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Gamification and Adaptive Learning Innovations for Enhancing Students' Critical Thinking and Creativity at an Islamic Boarding School in Indonesia

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Abstract

This study aims to identify the factors influencing students' critical thinking and creativity and to examine the role of gamification and adaptive learning in classroom learning activities at Cahaya Rancamaya Islamic Boarding School, Bogor, Indonesia. The study employed a mixed-methods approach using a sequential exploratory design. In the qualitative phase, semi-structured interviews were conducted with 30 teachers to explore instructional practices that support higher-order thinking skills across both general and Islamic education subjects. The qualitative findings identified four key variables associated with students' critical thinking and creativity: (1) the use of gamification in interactive learning, (2) the implementation of deep learning within adaptive learning environments, (3) learning motivation, and (4) learning engagement. Based on these findings, a structured questionnaire comprising validated indicators for the four constructs was developed and administered to 109 tenth-grade students. Quantitative data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM), which is appropriate for exploratory model development and moderate sample sizes. The results demonstrated that all four variables positively influenced students' critical thinking and creativity. Learning engagement emerged as the strongest predictor, followed by gamification, learning motivation, and adaptive learning. The measurement model satisfied the required validity and reliability criteria, confirming the robustness of the proposed framework. These findings highlight the importance of integrating gamification and adaptive learning strategies within student-centered learning environments to enhance higher-order thinking skills and creativity among secondary school students.

Keywords: Adaptive Learning, Critical Thinking and Creativity, Gamification, Learning Engagement, Learning Motivation

Abstrak

Penelitian ini bertujuan untuk mengidentifikasi faktor-faktor yang memengaruhi kemampuan berpikir kritis dan kreativitas siswa serta mengkaji peran gamification dan adaptive learning dalam kegiatan pembelajaran di Cahaya Rancamaya Islamic Boarding School, Bogor, Indonesia. Penelitian ini menggunakan pendekatan mixed methods dengan desain sequential exploratory. Pada tahap kualitatif, wawancara semi-terstruktur dilakukan terhadap 30 guru untuk mengeksplorasi praktik pembelajaran yang mendukung pengembangan keterampilan berpikir tingkat tinggi pada mata

pelajaran umum maupun mata pelajaran keislaman. Hasil analisis kualitatif mengidentifikasi empat variabel utama yang berhubungan dengan peningkatan kemampuan berpikir kritis dan kreativitas siswa, yaitu: (1) penggunaan gamification dalam pembelajaran interaktif, (2) penerapan deep learning dalam lingkungan adaptive learning, (3) motivasi belajar, dan (4) keterlibatan belajar. Berdasarkan temuan tersebut, dikembangkan instrumen kuesioner terstruktur yang memuat indikator-indikator teruji untuk merepresentasikan keempat konstruk, kemudian diujikan kepada 109 siswa kelas X. Data kuantitatif dianalisis menggunakan Partial Least Squares Structural Equation Modeling (PLS-SEM), yang sesuai untuk pengembangan model eksploratif dan ukuran sampel yang moderat. Hasil penelitian menunjukkan bahwa keempat variabel berpengaruh positif terhadap kemampuan berpikir kritis dan kreativitas siswa. Keterlibatan belajar menjadi prediktor paling dominan, diikuti oleh gamification, motivasi belajar, dan adaptive learning. Model pengukuran memenuhi seluruh kriteria validitas dan reliabilitas yang dipersyaratkan, sehingga mengonfirmasi ketepatan kerangka konseptual yang dikembangkan. Temuan ini menegaskan pentingnya integrasi strategi gamification dan adaptive learning dalam lingkungan pembelajaran yang berpusat pada siswa guna meningkatkan keterampilan berpikir tingkat tinggi dan kreativitas siswa sekolah menengah.

***Kata Kunci**: Adaptive Learning, Berpikir Kritis dan Kreativitas, Gamification, Keterlibatan Belajar, Motivasi Belajar.*

INTRODUCTION

Gamification, as an active pedagogical methodology, has been gaining increasing recognition within educational discourse for its capacity to address challenges related to student motivation, engagement, and social behavior (Férriz-Valero et al., 2020); (Prameswari et al., 2025). It incorporates game design principles into instructional contexts to motivate learners, foster participation, and improve academic outcomes (Li et al., 2023). Through this approach, students are encouraged to participate directly in the learning process, developing not only curricular and cognitive competencies but also interpersonal and social-emotional skills (Ruíz et al., 2024). In the contemporary educational landscape, where digital transformation has become integral to the learning environment, the integration of technology into pedagogy is not merely an enhancement but a necessity (Vieriu & Petrea, 2025). As the 21st-century labor market increasingly prioritizes higher-order cognitive skills such as critical thinking and creativity, educators face the challenge of cultivating these competencies among students. Conventional teaching models often struggle to meet this demand because they fail to provide individualized learning pathways or sustain learner engagement, ultimately hindering the development of reflective and creative thought (Ezeddine et al., 2023). The growing interest in gamification, supported by diverse empirical findings, reinforces the importance of exploring its implementation, process, and contextual impact in different educational environments (Kalogiannakis et al., 2021); (Vadodkar, 2022).

