

Analysis of the Implementation of Problem-Based Gamified Quizzes in Coding and AI Learning to Strengthen High School Students Computational Thinking Skills

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Abstract: The development of Computational Thinking Skills (CTS) is increasingly important in Coding and Artificial Intelligence (AI) learning; however, students' CTS remains influenced by multiple interrelated learning factors. Previous studies have generally examined these factors separately, leaving limited evidence on their integration within a single model in the context of Coding and AI learning at the high school level. This study contributes a novel integrated model that examines digital literacy, learning motivation, self-efficacy, and cognitive engagement in relation to students' CTS through the implementation of problem-based gamified quizzes in Coding and AI learning. This study employed a quantitative approach with an associative research design. Data were collected from 151 tenth-grade students at SMA Pertiwi 1 Padang using a five-point Likert-scale questionnaire. The data were analyzed using Structural Equation Modeling–Partial Least Squares (SEM-PLS) with SmartPLS 3. The results showed that digital literacy had a positive and significant effect on CTS ($\beta = 0.475$, $t = 3.838$, $p < 0.001$), while learning motivation also had a positive and significant effect on CTS ($\beta = 0.340$, $t = 2.967$, $p = 0.003$). Digital literacy significantly affected self-efficacy ($\beta = 0.509$, $t = 6.190$, $p < 0.001$) and cognitive engagement ($\beta = 0.508$, $t = 3.612$, $p < 0.001$), while learning motivation significantly affected self-efficacy ($\beta = 0.395$, $t = 4.681$, $p < 0.001$) and cognitive engagement ($\beta = 0.359$, $t = 2.695$, $p = 0.007$). Self-efficacy did not significantly affect CTS ($\beta = 0.109$, $t = 1.278$, $p = 0.201$), whereas cognitive engagement had the strongest positive effect on CTS ($\beta = 0.826$, $t = 11.066$, $p < 0.001$). These findings indicate that strengthening CTS in Coding and AI learning requires not only adequate digital literacy and learning motivation but also active cognitive engagement. Problem-based gamified quizzes can therefore provide a learning context that encourages students to actively understand concepts, analyze problems, and develop computational thinking.

Keywords: Computational Thinking Skills; Cognitive Engagement; Digital Literacy; Learning Motivation; Self-Efficacy.

Introduction

The rapid advancement of digital technology and educational transformation in the era of the Fourth Industrial Revolution has increased the demand for 21st-century competencies, one of which is Computational Thinking Skills (CTS). Computational thinking refers to

a problem-solving process that involves decomposition, pattern recognition, abstraction, and algorithm design to generate effective and efficient solutions (Shute et al., 2017). These skills are not only essential in computer science but have also become fundamental competencies that support critical thinking, creativity, and systematic problem-solving across various disciplines.

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As part of efforts to prepare students for the digital era, the Indonesian Ministry of Education has introduced Coding and Artificial Intelligence (AI) learning into the school curriculum. Coding and AI learning is expected to equip students with the ability to understand technology, solve problems logically, and adapt to rapid technological developments. However, the development of CTS is not determined solely by instructional content. Students' ability to utilize digital information, their motivation to learn, confidence in completing learning tasks, and cognitive involvement in the learning process may also influence their ability to develop computational thinking.

Digital literacy is an important factor in technology-enhanced learning because it enables students to access, evaluate, understand, and utilize digital information effectively and responsibly (Achmad & Mulyati, 2023; Greene et al., 2014; Ningsih et al., 2021). Recent studies have further emphasized the importance of digital literacy in technology-supported learning. Mardiana et al. (2026), for example, found that digital literacy-based learning materials can increase students' interest and engagement in learning activities. Similarly, recent research has highlighted the contribution of digital literacy to students' competence in using digital learning resources (Anggraini et al., 2024; Khair et al., 2023). In Coding and AI learning, adequate digital literacy can help students identify relevant information, utilize digital learning resources, and apply information in solving problems. Learning motivation is also important because it encourages students to participate actively, maintain effort when facing difficulties, and invest cognitive effort in completing challenging learning tasks (Dirgantoro et al., 2022; Hendrawati & Wuryandani, 2023; Rizki et al., 2023). Recent evidence indicates that learning motivation is an important factor influencing students' learning performance and persistence in technology-supported learning environments (Sembiring et al., 2025). Recent evidence also indicates that learning motivation is an important factor in students' learning performance and persistence (Hilmi et al., 2024; Sembiring et al., 2025). Moreover, Yulirismayenti et al. (2025) found that gamification in computer science learning significantly improved students' learning motivation and learning outcomes. Thus, digital literacy and learning motivation are theoretically relevant to the development of students' CTS. Furthermore, gamification in computer science learning has been shown to significantly improve students' learning motivation and learning outcomes, suggesting that gamified learning environments can support both cognitive and affective aspects of learning (Yulirismayenti et al., 2025).

