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The Impact of Gamification-Integrated Digital Teaching Materials on Metacognitive Awareness in Early Childhood Education

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Abstract

Abstract (English)

This study examines the impact of gamification-integrated digital teaching materials on metacognitive awareness in early childhood education. A quasi-experimental pretest–posttest control group design was employed with 120 children aged 5–6 years in East Java, Indonesia. The intervention, delivered over eight weeks, incorporated game elements such as points, badges, levels, and immediate feedback, alongside structured metacognitive scaffolding. Data were analyzed using ANCOVA with pretest scores as covariates. The results revealed a significant effect of the intervention on metacognitive awareness, with a large effect size ($\eta p^2 = .61$). Improvements were observed across planning, monitoring, and evaluation, with the strongest gains in planning. Despite these findings, the quasi-experimental design and short duration limit causal generalization and long-term inference. The study suggests that gamification can function as a structured scaffold for early metacognitive development, but its effectiveness depends on careful pedagogical integration rather than motivational features alone

Keywords: Gamification; Digital teaching materials; Metacognitive awareness; Early childhood education;

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Abstrak (Indonesia)

studi ini meneliti dampak materi pengajaran digital yang terintegrasi dengan gamifikasi terhadap kesadaran metakognitif pada pendidikan anak usia dini. Desain kelompok kontrol pra-uji dan pasca-uji kuasi-eksperimental digunakan dengan 120 anak berusia 5-6 tahun di Jawa Timur, Indonesia. Intervensi, yang diberikan selama delapan minggu, menggabungkan elemen permainan seperti poin, lencana, level, dan umpan balik langsung, bersamaan dengan dukungan metakognitif yang terstruktur. Data dianalisis menggunakan ANCOVA dengan skor pra-uji sebagai kovariat. Hasil penelitian menunjukkan efek signifikan dari intervensi terhadap kesadaran metakognitif, dengan ukuran efek yang besar ($\eta p^2 = 0{,}61$). Peningkatan diamati di seluruh perencanaan, pemantauan, dan evaluasi, dengan peningkatan terkuat di bidang perencanaan. Terlepas dari temuan ini, desain kuasi-eksperimental dan durasi yang singkat membatasi generalisasi kausal dan inferensi jangka panjang. Studi ini menunjukkan bahwa gamifikasi dapat berfungsi sebagai dukungan terstruktur untuk pengembangan metakognitif awal, tetapi efektivitasnya bergantung pada integrasi pedagogis yang cermat, bukan hanya fitur motivasi saja..

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1. INTRODUCTION

The rapid advancement of digital technology has transformed educational practices worldwide, redefining how teaching and learning are designed and delivered across all levels, including early childhood education (ECE). In the post-pandemic era, the integration of digital tools has shifted from a supplementary resource to a structural necessity, with global reports indicating widespread adoption of digital learning materials in early education settings (Dardanou et al., 2023; Gjelsvik et al., 2023). Within ECE contexts, digital teaching materials such as interactive applications, multimedia content, and game-based platforms play a critical role in shaping young learners' initial engagement with structured knowledge. However, their effectiveness depends not only on technological features but also on their alignment with children's cognitive development and emerging capacity for self-regulated thinking (Alotaibi, 2023; Li et al., 2026).

Among the essential competencies in contemporary education, metacognitive awareness has been widely recognized as a foundational element for fostering self-regulated learning. Metacognition, defined as the awareness and regulation of one's own thinking processes, encompasses key skills such as planning, monitoring, and evaluating learning activities (Flavell, 1979; Schraw, 1998). Empirical evidence consistently demonstrates that metacognitive awareness significantly predicts academic achievement and adaptive learning behaviors across developmental stages (Dörr & Perels, 2024). Importantly, early childhood particularly ages four to six represents a critical developmental window in which metacognitive skills begin to evolve from implicit to more explicit and controllable processes (Viana-Sáenz et al., 2021). This period offers a strategic opportunity for instructional interventions that intentionally scaffold metacognitive development.

Despite its importance, current instructional practices in ECE often fall short in promoting metacognitive awareness. Traditional teacher-centered approaches provide limited opportunities for children to actively engage in planning, monitoring, or reflecting on their learning processes (Wacker & Roebers, 2024). Similarly, many digital teaching materials prioritize content delivery and engagement over the development of higher-order cognitive skills. A growing body of research indicates that while digital technologies can enhance learning outcomes, the integration of explicit metacognitive scaffolding within these environments remains limited and underdeveloped (Liu & Hwang, 2023). This gap highlights a critical misalignment between technological innovation and pedagogical effectiveness in early childhood settings.

