curricula that emphasize the integration of problem-solving activities. In addition, educational institution policies can be directed to provide adequate technological infrastructure and online learning platforms that support maximum student interactivity and collaboration. Thus, these results emphasize the importance of utilizing blended learning as a strategy that not only supports computational thinking directly but also through a stronger motivational pathway to learning.

Learning Motivation was also shown to mediate the relationship between Digital Literacy and Computational Thinking, with a path coefficient of 0.223, a T-statistic of 4.16, and a P-value of 0.000. These findings suggest that digital literacy not only affects computational thinking skills directly but also indirectly through increasing students' learning motivation. Good digital literacy allows students to feel more confident in using technology, which in turn increases their interest and engagement in computational-based learning. This is in line with research conducted by Pariama (2024) supports these results by asserting that students with high digital literacy tend to be more motivated to participate in activities that require pattern analysis, algorithm construction, and problem-solving. Other studies also show that students who can use digital literacy well, supported by appropriate learning styles, show improvements in understanding economic learning and solving the problems they face (Rochmatika & Yana, 2022). To support education policies, schools, and educational institutions can develop digital literacy training programs for students and educators, focusing on the use of digital devices that support the development of 21st-century skills. Furthermore, the integration of learning technology in the national curriculum should be directed at the use of educational software that can improve students' analytical and algorithmic abilities. Thus, these results highlight the importance of digital literacy as a key element in building learning motivation, which ultimately supports the development of computational thinking skills that are relevant to the needs of 21st-century education.

This research underscores the pivotal influence of digital literacy and blended learning in fostering computational thinking skills, facilitated by the mediating impact of learning motivation. Employing a rigorous quantitative methodology through Partial Least Squares-Structural Equation Modeling (PLS-SEM), the study validates the constructs' strong reliability and validity, ensuring a clear distinction between the variables analyzed. The findings indicate that both blended learning and digital literacy exert a direct and mediated influence on computational thinking skills, emphasizing the importance of integrating these components into educational practices. However, this study has certain limitations. First, it focuses exclusively on higher education settings, limiting its applicability to other educational levels, such as secondary or primary education. Second, individual differences, including demographic characteristics like age and academic background, were not deeply analyzed as potential moderators. Finally, while learning motivation was examined as a mediator, other psychological factors, such as anxiety or emotional engagement, were not explored, leaving room for further research to investigate these dimensions in the context of digital and blended learning environments.

LIMITATION

This study has several limitations. First, the respondent population is limited to students from two universities, making the findings difficult to generalize to other contexts. Second, the cross-sectional design only evaluates the relationship of variables at one point in time, without long-term causal analysis. Third, the use of a Likert-based questionnaire is susceptible to respondent bias. Fourth, the study only focuses on learning motivation as a mediator, without considering other factors such as technology anxiety or learning styles. Finally, the context of the local education system and the predictive nature of the PLS-SEM approach require further validation through longitudinal studies and larger populations.

CONCLUSION

This study reveals that digital literacy and blended learning, when optimally implemented, can improve computational thinking skills through learning motivation. This study shows strong discriminant validity of the model used, ensuring that each construct analyzed is valid and has clear differences. Through quantitative analysis using Partial Least Squares-Structural Equation Modeling (PLS-SEM), it was revealed that blended learning and digital literacy have a significant effect on computational thinking skills, both directly and through the mediating role of learning motivation. These results recommend the implementation of learning strategies that integrate technology with interactive methods to improve students' abilities while emphasizing the incorporation of digital literacy as a fundamental component of the educational curriculum.

AUTHOR CONTRIBUTIONS

Conceptualization was led by PN. The methodology was developed by PN and DFS. Formal analysis was performed by PN and MFB, while investigation was performed by PN, DFS, and ABK. Resources were provided by S and ABK. The original draft of the manuscript was written by PN and IS. Writing, review, and proofreading were performed by S, MFB, and IS. Visualization was performed by PN, DFS, and MFB, supervision was provided by S. All authors have read and approved the final version of the manuscript.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to Makassar State University and Alauddin State Islamic University Makassar for providing the necessary resources and support for conducting this research. Special appreciation is extended to the faculty members and students who participated in the study, offering valuable insights that enriched the findings. We also acknowledge the contributions of our colleagues and research assistants for their assistance in data collection and analysis. Additionally, we extend our thanks to the reviewers and editors for their constructive feedback, which has significantly improved the quality of this manuscript.

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