In addition, self-efficacy and cognitive engagement represent important psychological and cognitive aspects

of learning. Self-efficacy refers to students' beliefs in their ability to successfully perform learning tasks, while cognitive engagement refers to the mental effort students invest in understanding concepts, applying learning strategies, and solving problems (Azizia et al., 2023; Basith et al., 2020; Haniifah & Nugraheni, 2024; Safitri et al., 2023). Recent research continues to demonstrate the relevance of self-efficacy to computational thinking. Haniifah and Nugraheni (2024) examined mathematical computational thinking in relation to students' self-efficacy, while Nalim et al. (2026) specifically investigated the role of self-efficacy in students' computational thinking abilities during geometry problem solving. These findings indicate that students' confidence in their capabilities remains an important psychological factor to consider when examining computational thinking. Cognitive engagement is also important because students need to devote mental effort to processing information, analyzing problems, and constructing solutions. Recent research on technology-supported learning has likewise highlighted the importance of students' active engagement and cognitive participation in learning activities (Silvia et al., 2026). In Coding and AI learning, these factors are relevant because students are required to persist in challenging tasks and actively process information to develop logical and systematic solutions.

To support student participation and engagement, this study applies problem-based gamified quizzes using Wayground in Coding and AI learning. Gamification incorporates elements such as points, rankings, challenges, and immediate feedback into learning activities. Recent studies have demonstrated that gamified web-based learning can improve students' evaluation skills and learning performance, indicating the effectiveness of gamification in supporting meaningful learning experiences (Hidayat et al., 2025). While problem-based activities encourage students to identify, analyze, and solve problems systematically (Koivisto & Hamari, 2019; Sailer & Homner, 2020). Recent empirical evidence provides stronger support for this approach. Hidayat et al. (2025) reported that gamified web-based learning can improve students' evaluation skills, while Yulirismayenti et al. (2025) found that gamification in computer science learning significantly improved students' motivation and learning outcomes. The combination of these approaches is expected to create a more interactive learning environment and encourage students to engage actively in learning tasks. Previous studies have reported the potential of programming and problem-based learning to support computational thinking, while gamification has been associated with increased motivation, self-efficacy, and student engagement (Bai et al., 2020; Yildirim, 2017).

Despite these findings, a research gap remains in the integration of digital literacy, learning motivation, self-efficacy, and cognitive engagement within a single model of Coding and AI learning to the high school level. Previous studies have generally examined one or two factors related to CTS or focused on the effectiveness of particular instructional approaches. Moreover, empirical evidence concerning the direct relationships among these technological, motivational, psychological, and cognitive factors in the context of gamified Coding and AI learning, particularly among Indonesian high school students, remains limited. This gap is important to address because strengthening CTS requires a broader understanding of the factors that support students' ability to engage with and solve computational problems.

The novelty of this study lies in integrating digital literacy, learning motivation, self-efficacy, and cognitive engagement into a single structural model to examine their direct relationships with students' CTS in Coding and AI learning through problem-based gamified quizzes using Wayground. Unlike studies that examine these factors separately, this study provides an integrated empirical model that considers technological, motivational, psychological, and cognitive factors simultaneously. The study also identifies the relative contribution of each factor to CTS, thereby providing evidence regarding which aspects should receive greater attention in Coding and AI learning.