Gamification, the integration of game design elements into non-game educational contexts, has emerged as a promising strategy for increasing students' motivation and engagement (Evmenova et al., 2025);. Likewise, adaptive learning technologies, which dynamically tailor learning materials and pacing according to individual student performance, have demonstrated considerable potential in delivering personalized education (Alwi & Mumtahana, 2023; Rojas et al., 2025; Sagoro et al., 2025). Previous studies have emphasized that both gamification and adaptive learning can enhance learning outcomes; however, research that combines these two pedagogical innovations remains limited, particularly in the context of developing nations such as Indonesia (Atmaja & Mandyartha, 2020; Mahalle & Zailani, 2025; Pujihastuti et al., 2022; Wibowo & Saliman, 2025).

Recent studies further highlight the interconnectedness between critical thinking and creativity, revealing that these two skills mutually reinforce one another and may vary across demographic or institutional contexts (Shaber et al., 2025). Moreover, the emergence of generative artificial intelligence (AI) in educational settings has amplified the role of critical thinking, reducing dependency on rote knowledge and fostering deeper learning engagement (Indasari, 2026; Ridlo et al., 2026; Wale, 2024; Zhao et al., 2025). These findings point to the need for innovative instructional models that blend motivational game-based learning with adaptive digital technologies to cultivate critical and creative capacities effectively.

This study does not merely examine the use of educational technology in classroom instruction, as the integration of digital tools, gamification, and online learning platforms has already been widely implemented in many modern schools and Islamic boarding schools. Instead, the novelty of this research lies in the development and empirical validation of an integrated learning model that explains how gamification and adaptive learning jointly influence students' critical thinking and creativity through the mediating roles of learning motivation and learning engagement (Kuo et al., 2024); (Titin et al., 2023); (Khamcharoen et al., 2022); (Purwanto et al., 2021). While previous studies have generally investigated these variables separately, limited empirical evidence exists regarding their simultaneous interaction within a unified framework, particularly in the context of Islamic boarding schools that combine academic learning, character education, and religious values (Nuri et al., 2025).

Furthermore, this study provides evidence from Cahaya Rancamaya Islamic Boarding School, where digital learning innovations are implemented within a boarding-school environment characterized by intensive teacher–student interaction, structured learning routines, and the integration of national and Islamic curricula. Such characteristics create a unique educational context that differs from conventional secondary schools and may influence how students respond to gamified and adaptive learning environments. Therefore, this research extends existing knowledge by examining not only the technological dimension of learning innovation but also the psychological and pedagogical mechanisms through which technology-enhanced learning contributes to the development of critical thinking and creative problem-solving skills (Gómez et al., 2025).

By addressing this gap, the study contributes to the growing discourse on digital pedagogy and student-centered learning by proposing a validated model that links gamification, adaptive learning, learning motivation, and learning engagement to students' critical thinking and creativity. The findings are expected to provide practical implications for educators, policymakers, and educational technology developers seeking to design more effective learning environments in Islamic educational institutions and other comparable educational settings (Maf'ulah et al., 2025). Ultimately, the study demonstrates that the effectiveness of educational technology depends not only on its adoption but also on its capacity to foster meaningful engagement, sustained motivation, and higher-order thinking among learners (Tenório et al., 2018).

METHOD

This study adopted a sequential exploratory mixed-method design, integrating qualitative and quantitative approaches to provide a comprehensive understanding of the factors influencing students' critical thinking and creativity within the framework of interactive learning innovation (Zhao et al., 2025); (Ratnaningtyas et al., 2023); (Karimuddin et al., 2022). The research was conducted exclusively at Cahaya Rancamaya Islamic Boarding School in Bogor, Indonesia, an educational institution that integrates the national curriculum with the distinctive learning culture of an Islamic boarding school (pesantren). This setting was selected because it provides a unique context for examining how gamification and

adaptive learning can support students' higher-order thinking skills within a learning environment that emphasizes academic achievement, character formation, discipline, and religious values.