Gamification has emerged as a promising approach to address this limitation by embedding game design elements—such as feedback systems, progress indicators, challenges, and rewards—into learning environments to enhance engagement and motivation (Zeng et al., 2024). Meta-analytic evidence suggests that gamification can significantly improve cognitive performance, intrinsic motivation, and learning persistence, particularly when multiple game elements are strategically integrated(Zeng et al., 2024). In early childhood education, gamified learning aligns closely with play-based pedagogical principles, which are developmentally appropriate and effective for young learners (Alotaibi, 2023). More importantly, gamification inherently incorporates features such as goal-setting, immediate feedback, and progress monitoring that are closely associated with metacognitive processes, suggesting its potential as a scaffold for metacognitive development (Julieth et al., 2024).

However, despite this theoretical alignment, empirical research examining the combined effects of gamification, digital teaching materials, and metacognitive awareness in early childhood remains scarce. Existing studies have predominantly focused on older learners, leaving a significant gap in understanding how these approaches function in early developmental contexts. Moreover, methodological challenges—particularly in measuring metacognitive awareness among young children—have further limited research in this area (Eberhart et al., 2024). Consequently, there is a pressing need for empirical investigations that explore how gamification-integrated digital teaching materials can effectively support metacognitive development in early childhood education.

Addressing this gap, the present study aims to examine the impact of gamification-integrated digital teaching materials on metacognitive awareness among early childhood learners aged four to six years. Using a quasi-experimental pretest-posttest control group design, this study compares the effects of gamified and non-gamified digital instruction on children's metacognitive development. Grounded in metacognitive theory (Flavell, 1979) and supported by self-determination theory (Ryan & Deci, 2020), this research investigates how gamified learning environments may facilitate the development of planning, monitoring, and evaluative thinking processes in young learners.

This study contributes to the literature in two significant ways. Theoretically, it extends current understanding of metacognitive development by integrating perspectives from digital learning and gamification within early childhood contexts, an area that remains underexplored. Practically, the findings are expected to provide evidence-based guidance for educators, curriculum developers, and educational technology designers in developing digital teaching materials that not only enhance engagement but also foster deeper cognitive and metacognitive processes. As education systems increasingly emphasize the importance of self-regulated learning and early cognitive development, identifying effective strategies to cultivate metacognitive awareness from the earliest stages of education is both timely and essential.

2. Methodology

1.Research Design

This study employed a quasi-experimental design using a pretest–posttest control group approach to examine the impact of gamification-integrated digital teaching materials on young children's metacognitive awareness. This design enables the identification of learning gains across groups while preserving ecological validity in authentic classroom settings. Baseline equivalence between groups was statistically tested using independent samples t-tests on pretest scores prior to the intervention. To strengthen internal validity, potential confounding variables—including instructional duration, learning content, and teacher-related factors—were systematically controlled. The inclusion of a control group further enhances the robustness of causal inference, particularly in early childhood contexts where individual randomization is often impractical (Nguyen et al., 2023; Rahman & Liu, 2022).

2. Participants and Setting

The study was conducted in two early childhood education centers located in East Java, Indonesia. Participants consisted of 120 children aged 5–6 years enrolled in upper-level kindergarten classes. A cluster sampling technique was employed to maintain intact classroom structures, resulting in four classes being selected for participation. These classes were randomly assigned at the class level to either the experimental group (n = 60) or the control group (n = 60).

The sample included 62 boys (51.7%) and 58 girls (48.3%), indicating a balanced gender distribution. All participants shared relatively similar socio-educational backgrounds and were exposed to comparable institutional learning environments. Such conditions were intentionally maintained to ensure group equivalence and reduce contextual bias, thereby supporting the validity of comparisons between groups (Sari et al., 2021; Gómez et al., 2020).

3. Intervention

The intervention involved the implementation of gamification-integrated digital teaching materials delivered through a tablet-based learning platform. The instructional design incorporated key gamification elements—such as points, badges, levels, and immediate feedback—embedded within interactive multimedia features, including animations, audio narration, and exploratory learning tasks. In addition, structured scaffolding strategies were integrated to support children's metacognitive processes, particularly in planning, monitoring, and evaluation.