Based on the empirical problem and research gap, this study aims to analyze the direct effects of digital literacy and learning motivation on CTS, the effects of digital literacy and learning motivation on self-efficacy and cognitive engagement, and the effects of self-efficacy and cognitive engagement on CTS among high school students participating in Coding and AI learning through problem-based gamified quizzes. The findings are expected to contribute to the understanding of factors associated with CTS and provide practical implications for educators in designing Coding and AI learning activities that promote meaningful cognitive engagement and computational problem-solving.

Method

This study employed a quantitative associative research design using Partial Least Squares Structural Equation Modeling (PLS-SEM). The research was conducted at SMA Pertiwi 1 Padang, Indonesia, involving 151 tenth-grade students enrolled in Coding and Artificial Intelligence (AI) learning. A total sampling technique was applied, allowing all students in the population to participate in the study.

The research model consisted of five constructs: digital literacy (X1), learning motivation (X2), self-

efficacy (M1), cognitive engagement (M2), and computational thinking skills (Y). The study examined eight direct relationships among these constructs. The learning activities were conducted through problem-based gamified quizzes using the Wayground platform in Coding and AI learning. Data were collected using a questionnaire distributed through Google Forms after students participated in the learning activities. The questionnaire consisted of 36 valid items measured using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

Data analysis was performed using SmartPLS 3 based on the Partial Least Squares Structural Equation Modeling (PLS-SEM) approach. The measurement model was evaluated based on indicator reliability, convergent validity, discriminant validity, composite reliability, and Cronbach's alpha (Hair et al., 2022). The structural model was assessed through collinearity analysis and path coefficients (Hair et al., 2022). Hypothesis testing was conducted using the bootstrapping procedure to assess the significance of the hypothesized direct relationships (Hair et al., 2022). A direct relationship was considered statistically significant when the *t*-statistic was ≥ 1.96 and the *p*-value was < 0.05 . The research procedure is presented in Figure 1.

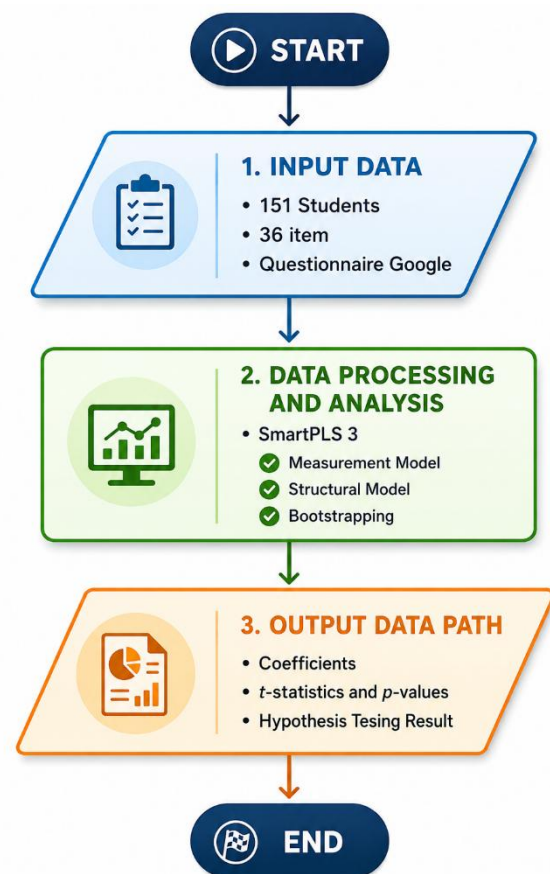


Figure 1. Research Procedure

Result and Discussion

Result

Respondent Characteristics

The respondents of this study were 151 tenth-grade (Phase E) students at SMA Pertiwi 1 Padang in the 2025/2026 academic year who participated in Coding and Artificial Intelligence learning through problem-based gamified quizzes using the Wayground platform. A total sampling approach was applied across five classes (XE1 to XE5). Table 1 presents the demographic distribution of respondents by class.

Table 1. Demographic Characteristics of Respondents Based on Class

Class	Frequency	Percentage (%)
XE1	32	21.19
XE2	32	21.19
XE3	30	19.87
XE4	32	21.19
XE5	25	16.56
Total	151	100.00

Table 1 shows that the respondents consisted of 151 tenth-grade students from five classes. Classes XE1, XE2, and XE4 each contributed 21.19% of the total respondents, while XE5 contributed the smallest proportion at 16.56%. The distribution covered all five classes involved in Coding and Artificial Intelligence learning at SMA Pertiwi 1 Padang.