The study investigated four exogenous constructs, Use of Gamification in Interactive Learning (UGIL), Deep Learning in Adaptive Learning (DLAL), Learning Motivation (LM), and Learning Engagement (LE), and their influence on the endogenous construct, Critical Thinking and Creativity Performance (CTCP). Critical thinking and creativity were operationalized through indicators reflecting students' ability to analyze information, evaluate arguments, solve problems systematically, generate original ideas, propose alternative solutions, and apply knowledge in new situations. These indicators were identified during the qualitative phase and subsequently refined into measurable questionnaire items for quantitative validation. The integrated model was designed to examine both the direct and indirect relationships among the constructs and to determine the relative contribution of each factor in enhancing students' critical thinking and creativity.

Table 1 Research Variables and Indicators

Variable	Indicators
Use of Gamification in Interactive Learning (UGIL)	points, badges, leaderboard, challenges, instant feedback
Deep Learning in Adaptive Learning (DLAL)	personalized content, adaptive difficulty, meaningful learning, reflective learning
Learning Motivation (LM)	learning enthusiasm, persistence, self-confidence, willingness to complete tasks
Learning Engagement (LE)	participation, attention, collaboration, cognitive involvement
Critical Thinking and Creativity Performance (CTCP)	analysis, evaluation, problem solving, originality, idea generation, innovation

Phase 1: Qualitative Exploration

The qualitative phase employed an exploratory case study approach to obtain an in-depth understanding of teachers' perspectives regarding instructional practices that promote students' critical thinking and creativity within the educational context of Cahaya Rancamaya Islamic Boarding School. This approach was selected because it allows researchers to investigate a contemporary educational phenomenon within its real-life setting and to identify contextual factors that may influence learning outcomes. Data were collected through semi-structured interviews with 30 teachers who taught Grade 10 students across both general and Islamic education subjects. The interviews explored teachers' experiences with technology-enhanced learning, gamification strategies, adaptive learning practices, student engagement, learning motivation, and challenges associated with developing higher-order thinking skills.

The interview data were transcribed verbatim and analyzed using thematic analysis. The analysis followed several stages, including data familiarization, initial coding, category development, theme identification, and theme refinement. To enhance the trustworthiness of the findings, member checking was conducted by inviting several participants to review the interpretation of the interview results, while peer debriefing was employed to minimize researcher bias during the coding process. The analysis identified four recurring themes that were consistently reported by participants as influential factors in enhancing students' critical thinking and creativity: (1) the use of gamification in interactive learning, (2) the implementation of deep learning within adaptive learning systems, (3) learning motivation, and (4) learning engagement. These themes subsequently served as the conceptual foundation

for the quantitative phase and informed the development of the survey instrument used for model validation.

Phase 2: Quantitative Validation

A quantitative phase was subsequently conducted to validate the conceptual model generated from the qualitative findings. The target population consisted of all Grade 10 students enrolled at Cahaya Rancamaya Islamic Boarding School, Bogor, during the 2024/2025 academic year. Using a census-based approach, questionnaires were distributed to all accessible students who met the inclusion criteria, resulting in 109 valid responses. The respondents were between 15 and 17 years old and had prior experience participating in technology-supported and interactive learning activities. The minimum sample size was considered adequate for Partial Least Squares Structural Equation Modeling (PLS-SEM), as the model fulfilled the ten-times rule and met the minimum sample requirements for exploratory predictive analysis.

The quantitative instrument was developed directly from the themes identified during the qualitative phase. The questionnaire consisted of five latent constructs: Use of Gamification in Interactive Learning (UGIL), Deep Learning in Adaptive Learning (DLAL), Learning Motivation (LM), Learning Engagement (LE), and Critical Thinking and Creativity Performance (CTCP). Indicators measuring critical thinking and creativity were adapted from the higher-order thinking skills (HOTS) framework and included students' abilities to analyze information, evaluate arguments, solve contextual problems, generate original ideas, and propose alternative solutions. Prior to large-scale data collection, the instrument underwent expert judgment involving three specialists in educational technology and learning assessment. A pilot test was subsequently conducted to evaluate item clarity, content validity, and internal consistency. Only items meeting the required validity and reliability standards were retained for the final survey.

The collected data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4.0 software (Novrinda et al., 2025). PLS-SEM was selected because the study aimed to develop and predict relationships among latent constructs within an exploratory educational model while accommodating a relatively moderate sample size. The analysis was performed in two stages. First, the measurement model (outer model) was evaluated to assess construct quality through indicator loadings, Average Variance Extracted (AVE), Composite Reliability (CR), Cronbach's Alpha, Fornell–Larcker Criterion, Heterotrait–Monotrait Ratio (HTMT), and Variance Inflation Factor (VIF). Second, the structural model (inner model) was examined by analyzing path coefficients, coefficients of determination (R^2), predictive relevance, effect sizes (f^2), and bootstrapping significance tests. This procedure ensured that both the measurement properties of the constructs and the hypothesized relationships among variables were statistically robust and empirically valid.