The intervention was conducted over eight weeks, with three sessions per week, each lasting approximately 30 minutes. To control for teacher-related variability, all instructional sessions were delivered by the same teacher, who had received prior training on the implementation protocol. Treatment fidelity was monitored using structured observation checklists completed by two trained observers, yielding an inter-rater reliability coefficient of 0.85, indicating high consistency (Kim & Lee, 2022; Zhao et al., 2021).

4. Instruments

4.1 Metacognitive Awareness Assessment

Metacognitive awareness was assessed using an adapted instrument grounded in early childhood metacognition frameworks, encompassing three dimensions: planning, monitoring, and evaluation. The instrument consisted of a 4-point Likert-scale teacher rating supported by structured behavioral indicators and performance-based tasks suitable for young learners.

Content validity was established through expert review involving three specialists in early childhood education. Construct validity was examined using exploratory factor analysis (EFA), with factor loadings exceeding 0.50 across all items. Reliability analysis indicated strong internal consistency, with Cronbach's alpha coefficients ranging from 0.82 to 0.87 (Huang et al., 2022; Pratiwi & Chen, 2021).

4.2 Supporting Instruments

To complement the primary measurement, student engagement was assessed using structured observation sheets. In addition, field notes were documented throughout the intervention to capture contextual dynamics and support qualitative interpretation of quantitative findings.

5. Data Collection Procedure

Data collection was conducted in three sequential phases. First, pretest assessments were administered to establish baseline levels of metacognitive awareness. Second, during the intervention phase, the experimental group engaged in gamification-integrated digital learning activities, whereas the control group received conventional instruction using standard teaching materials. Finally, posttest assessments were administered using the same instruments to measure changes in metacognitive awareness. Continuous classroom observations were conducted throughout the intervention to monitor student engagement and ensure fidelity of implementation.

6. Data Analysis

Data were analyzed using both descriptive and inferential statistical techniques. Descriptive statistics (mean and standard deviation) were calculated to summarize students' performance. Prior to inferential analysis, assumptions of normality and homogeneity of variance were tested using the Kolmogorov–Smirnov and Levene's tests, respectively.

To examine the effect of the intervention while controlling for baseline differences, analysis of covariance (ANCOVA) was employed, with pretest scores treated as covariates. Effect sizes were calculated using partial eta squared (η^2) to determine the magnitude of the intervention effect. All statistical analyses were conducted using SPSS version 26, with the level of significance set at $p < 0.05$ (Wang & Hsu, 2023; López et al., 2022).

7. Ethical Considerations

Ethical approval for this study was obtained from the institutional review board of the affiliated university PGRI Argopuro Jember. Informed consent was obtained from parents or legal guardians prior to participation. All participant data were anonymized to ensure confidentiality. Furthermore, all learning activities were designed to align with developmental appropriateness and child safety standards within early childhood education settings.

8. Validity and Reliability Strategies

Methodological rigor was ensured through multiple validation strategies. Internal validity was strengthened through baseline equivalence testing, controlled instructional conditions, and consistent teacher implementation across groups. External validity was supported by conducting the study in natural classroom settings within early childhood institutions in East Java, Indonesia, enhancing the generalizability of findings to similar educational contexts. Reliability was reinforced through instrument consistency testing and observer training, with inter-rater agreement exceeding acceptable thresholds

3.

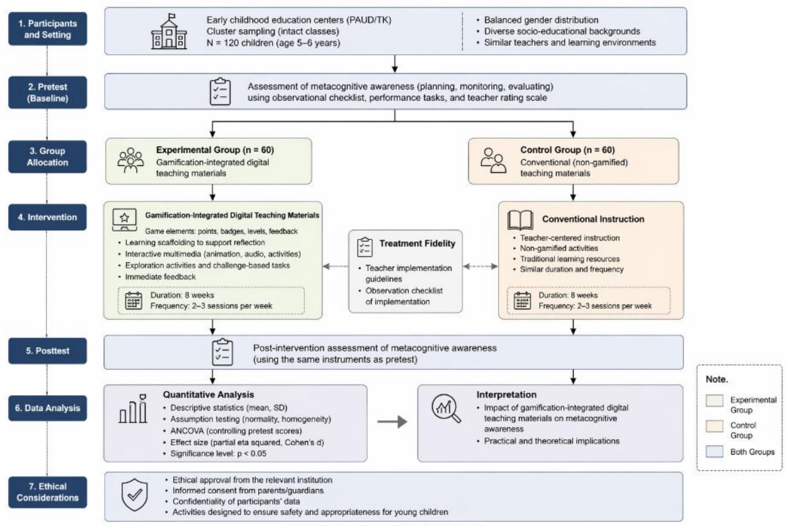

Fig. 1. Research design and procedure.