Descriptive Analysis (Respondent Achievement Level / TCR)

Descriptive analysis using the Achievement Level of Respondents (Tingkat Capaian Responden / TCR) was evaluated to measure the descriptive profile of each variable. The TCR values across all constructs fell into the "Very High" and "High" categories:

Digital Literacy (X1): Achieved an average TCR of 83.18% (Good/High category). The highest indicator score was found in functional digital skills (ability to operate platforms/apps) at 84.11%, while critical evaluation of digital information was 82.25%.

Learning Motivation (X2): Achieved an average TCR of 81.56% (Good/High category). Attention and relevance during gamified activities recorded the highest contribution (83.05%).

Self-Efficacy (M1): Recorded an average TCR of 80.92% (Good/High category). Students showed strong confidence in completing basic tasks (82.12%), but slightly lower confidence when encountering complex debugging tasks (79.14%).

Cognitive Engagement (M2): Reached an average TCR of 84.72% (Very High category), driven strongly by mental effort in analytical problem-solving during gamified quizzes.

Computational Thinking Skills (Y1): Achieved an average TCR of 83.45% (Good/High category), with Abstraction (84.60%) and Decomposition (84.10%) showing high mastery levels among students.

Measurement Model Assessment

The measurement model was evaluated using Partial Least Squares Structural Equation Modeling (PLS-SEM) in SmartPLS 3 to verify indicator reliability, convergent validity, discriminant validity, and internal consistency.

Convergent validity

Convergent validity was evaluated through indicator outer loadings and Average Variance Extracted (AVE). All 36 final measurement indicators exhibited outer loading values exceeding the standard threshold of 0.70. Furthermore, the AVE values for all constructs exceeded the minimum criterion of 0.50, as summarized in Table 2.

Table 2. Average Variable Extracted (AVE)

Construct	AVE
Cognitive Engagement	0.81
Computational Thinking	0.80
Digital Literacy	0.72
Learning Motivation	0.68
Self Efficacy	0.71

The results demonstrate that each construct explained more than 50% of the variance of its indicators, confirming satisfactory convergent validity. The original AVE values reported in the thesis were 0.812, 0.803, 0.717, 0.682, and 0.706, respectively.

Discriminant Validity

Discriminant validity was established through the Fornell-Larcker criterion and the Heterotrait-Monotrait (HTMT) ratio. The square root of the AVE for each construct was greater than its highest correlation with any other construct. Additionally, all HTMT values were below the conservative threshold of 0.85 (and well below 0.90), confirming that all constructs in the structural model are empirically distinct.

Reliability

Reliability was assessed using Cronbach's alpha and composite reliability. All constructs achieved values above 0.70 for both measures, indicating satisfactory internal consistency and reliability.

Table 3. Reliability Result

Construct	Cronbach's Alpha	Composite Reliability
Cognitive Engagement	0.88	0.93
Computational Thinking Skill	0.88	0.92
Digital Literacy	0.93	0.95
Learning Motivasi	0.85	0.89
Self Efficacy	0.91	0.89

All constructs achieved Cronbach's Alpha and Composite Reliability values above 0.70, indicating satisfactory internal consistency and reliability.

Structural Model Assessment (Inner Model)

The structural model was evaluated using the PLS-SEM approach in SmartPLS 3. Bootstrapping was applied to assess the significance of the hypothesized direct relationships among digital literacy, learning motivation, self-efficacy, cognitive engagement, and computational thinking skills.

Collinearity Analysis

Prior to structural evaluation, potential collinearity among predictor constructs was checked using the Variance Inflation Factor (VIF). All inner VIF values ranged between 1.342 and 2.115, well below the maximum limit of 5.0 (and below 3.3), indicating no lateral collinearity issues within the model.