RESULTS AND DISCUSSION

The Result of Qualitative Research Method

The qualitative research was conducted through observation and semi-structured interviews with 30 teachers from Cahaya Rancamaya Islamic Boarding School in Bogor, Indonesia. The purpose of this stage was to explore the factors influencing students' creativity and critical thinking during the learning process within the unique context of an Islamic boarding school that combines formal education with religious character formation. During the interviews, teachers were asked to describe:

- The level of students' interest and commitment when participating in classroom learning;
- The obstacles commonly faced during teaching;
- The extent to which students tend to be active or passive in class;
- The importance of developing creativity and critical thinking in supporting the learning process;
- The strategies or methods used by teachers to foster critical and creative thinking;
- Students' difficulties in solving analytical problems;
- Teachers' experiences in using technology-based learning media (such as educational games);
- The types of media used and students' responses to them;
- The benefits of using interactive or gamified learning approaches; and
- Challenges in integrating technology into classroom instruction.

Table 2 Interview Result Summary

No.	Questioned Aspects	Summary of Interview Findings
1.	Student Interest and Seriousness	1. Most students demonstrate strong enthusiasm and curiosity, especially when interactive or contextual methods are used. 2.Engagement increases significantly when lessons incorporate technology-based approaches.
2.	Obstacles in Teaching	1.Teachers noted challenges such as students' short attention span, sleepiness, or side conversations. 2.Difficulties in understanding abstract concepts and low learning motivation were also common.
3.	Student Activity in Class	1.Student participation varies depending on the subject and teaching method. 2.Learners are more active when digital media or enjoyable learning activities are introduced.
4.	Importance of Creativity & Critical Thinking	1.All teachers agree that creativity and critical thinking are essential for deep understanding and effective problem-solving. 2. These skills are vital for nurturing higher-order thinking abilities.
5.	Strategies to Encourage Critical & Creative Thinking	1.Teachers apply HOTS-based questions, trigger questions, group discussions, and project-based learning. 2.Lessons are often contextualized to real-world applications to stimulate deeper reasoning.
6.	Students' Difficulties in Problem Analysis	1. Students struggle to connect concepts, visualize problems, and apply analytical reasoning. 2. Some tend to avoid questions requiring complex analysis.
7.	Use of Technology-Based Media	1. Nearly all teachers have used media such as Quizizz, Kahoot, Blooket, PhET Colorado, and Musicca. 2.Students generally respond positively, showing greater interest and active participation.
8.	Benefits of Gamification	1.Gamification increases students' enthusiasm, focus, and comprehension. 2.It makes learning enjoyable, promotes problem-solving, and strengthens engagement.

9.	Technology Integration Challenges	1.Main challenges include unstable internet connectivity, limited adaptation time, and the risk of technology dependence. 2.Teachers also expressed the need for professional development in educational technology.
10.	Expectations for AI-Based Gamification Applications	1.Teachers expect features such as problem-solving steps, simulations, scoring/battle systems, audiovisual support, and AI (Machine Learning and Deep Learning) integration. 2.The applications should enhance understanding, be easy to use, and be properly introduced through training and socialization.

The qualitative findings were derived from thematic analysis of semi-structured interviews conducted with 30 teachers at Cahaya Rancamaya Islamic Boarding School. To ensure the trustworthiness of the findings, several validation procedures were employed, including member checking, peer debriefing, and data triangulation through cross-comparison of interview responses among teachers from different subject areas. The interview transcripts were coded iteratively, and emerging themes were refined through repeated review to ensure consistency and credibility of interpretation.

The analysis revealed a central theme concerning the importance of student engagement as a prerequisite for the development of critical thinking and creativity. Most teachers consistently reported that students demonstrated higher levels of participation, curiosity, and persistence when learning activities were designed to be interactive, contextual, and technology-supported. Teachers observed that conventional teacher-centered instruction often resulted in passive learning behaviors, whereas interactive learning environments encouraged students to ask questions, explore ideas, and participate more actively in classroom discussions. These findings suggest that engagement functions not merely as a learning outcome but as a foundational condition that enables higher-order thinking processes to emerge.

A second major theme concerned barriers to higher-order thinking development. Teachers repeatedly highlighted that students frequently struggled with conceptual understanding, analytical reasoning, and the ability to connect knowledge across different contexts. Many participants reported that students tended to focus on memorization rather than interpretation and evaluation, making it difficult for them to solve complex or open-ended problems. Teachers also identified low learning motivation, limited reading literacy, and insufficient opportunities to engage in reflective thinking as important factors constraining students' critical and creative performance. These findings indicate that challenges in higher-order thinking are multidimensional, involving cognitive, motivational, and behavioral aspects simultaneously.