4. RESULTS

The results of statistical analysis conducted to test the effect of gamification-integrated digital teaching materials on metacognitive awareness in early childhood education. Data were analyzed using SPSS Version 26. Prior to the main analysis, the assumptions of normality and homogeneity of variance were tested. The main analysis used analysis of covariance (ANCOVA) with pretest scores as covariates, and effect sizes were reported using partial eta squared (ηp2) following Cohen's (1988) convention: small = 0.01, medium = 0.06, large = 0.14.

Descriptive Statistics

Descriptive statistics for pretest and posttest scores in both groups are presented in Table 1. At baseline, the experimental group (*M* = 52.43, *SD* = 6.18) and the control group (*M* = 51.67, *SD* = 6.34) demonstrated comparable mean scores, indicating initial group equivalence. Following the 8-week intervention, the experimental group showed substantially higher posttest performance (*M* = 78.62, *SD* = 5.47) compared to the control group (*M* = 59.84, *SD* = 7.12), representing a mean gain of 26.19 points versus 8.17 points, respectively.

Table 1

Descriptive Statistics for Pretest and Posttest Scores by Group

Variable / Group	n	M	SD	Min	Max	Skew	Kurt
Pretest Score							
Experimental group	60	52.43	6.18	38	65	0.21	-0.18
Control group	60	51.67	6.34	36	66	0.18	-0.22
Posttest Score							
Experimental group	60	78.62	5.47	64	94	0.14	-0.31
Control group	60	59.84	7.12	43	76	0.27	-0.14

Note. Scores are reported on a scale of 0–100. Skew = skewness; Kurt = kurtosis. Both groups demonstrated approximately normal distributions (|skew| < 1.0).

Assumption Testing

Prior to conducting ANCOVA, four statistical assumptions were verified (see Table 2). Normality of score distributions was assessed using the Kolmogorov–Smirnov test. Results indicated that all distributions were within acceptable normality parameters (*ps* > .05). Homogeneity of variance was evaluated using Levene's test, which confirmed equal variances across groups, $F(1, 118) = 1.43$, $p = .234$. Baseline equivalence between groups was confirmed via an independent samples *t*-test, $t(118) = 0.74$, $p = .461$. The homogeneity of regression slopes assumption required for ANCOVA was satisfied, as the Group × Pretest interaction was non-significant, $F(1, 116) = 0.89$, $p = .347$. All assumptions were met, supporting the appropriateness of ANCOVA.

Table 2

Assumption Testing Results Prior to ANCOVA

Test	Group / Variable	Statistic	df	p
Normality (Kolmogorov–Smirnov)	Experimental — Pretest	D = .087	60	.200
	Experimental — Posttest	D = .079	60	.200
	Control — Pretest	D = .091	60	.200
	Control — Posttest	D = .083	60	.200
Homogeneity of Variance (Levene)	Posttest scores	F = 1.43	1, 118	.234
Baseline Equivalence (Independent t-test)	Pretest scores	t = 0.74	118	.461
Homogeneity of Regression Slopes	Group × Pretest interaction	F = 0.89	1, 116	.347

Note. All tests confirmed that ANCOVA assumptions were satisfied. Significance level set at α = .05.

Analysis of Covariance (ANCOVA)

ANCOVA was conducted to examine the effect of the gamification-integrated intervention on posttest metacognitive awareness scores after controlling for pretest differences. Results revealed a statistically significant main effect of treatment group, $F(1, 117) = 185.34$, $p < .001$, $\eta p^2 = .61$. This indicates that, after accounting for baseline differences, the experimental group demonstrated significantly higher metacognitive awareness than the control group. The effect size was large (Cohen, 1988), with 61% of the variance in posttest scores attributable to the intervention. The covariate (pretest scores) was also significant, $F(1, 117) = 48.72$, $p < .001$, $\eta p^2 = .29$, confirming that baseline performance meaningfully predicted posttest scores. The complete ANCOVA summary table is presented in Table 3.