Hypothesis Testing

The hypothesis testing results demonstrated that seven of the eight proposed direct relationships were positive and statistically significant. Digital literacy had a positive and significant effect on computational thinking skills ($\beta = 0.475$, $t = 3.838$, $p < 0.001$). Learning motivation also had a positive and significant effect on computational thinking skills ($\beta = 0.340$, $t = 2.967$, $p = 0.003$).

Digital literacy significantly affected self-efficacy ($\beta = 0.509$, $t = 6.190$, $p < 0.001$), while learning motivation also had a significant positive effect on self-efficacy ($\beta = 0.395$, $t = 4.681$, $p < 0.001$). Furthermore, digital literacy had a positive and significant effect on cognitive engagement ($\beta = 0.508$, $p < 0.001$), and learning motivation also had a positive and significant effect on cognitive engagement ($\beta = 0.359$, $p = 0.007$).

Cognitive engagement had the strongest positive effect on computational thinking skills ($\beta = 0.826$, $p < 0.001$). In contrast, self-efficacy did not have a statistically significant effect on computational thinking skills ($\beta = 0.109$, $p = 0.201$).

Table 4. Relationship Testing Result

Relationship	Path Coefficient(β)	p-Value	Result
Digital Literacy → Computational Thinking Skill	0.48	0.001	Significant
Learning Motivation → Computational Thinking Skill	0.34	0.003	Significant
Digital Literacy → Self Efficacy	0.51	0.001	Significant
Learning Motivation → Self Efficacy	0.40	0.001	Significant
Digital Literacy → Cognitive Engagement	0.51	0.001	Significant
Learning Motivation → Cognitive Engagement	0.36	0.007	Significant
Self Efficacy → Computational Thinking Skill	0.11	0.201	Not Significant
Cognitive Engagement → Computational Thinking Skill	0.001		Significant

The results indicate that digital literacy and learning motivation were significant predictors of computational thinking skills, self-efficacy, and cognitive engagement. Among the variables examined, cognitive engagement demonstrated the strongest direct effect on computational thinking skills ($\beta = 0.826$, $p < 0.001$). Conversely, self-efficacy did not show a significant direct effect on computational thinking skills ($\beta = 0.109$, $p = 0.201$).

Discussion

The results indicate that digital literacy and learning motivation play significant roles in improving students' computational thinking skills. Students with higher levels of digital literacy are better able to access, evaluate, and utilize information from digital resources, enabling them to perform computational problem-solving more effectively (Greene et al., 2014; Perdana et al., 2019; Zamista & Azmi, 2023). This finding is supported by recent research emphasizing the role of digital literacy in technology-supported learning. Mardiana et al. (2026) demonstrated that digital literacy-based learning materials can increase students' interest and engagement, while Anggraini et al. (2024) and Khair et al. (2023) highlighted the importance of digital learning resources in supporting students' learning competencies. This finding is supported by recent

research emphasizing the role of digital literacy in technology-supported learning. Mardiana et al. (2026) demonstrated that digital literacy-based learning materials can increase students' interest and engagement, while Anggraini et al. (2024) and Khair et al. (2023) highlighted the importance of digital learning resources in supporting students' learning competencies. Likewise, highly motivated students tend to demonstrate greater persistence, effort, and engagement in learning activities, leading to improved computational thinking performance (Dirgantoro et al., 2022; Hendrawati & Wuryandani, 2023; Rizki et al., 2023). This result is consistent with recent evidence showing that learning motivation contributes to students' learning performance (Hilmi et al., 2024; Sembiring et al., 2025). Furthermore, Yulirismayenti et al. (2025) found that gamification in computer science learning significantly increased students' motivation and learning outcomes, supporting the importance of motivational support in technology-based learning.

Another important finding is the significant role of cognitive engagement in predicting computational thinking skills. Cognitive engagement reflects students' mental effort, concentration, and strategic learning behaviors during instructional activities (Ding et al., 2017; Ridha et al., 2024). The particularly strong effect found in this study indicates that computational thinking depends substantially on students' active mental involvement in understanding problems, processing information, and constructing possible solutions. This interpretation is supported by recent research emphasizing the role of learning engagement in computational thinking development (Silvia et al., 2026). The strong effect of cognitive engagement found in this study supports constructivist learning theory, which emphasizes that meaningful learning occurs when learners actively construct knowledge through cognitive interaction with learning tasks. In Coding and AI learning, this active involvement is particularly important because students need to analyze problems, identify relevant patterns, formulate logical procedures, and evaluate possible solutions. Therefore, the strong contribution of cognitive engagement suggests that students' computational thinking development depends substantially on the extent to which they actively process and work with computational problems during learning.