The third theme focused on the pedagogical role of technology-enhanced learning. Teachers described how digital tools such as Quizizz, Kahoot, and PhET simulations transformed classroom dynamics by increasing students' attention, participation, and willingness to collaborate. Gamified learning activities were perceived as particularly effective in reducing boredom and creating a more enjoyable learning atmosphere. However, teachers also emphasized several implementation challenges, including limitations in technological infrastructure, unequal digital literacy levels among students, and concerns regarding excessive dependence on digital devices. These findings demonstrate that while technology offers

significant pedagogical benefits, its effectiveness depends heavily on instructional design and contextual readiness.

The final theme reflected teachers' expectations regarding future AI-supported learning innovations. Participants expressed a strong preference for adaptive gamification systems capable of providing personalized feedback, step-by-step problem-solving guidance, interactive simulations, and real-time learning analytics. Teachers believed that such systems could better accommodate individual learning differences while simultaneously strengthening students' critical thinking and creativity. Within the context of Islamic boarding school education, participants further emphasized that technological innovation should complement, not replace, the values of discipline, character formation, collaboration, and reflective learning that constitute essential components of the pesantren educational culture.

Based on the thematic synthesis of the interview data, four interrelated variables were identified as the primary factors influencing students' critical thinking and creativity performance: (1) the use of gamification in interactive learning, (2) the implementation of deep learning in adaptive learning, (3) learning motivation, and (4) learning engagement. These themes subsequently served as the conceptual basis for the development of the quantitative research model and the formulation of hypotheses tested in the subsequent PLS-SEM analysis.

The Result of Quantitative Research Method

This section presents the results of the Partial Least Squares Structural Equation Modeling (PLS-SEM) analysis, which was conducted to examine the relationships among gamification, adaptive learning, learning motivation, learning engagement, and students' critical thinking and creativity at Cahaya Rancamaya Islamic Boarding School in Bogor. Prior to evaluating the measurement and structural models, several preliminary assessments were performed to ensure that the data met the requirements for PLS-SEM analysis. The final dataset consisted of 109 valid student responses. This sample size exceeded the minimum requirement recommended by the ten-times rule, as the largest number of structural paths directed toward a single endogenous construct was four. Therefore, the sample was considered adequate for estimating the proposed model and generating reliable path coefficients. In addition, collinearity diagnostics indicated acceptable Variance Inflation Factor (VIF) values below the recommended threshold, suggesting the absence of problematic multicollinearity among predictor variables. These results confirmed that the dataset was suitable for subsequent PLS-SEM analysis.

Table 3 PLS-SEM Assumption Assessment

No.	Criterion	Result	Threshold	Status
1.	Sample Size	109	> 40 (10-times rule)	Fulfilled
2.	Maximum Structural Paths	4	,	Fulfilled
3.	Highest VIF	1.910	< 3.3	Fulfilled
4.	Missing Data	0%	< 5%	Fulfilled
5.	Multicollinearity	Not detected	VIF < 3.3	Fulfilled

Following the assumption assessment, the measurement model and structural model were evaluated. The analysis included examinations of construct validity and reliability, discriminant validity, path coefficients, coefficient of determination (R^2), effect sizes (f^2), and significance testing using the bootstrapping procedure. The results of the convergent validity assessment for the measurement model are presented in Figure 1.