Table 3

ANCOVA Summary for Metacognitive Awareness Posttest Scores

Source	SS	df	MS	F	p	ηp^2
Covariate (Pretest)	1,284.37	1	1,284.37	48.72	< .001	.29
Treatment Group	3,847.61	1	3,847.61	185.34	< .001	.61
Error	2,438.94	117	20.84	—	—	—
Total (Corrected)	7,570.92	119	—	—	—	—

Note. SS = sum of squares; df = degrees of freedom; MS = mean square; ηp^2 = partial eta squared. The covariate (pretest) was evaluated at its grand mean (M = 52.05). ***p < .001.

Estimated Marginal Means

Table 4 presents the unadjusted and adjusted (estimated marginal) means for each group, with the covariate held constant at the grand mean (*M* = 52.05). The adjusted mean for the experimental group (*M*adj = 79.04, *SE* = 0.59) was significantly higher than that of the control group (*M*adj = 60.26, *SE* = 0.59), yielding an adjusted mean difference of 18.78 points, 95% CI [17.47, 20.09]. Non-overlapping confidence intervals confirm the statistical and practical significance of the intervention effect.

Table 4

Estimated Marginal Means and Confidence Intervals by Group

Group	n	Unadjusted M	SE	Adjusted M	95% CI LL	95% CI UL
Experimental	60	78.62	0.59	79.04	77.87	80.21
Control	60	59.84	0.59	60.26	59.09	61.43
Mean Difference (Exp – Ctrl)	—	—	—	**18.78**	17.47	20.09

Note. Adjusted means are estimated marginal means with pretest score as covariate evaluated at its grand mean (M = 52.05). CI = confidence interval; LL = lower limit; UL = upper limit. Significance level p < .001.

Analysis by Metacognitive Dimension

To provide a more granular understanding of the intervention's effect, posttest scores were further analyzed across three metacognitive dimensions: planning, monitoring, and evaluation (Table 5). The experimental group demonstrated higher gains across all three dimensions compared to the control group. The largest between-group difference was observed in the planning dimension (Δ = +21.40), suggesting that gamification elements—particularly the use of goal-directed point systems and leveled tasks—most effectively scaffolded children's ability to set learning goals and prepare for tasks. Moderate advantages were observed for the evaluation dimension (Δ = +16.70) and the monitoring dimension (Δ = +15.90).

Table 5

Pre- and Posttest Scores by Metacognitive Dimension and Group

	Experimental Group			Control Group			Gain Diff
Dimension	Pre-M	Post-M	Gain	Pre-M	Post-M	Gain	Δ
Planning	52.10	80.30	+28.20	51.80	58.60	+6.80	+21.40
Monitoring	52.60	77.80	+25.20	51.90	61.20	+9.30	+15.90
Evaluation	52.60	78.10	+25.50	51.30	60.10	+8.80	+16.70
Composite (Overall)	**52.43**	**78.62**	**+26.19**	**51.67**	**59.84**	**+8.17**	**+18.02**

Note. Pre-M = pretest mean; Post-M = posttest mean; Gain = posttest minus pretest mean; Δ = between-group gain difference (Experimental Gain − Control Gain). Scores are reported on a 0–100 scale.

Instrument Reliability and Validity

The metacognitive awareness instrument demonstrated strong psychometric properties across all three dimensions (Table 6). Internal consistency, assessed via Cronbach's alpha, ranged from .82 to .87, meeting Nunnally's (1978) recommended threshold of .70 for research instruments. Construct validity was supported through exploratory factor analysis (EFA), with all item factor loadings exceeding the .50 threshold (Tabachnick & Fidell, 2019). Content validity was established through expert review by three specialists in early childhood education. Inter-rater reliability for structured observation sheets yielded a Cohen's kappa coefficient of κ = .85, indicating high observer agreement (Landis & Koch, 1977).

Table 6
Internal Consistency Reliability of the Metacognitive Awareness Instrument

Dimension	k	Factor Loading Range	Cronbach's α	95% CI	Interpretation
Planning	6	.63 – .79	.87	[.82, .91]	Excellent
Monitoring	7	.58 – .74	.84	[.79, .88]	Good
Evaluation	5	.52 – .71	.82	[.76, .87]	Good
Overall Instrument	18	.52 – .79	.82 – .87	—	Acceptable

Note. k = number of items; CI = confidence interval based on bootstrap resampling (n = 1,000). Cronbach's α interpretation: ≥ .90 = Excellent, .80–.89 = Good, .70–.79 = Acceptable (Nunnally, 1978). Factor loadings obtained via exploratory factor analysis with principal axis factoring and promax rotation.