Conversely, self-efficacy did not significantly influence computational thinking skills. Although students generally reported confidence in their abilities, confidence alone was insufficient to directly improve computational thinking performance. This finding differs from recent studies that have identified a relationship between self-efficacy and computational thinking. Haniifah and Nugraheni (2024) examined

computational thinking in relation to students' self-efficacy, while Nalim et al. (2026) specifically investigated self-efficacy as a factor associated with computational thinking abilities in problem-solving contexts. One possible explanation is that self-efficacy represents students' beliefs about their capability rather than the cognitive processes required to solve computational problems. Thus, students may perceive themselves as capable of completing Coding and AI tasks but may still require sufficient cognitive engagement and practice to translate this confidence into computational performance. This interpretation is particularly relevant to the present findings because cognitive engagement demonstrated a much stronger direct contribution to CTS than self-efficacy. This finding suggests that successful computational thinking development requires active cognitive involvement rather than relying solely on students' beliefs about their capabilities.

Overall, the findings emphasize the importance of fostering meaningful cognitive engagement in technology-enhanced learning environments. Educational practices should therefore focus not only on improving students' digital literacy and learning motivation but also on designing instructional activities that encourage deep cognitive processing. The recent findings of Yulirismayenti et al. (2025) provide empirical support for the motivational value of gamification in computer science learning, while Hidayat et al. (2025) demonstrate the potential of gamified web-based learning to support students' learning performance. Sari et al. (2024) likewise reported positive effects of gamification-based learning on motivation and learning outcomes. These findings suggest that the value of gamification should not be limited to increasing enjoyment or competition; rather, gamified activities should be designed to encourage students to interact with meaningful problems, respond to challenges, receive feedback, and remain cognitively involved in the learning process. Wayground-based gamified learning can serve as an effective strategy for promoting such engagement and enhancing students' computational thinking skills in Coding and Artificial Intelligence education. (Bai et al., 2020; Sailer & Homner, 2020; Yildirim, 2017).

Conclusion

This study demonstrates that digital literacy and learning motivation are important factors in strengthening students' computational thinking skills in Wayground-based gamified Coding and Artificial Intelligence learning. Digital literacy and learning motivation significantly contribute to students' self-efficacy and cognitive engagement, while both variables

also have significant direct effects on computational thinking skills. Cognitive engagement shows a strong positive contribution to computational thinking skills, whereas self-efficacy does not have a significant direct effect.

The scientific contribution of this study lies in providing empirical evidence on the relationships among digital literacy, learning motivation, self-efficacy, cognitive engagement, and computational thinking skills within a gamification-based Coding and Artificial Intelligence learning context. The findings emphasize that the development of computational thinking should not rely solely on students' digital abilities and learning motivation but should also encourage active cognitive engagement during learning. Thus, Wayground-based gamified learning can be considered a relevant learning approach for supporting students' engagement and the development of computational thinking skills in Coding and Artificial Intelligence education.

This study has several limitations. The research involved tenth-grade students from only one high school, and the data were collected through a cross-sectional questionnaire. Therefore, the findings should be interpreted within the specific educational context of the study and may not be fully generalizable to other schools, student groups, or educational levels. Future research is recommended to involve larger and more diverse samples and to employ longitudinal or experimental designs to provide stronger evidence regarding the development of computational thinking skills through gamification-based Coding and Artificial Intelligence learning. Further research may also examine other factors that contribute to students' computational thinking skills.

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Author Contributions

Conceptualization, M.E.; methodology, M.E.; validation, H.H.; formal analysis, H.H.; investigation, M.E.; resources, H.H.; data curation, H.H.; data collection, M.E.; writing—original draft preparation, M.E.; writing—review and editing, T.S.W. and E.I.; visualization, T.S.W. and E.I.; supervision, H.H. All authors have read and agreed to the published version of the manuscript. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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