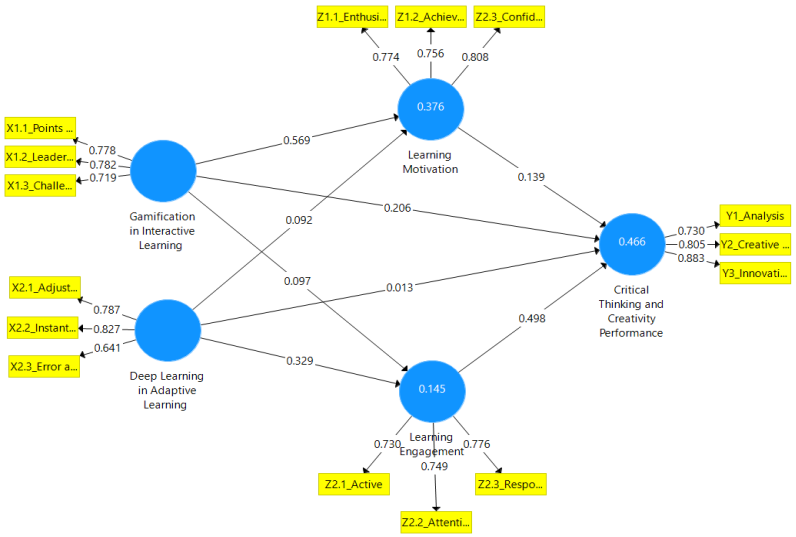

Figure 1 PLS Algorithm Result

Based on Figure 1, all loading factor values of the indicators exceeded the recommended threshold of 0.600. Factor loadings indicate the extent to which each indicator reflects its underlying latent construct. The obtained values demonstrate that all indicators substantially contribute to measuring their respective constructs and possess satisfactory indicator reliability. Consequently, the measurement model fulfills the requirements of convergent validity, indicating that the indicators accurately represent the theoretical constructs under investigation.

Table 4 Construct Reliability and Validity

No.	Construct	Composite Reliability	Average Variance Extracted (AVE)	Interpretation
1.	Critical Thinking and Creativity Performance	0.849	0.653	Reliable and valid. All values exceed the threshold. Internal consistency and convergent validity are acceptable.
2.	Deep Learning in Adaptive Learning	0.798	0.571	
3.	Use of Gamification in Interactive Learning	0.804	0.578	
4.	Learning Engagement	0.796	0.565	
5.	Learning Motivation	0.823	0.608	

Composite Reliability (CR) was employed to evaluate the internal consistency of each construct. As shown in Table 4, all CR values exceeded the recommended threshold of 0.700, indicating satisfactory reliability. Furthermore, Average Variance Extracted (AVE) values ranged from 0.565 to 0.653, all surpassing the minimum criterion of 0.500. These findings

confirm that the constructs demonstrate adequate convergent validity and explain a substantial proportion of variance in their indicators. Therefore, all constructs satisfy the required standards of reliability and validity and are appropriate for further structural model evaluation.

The next stage of the outer model assessment involved examining discriminant validity using the Fornell–Larcker Criterion. Discriminant validity evaluates whether a construct is empirically distinct from other constructs within the model. The results of the Fornell–Larcker analysis are presented in Table 5.

Table 5 Fornell–Larcker Criterion for Discriminant Validity

No.	Construct	CTCP	DLAL	UGIL	LE
1.	Critical Thinking and Creativity Performance (CTCP)	0.808			
2.	Deep Learning in Adaptive Learning (DLAL)	0.333	0.756		
3.	Use of Gamification in Interactive Learning (UGIL)	0.414	0.428	0.760	
4.	Learning Engagement (LE)	0.616	0.370	0.238	0.752
5.	Learning Motivation (LM)	0.498	0.335	0.608	0.461

As seen in Table 5, all diagonal values (the square roots of AVE) are higher than their corresponding correlations with other constructs. This indicates that discriminant validity has been achieved for all constructs, demonstrating that each construct measures a unique concept and does not significantly overlap with others.

Finally, the Variance Inflation Factor (VIF) test was conducted to detect multicollinearity among independent variables (predictors) in the structural model. Multicollinearity occurs when independent variables are highly correlated, which can distort the estimation of path coefficients. Table 6 summarizes the VIF test results.

Table 6 Variance Inflation Factor (VIF) Result

No.	Construct	CTCP	LE	LM
1.	Deep Learning in Adaptive Learning (DLAL)	1.352	1.225	1.225
2.	Use of Gamification in Interactive Learning (UGIL)	1.783	1.225	1.225
3.	Learning Engagement (LE)	1.393		
4.	Learning Motivation (LM)	1.910		

Table 6 indicates that all VIF values between constructs and the main dependent variable (CTCP) are below 3.3, implying that no significant multicollinearity exists among the independent variables. Therefore, the model is considered stable and valid regarding construct relationships.

The Goodness of Fit (GoF) criteria were also examined to determine how well the structural model fits the empirical data. Table 7 presents several key indices used in the PLS-SEM GoF assessment.

Table 7 Goodness of Fit

No.	Criteria	Saturated Model	Estimated Model	Interpretation
1.	SRMR	0.107	0.118	Error score is slightly above the limit but remains acceptable.
2.	NFI	0.516	0.502	Medium fit.

As shown in Table 7, the Standardized Root Mean Square Residual (SRMR) value of 0.118 remains within the acceptable range, indicating a moderate yet acceptable model fit within the exploratory framework of PLS-SEM. The Normed Fit Index (NFI) value, though below 0.9, still indicates a reasonable fit considering the exploratory nature of the research. Since this study aims to develop an initial model of interactive learning innovation, the obtained GoF results are still valid for interpretation.