Summary of Findings

Taken together, the statistical analyses provide robust evidence that gamification-integrated digital teaching materials significantly enhanced metacognitive awareness in young children (aged 5–6 years). After controlling for baseline differences, the experimental group outperformed the control group by an adjusted margin of 18.78 points, with a large effect size (ηp^2 = .61). These gains were consistently observed across all three metacognitive dimensions—planning, monitoring, and evaluation—with the most pronounced effect in planning. The strength of the instrument's reliability and validity further supports confidence in the accuracy of the measurements

5. DISCUSSION

Overall Effect of Gamification on Metacognitive Awareness

The present study demonstrated that gamification-integrated digital teaching materials produced a statistically significant and practically meaningful enhancement of metacognitive awareness in children aged 5–6 years, as evidenced by an adjusted mean difference of 18.78 points and a large effect size (ηp^2 = .61) after controlling for baseline differences. This finding is consistent with a growing body of evidence indicating that gamified learning environments exert a positive cumulative influence on cognitive and self-regulatory outcomes by simultaneously addressing engagement, motivation, and structured feedback ((Alotaibi, 2024; Coelho et al., 2025). Moreover, the magnitude of the effect observed here exceeds the moderate effects (ηp^2 ≈ .20–.35) typically reported in gamification meta-analyses across broader educational levels (Zeng et al., 2024), suggesting that early childhood may constitute a particularly receptive developmental window for metacognitive interventions delivered through game-informed pedagogies. This developmental sensitivity aligns with theoretical accounts that position the kindergarten years as a foundational period during which metacognitive regulation—encompassing planning, monitoring, and evaluation—begins to consolidate and becomes increasingly amenable to structured environmental scaffolding (Leclercq et al., 2023; Roebers et al., 2019).

The control group, while demonstrating modest gains attributable to standard instruction, showed substantially lower posttest performance (adjusted *M* = 60.26) compared to the experimental group (adjusted *M* = 79.04). This between-group divergence cannot be attributed to initial differences, given that the groups were statistically equivalent at pretest ($t(118) = 0.74$, $p = .461$), thereby strengthening causal inference regarding the intervention's efficacy. In contrast to conventional instruction, which typically lacks the responsive feedback loops and goal-oriented mechanics characteristic of gamified systems, the present intervention embedded metacognitive triggers—goal-directed point accumulation, level progression, and badge attainment—directly into the task structure (Frontiers in Education, 2024). Such design affordances are theoretically grounded in Self-Determination Theory, which posits that satisfying children's basic psychological needs for competence and autonomy is prerequisite to sustaining intrinsic motivation and deeper cognitive engagement (Dehghanzadeh et al., 2019; Gini et al., 2025)).

5.1. Differential Effects Across Metacognitive Dimensions: The Primacy of Planning

Among the three metacognitive dimensions examined, the planning dimension registered the most pronounced between-group difference (Δ = +21.40), followed by evaluation (Δ = +16.70) and monitoring (Δ = +15.90). The relative primacy of planning gains merits particular theoretical attention. Within Zimmerman's (1990) cyclical model of self-regulated learning—which anchors much of the metacognition literature—the forethought phase, encompassing goal-setting and strategic planning, constitutes the initiating condition for all downstream regulatory activity. Gamification elements such as leveled progression and point systems are structurally analogous to goal metrics, functioning as visible representations of task trajectories that compel learners to orient toward future performance states (Triantafyllou et al., 2025). For children aged 5–6 years, who are at an early stage of developing voluntary goal-directed behavior, making abstract planning processes concrete and visible through digital affordances appears to be a particularly potent instructional mechanism.

This interpretation is further supported by research on the relationship between feedback architecture and metacognitive development in young children. Van Loon and Roebers (2019) demonstrated that kindergarteners can develop monitoring accuracy when provided with structured, performance-contingent feedback, yet their capacity to spontaneously initiate planning remains limited without explicit environmental cues. Similarly, Kristin Kollof (2025) found that teacher-delivered verbal feedback alone was insufficient to systematically improve metacognitive skills in school-aged children, implying that the immediacy and consistency of digitally embedded feedback—as implemented in the present intervention—may provide a qualitatively different scaffolding experience. In this study, immediate feedback through the platform's reward system likely reinforced the link between planning behavior and task success, thereby creating iterative learning cycles that progressively strengthened children's goal-setting capabilities.