This research model is valid, reliable, and demonstrates strong predictive power in explaining the factors influencing the enhancement of students' critical thinking and creativity at Cahaya Rancamaya Islamic Boarding School. Although the overall fit indices are not statistically optimal (NFI and SRMR), they remain acceptable for exploratory studies. The model provides a valuable foundation for policy development and instructional design strategies, particularly in integrating gamification, adaptive learning, motivation, and student engagement to strengthen 21st-century learning in Islamic boarding school environments.

Discussion

The present study examined the relationships among gamification, adaptive learning, learning motivation, learning engagement, and students' critical thinking and creativity within the educational context of Cahaya Rancamaya Islamic Boarding School, Bogor. Unlike experimental studies that seek to measure learning gains before and after an intervention, the current study employed a sequential exploratory mixed-method design and analyzed the quantitative data using PLS-SEM. Therefore, the findings should be interpreted as evidence of relationships and predictive influences among variables rather than direct proof of improvement or causal effects. The structural model demonstrated that all proposed variables contributed positively to Critical Thinking and Creativity Performance (CTCP), although the magnitude of their contributions varied considerably.

The PLS-SEM analysis revealed that learning engagement was the strongest predictor of CTCP, with a path coefficient of 0.498. This finding suggests that students who demonstrate higher levels of participation, attention, enthusiasm, and involvement in learning activities tend to report stronger critical thinking and creativity performance. However, this result should not be interpreted as indicating that engagement alone determines learning success. Rather, within the proposed model and among the sampled students, learning engagement explained a larger proportion of variance in CTCP than the other variables examined. This finding highlights the importance of creating learning environments that encourage active participation, collaborative interaction, reflective thinking, and meaningful involvement in classroom activities. Such engagement appears particularly relevant within the Islamic boarding school environment, where learning activities are often embedded within communal, character-building, and value-oriented educational practices.

The coefficient of determination ($R^2 = 0.466$) indicates that approximately 46.6% of the variance in students' critical thinking and creativity performance can be explained by the combined influence of gamification, adaptive learning, learning motivation, and learning engagement. According to Hair, this value represents a moderate level of predictive power (Hair et al., 2021). Consequently, the findings suggest that the proposed model possesses adequate explanatory capability while also indicating that a substantial proportion of variance remains attributable to other factors not included in the model. These factors may include prior academic achievement, family support, learning culture, digital literacy, socio-economic background, teacher competence, and students' cognitive readiness. Therefore, caution should be exercised when generalizing the findings beyond the study population, which consisted of Grade 10 students at Cahaya Rancamaya Islamic Boarding School.

Among the exogenous variables, gamification demonstrated the second strongest influence within the model. The findings indicate that the use of game-based elements in learning environments contributes positively to students' motivation and engagement. More importantly, the results suggest that the contribution of gamification to critical thinking and creativity operates primarily through motivational and engagement-related mechanisms rather than through direct cognitive effects alone. The strong path coefficient from gamification to learning motivation ($\beta = 0.569$) supports this interpretation. In practice, game elements such as points, badges, levels, challenges, leaderboards, and instant feedback appear to stimulate students' willingness to participate actively in learning activities. Consequently, gamification should not merely be viewed as a technological feature but rather as an instructional strategy that creates meaningful learning experiences and encourages sustained student involvement.

These findings are consistent with previous studies conducted by Smirani and Yamani (2024) and Elsa Dian et al. (2024), who reported that gamification significantly increased student motivation and engagement through the use of rewards, challenges, and competition mechanisms (Smirani & Yamani, 2024); (Elsa Dian et al., 2024). Likewise, Prameswari et al. (2025) and Nurhayati and Fathurrohman (2025) found that gamified learning environments improved engagement and learning outcomes by providing interactive experiences and immediate feedback (Prameswari et al., 2025); (Nurhayati & Fathurrohman, 2025). The qualitative findings of the present study further support these conclusions, as teachers consistently reported increased enthusiasm, participation, and classroom interaction when digital gamification platforms such as Quizizz and Kahoot were incorporated into lessons.

The results also align with studies conducted by Fitria, Siregar, and Rahmawati (2023), who found a significant relationship between gamification and students' critical thinking abilities (Fitria et al., 2023). Similar findings were reported by Abbassyakhrin et al. (2024), who demonstrated that gamification supports metacognitive development and critical reasoning when aligned with students' academic readiness (Abbassyakhrin et al., 2024); (Anwar et al., 2018); (Tamara & FH, 2024); (Indah et al., 2022); (Hasan, 2021); (Zarkasyi et al., 2024); (Nurfazri & Septi Irwansyah, 2024). Furthermore, Boom-Cárcamo et al. concluded that combining gamification with Problem-Based Learning (PBL) enhances creativity and problem-solving performance (Boom-Cárcamo et al., 2024); (Kim et al., 2024); (Suryo Buwono & Dirgahayu, 2020); (Ananda et al., 2024). These findings reinforce the notion that gamification is most effective when integrated with active learning strategies rather than implemented as an isolated technological intervention.

The present study also identified positive relationships involving adaptive learning, although the magnitude of its direct contribution was relatively small compared with engagement and motivation. This finding should not be interpreted as evidence that adaptive learning lacks educational value. Rather, it may indicate that the implementation of adaptive learning technologies within the studied context remains at an early stage of development. Effective adaptive learning systems require adequate technological infrastructure, teacher preparedness, high-quality learning analytics, and students' readiness to engage with personalized learning pathways. These contextual factors may have limited the observable influence of adaptive learning within the current model.

Nevertheless, the findings remain consistent with previous adaptive learning literature. Lavieri (2014) and Calongne and Stricker (2014) emphasized that adaptive learning environments generally produce positive educational outcomes when supported by well-designed instructional frameworks (Lavieri E. D., 2014); (Calongne & Stricker, 2014). Similarly, the ALGAE model highlights the importance of integrating adaptive mechanisms with gamification features to create more personalized and engaging learning experiences (Lavieri E. D., 2014); (Dennis Mega et al., 2024); (Fitri Marisa et al., 2022). Correia and Lobo

(2024) further demonstrated that AI-based adaptive gamification systems can contribute to critical thinking development through intelligent feedback and personalized learning support (Correia & Lobo, 2024); (Aris Triwahyu Febriansah et al., 2024); (Jusuf, 2016); (Fadilla & Nurfadhilah, 2022). The aspirations expressed by teachers during interviews strongly reflected these principles, particularly regarding the need for AI-supported feedback, learning personalization, and adaptive problem-solving guidance.

The findings concerning creativity are likewise supported by previous studies. Research conducted by Fitria et al. (2023), Boom-Cárcamo et al. (2024), and related scholars demonstrated that learning environments incorporating creative tasks, reflective activities, SCAMPER strategies, and structured problem-solving approaches contribute positively to students' creative performance (Fitria et al., 2023); (Boom-Cárcamo et al., 2024); (Isma et al., 2024); (Setiyawan et al., 2019); (Saputra et al., 2025). Teacher interviews in the present study similarly emphasized the importance of providing opportunities for students to analyze, reflect, collaborate, and generate original solutions within authentic learning contexts.

Despite these promising findings, several implementation challenges were identified. Teachers reported issues related to limited concentration, technology dependence, digital infrastructure constraints, and unstable internet connectivity. Consistent with Smirani and Yamani, excessive reliance on competitive mechanisms such as leaderboards may diminish long-term educational effectiveness if not balanced with meaningful learning objectives and reflective activities (Smirani & Yamani, 2024). Furthermore, the novelty effect associated with gamification may decline over time if instructional content is not continuously updated and aligned with students' needs. Consequently, sustainable implementation requires ongoing teacher professional development, adequate technological support, and thoughtful instructional design. Within the context of Islamic boarding school education, technological innovation should complement existing pedagogical values, including character formation, discipline, collaboration, and reflective learning, rather than replace them.

CONCLUSION

The findings of this study indicate that gamification in interactive learning, adaptive learning supported by deep learning principles, learning motivation, and learning engagement are significantly associated with students' critical thinking and creativity at Cahaya Rancamaya Islamic Boarding School in Bogor. The PLS-SEM analysis revealed that all proposed relationships were positive, with learning engagement emerging as the strongest predictor of students' critical thinking and creativity, followed by gamification, learning motivation, and adaptive learning. The measurement and structural models satisfied the required reliability and validity criteria, indicating that the proposed model provides a statistically acceptable explanation of the relationships among the studied constructs. Although the model demonstrated moderate predictive power, the results suggest that student engagement plays a central role in the development of higher-order thinking and creative capacities within technology-supported learning environments.

From a practical perspective, the study highlights the importance of designing learning experiences that actively involve students through meaningful interaction, collaborative activities, contextual problem-solving tasks, and well-structured gamification elements. Rather than demonstrating direct improvement, the findings provide empirical evidence that gamification, adaptive learning, motivation, and engagement contribute positively to the variation in students' critical thinking and creativity. These results offer valuable implications for educators, school leaders, and policymakers seeking to strengthen digital learning practices in Islamic boarding schools. Future studies are encouraged to employ experimental, quasi-

experimental, or longitudinal research designs to examine causal effects and measure actual improvements in students' critical thinking and creativity over time.

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