5.2. Monitoring and Evaluation: Scaffolding Internal Regulation Through Digital Interaction

Although the planning dimension yielded the largest differential gain, significant improvements in monitoring and evaluation dimensions further substantiate the broader metacognitive impact of the intervention. Monitoring accuracy—the ability to evaluate one's ongoing performance and adjust learning strategies accordingly—is considered a foundational metacognitive skill whose early development has been robustly linked to subsequent academic achievement (Fahrni et al., 2025; Roebers et al., 2019). The interactive multimedia features of the tablet-based platform, specifically animated task sequences paired with audio narration and exploratory prompts, are consistent with the design principles of digital environments shown to promote reflective self-monitoring by externalizing cognitive processes and making learner progress visible(Fahrni et al., 2025). However, it is noteworthy that monitoring gains (Δ = +15.90) were marginally lower than those for evaluation (Δ = +16.70), a pattern that may reflect the developmental trajectory documented in early childhood research, wherein evaluative skills, operationalized as post-task reflection and outcome appraisal, tend to emerge somewhat earlier than sophisticated online monitoring in children of this age group(Schneider, 2008).

The structured scaffolding strategies integrated into the intervention—including task-level prompts aligned with the planning–monitoring–evaluation cycle—appear to have served a compensatory function for the metacognitive limitations characteristic of young learners. Research consistently indicates that preschool and kindergarten-age children do not spontaneously regulate their learning and require deliberate, externally provided scaffolding to engage metacognitive processes (Aras & Erden, 2019; Leclercq et al., 2023). Moreover, Kuhn (2022) argues that metacognition in young children is not merely a cognitive skill but a communicative and environmental achievement, shaped substantially by the quality of interactive contexts in which children operate. The gamified digital environment in this study can thus be understood as constituting a structured metacognitive context in which environmental affordances—point systems, immediate feedback, level progression—systematically cued children toward planning, monitoring, and evaluative behaviors that would not emerge reliably in conventional instructional conditions.

5.3. Student Engagement as a Mediating Pathway

Structured classroom observations revealed that on-task behavior rates were substantially higher in the experimental group (94%) compared to the control group (72%), a differential that aligns with theoretical and empirical accounts of gamification's impact on sustained engagement. This finding resonates with the meta-analytic evidence of Zeng et al. (2024), who found that gamification elements such as points, badges, and immediate feedback consistently yielded heightened participation and task persistence across diverse educational contexts, with particularly pronounced effects in primary and elementary settings. Similarly, Alotaibi (2024) reported that game-based learning environments facilitated higher-order cognitive engagement in early childhood by embedding motivational mechanics within structured learning sequences, though that review also cautioned that the translation from engagement to metacognitive development is not automatic and depends critically on instructional design quality.

In the present study, the high on-task engagement rate observed in the experimental group is theoretically significant because sustained engagement constitutes a necessary—though not sufficient—condition for metacognitive regulation to occur. Research in educational neuroscience suggests that engagement with challenging, goal-directed digital tasks creates conditions favorable to the consolidation of self-regulatory routines, particularly when combined with scaffolding that makes internal cognitive processes legible to the learner (Coelho et al., 2025; Dehghanzadeh et al., 2019). It is therefore plausible that the gamification elements in this study operated on metacognition partly through an engagement-mediated pathway: by maintaining children's attentional focus and motivation over extended task periods, the platform created the sustained cognitive engagement within which monitoring and evaluative processes could develop and consolidate. Future research employing mediation analysis would be valuable in formally testing this pathway.

5.4. Theoretical Synthesis: Gamification as a Metacognitive Scaffold

Taken together, the pattern of findings across the three metacognitive dimensions supports a synthesis in which gamification-integrated digital teaching materials function as an ecological scaffold for metacognition in early childhood—that is, as an environmental system that compensates for young children's limited capacity for spontaneous self-regulation by embedding metacognitive cues directly into the task architecture. This conceptualization extends recent theoretical proposals from the self-regulated learning literature, which have increasingly emphasized the role of digitally mediated, adaptive environments in externalizing and distributing metacognitive processes beyond the individual learner (Xie & Guo, 2022). In early childhood specifically, where internal metacognitive architecture remains nascent, the externalization function of gamified environments may be particularly critical: by making goal states visible (through levels), progress legible (through points), and achievement salient (through badges), the gamified platform effectively offloaded metacognitive work onto the environment in a form accessible to young learners.

This perspective also addresses a persistent concern in the gamification literature regarding the risk of over-reliance on extrinsic rewards, which, when poorly designed, can undermine intrinsic motivation and reduce the depth of cognitive engagement (Vergara-borge et al., 2025). The absence of such adverse effects in the present study—evidenced by large metacognitive gains and high engagement across the entire 8-week period—can plausibly be attributed to the intervention's integration of gamification elements with substantive scaffolding strategies and educationally meaningful content, rather than deploying rewards as isolated motivational devices. This finding is consistent with the observation by Nurhayati (2025) that the most effective gamification interventions in primary education combine points, badges, and immediate feedback with real-world application tasks and autonomy support—a design philosophy that the present intervention approximated through its interactive multimedia architecture and exploratory learning tasks.

5.5. Limitations and Directions for Future Research

Several limitations of the present study warrant acknowledgment. First, the quasi-experimental design, while strengthened by baseline equivalence testing and ANCOVA covariate control, precludes full randomization at the individual level due to the practical constraints of intact classroom structures in early childhood settings. Although class-level random assignment was employed, the possibility of residual between-class differences—in teacher–child relationship quality, classroom climate, or peer group composition cannot be entirely excluded(Gopalan et al., 2020). Second, the intervention was delivered within two early childhood centers in East Java, Indonesia, a context characterized by specific socio-cultural and institutional conditions that may limit the direct transferability of findings to settings with different resource environments, pedagogical cultures, or digital infrastructure. Third, the present study measured metacognitive awareness as a teacher-rated, behavioral construct over an 8-week period and did not capture potential long-term retention or transfer effects. Research examining whether gamification-induced metacognitive gains persist across developmental transitions particularly the kindergarten-to-primary school boundary would substantially strengthen the evidence base.

Future research should also investigate the specific mechanisms through which individual gamification elements points, badges, levels, and immediate feedback differentially contribute to metacognitive development across the three dimensions of planning, monitoring, and evaluation, ideally through dismantling designs that isolate the contribution of each element. Additionally, given the growing availability of intelligent tutoring systems and adaptive learning platforms in early childhood contexts, comparative studies examining gamification-integrated versus AI-augmented scaffolding approaches would offer theoretically and practically valuable insights (Oesch, 2024). Finally, the role of teacher facilitation quality as a moderating variable deserves systematic investigation; the present study controlled for teacher-related variability through a single trained instructor and fidelity monitoring, but naturalistic implementations are likely characterized by greater instructional variability, and understanding how pedagogical competence interacts with gamified digital environments is essential for scalable deployment.

6. Conclusion:

This study provides empirical evidence that gamification-integrated digital teaching materials significantly enhance metacognitive awareness in early childhood education. The intervention produced a large effect size, indicating that structured gamified environments can effectively scaffold planning, monitoring, and evaluation processes in young learners. The strongest gains in the planning dimension suggest that goal-oriented game mechanics play a central role in externalizing early metacognitive regulation.
However, these findings should be interpreted with caution. The quasi-experimental design limits full causal generalization, and the short intervention period does not capture long-term retention or transfer effects. In addition, reliance on teacher-rated measures may introduce subjective bias despite acceptable reliability.

Overall, the study supports the potential of gamification as a pedagogically meaningful, rather than purely motivational, tool in early childhood contexts. Future research should examine longitudinal effects, isolate the contribution of specific game elements, and explore scalability across diverse educational settings

Author Contributions

Conceptualization, Wiwik Sulistyawati and Sumartiningsih Indah; Methodology, Wiwik Sulistyawati; Validation, Sumartiningsih Indah; Formal Analysis, Wiwik Sulistyawati; Investigation, Wiwik Sulistyawati and Sumartiningsih Indah; Resources, Sumartiningsih Indah; Data Curation, Wiwik Sulistyawati; Writing—Original Draft Preparation, Wiwik Sulistyawati; Writing—Review & Editing, Sumartiningsih Indah; Visualization, Wiwik Sulistyawati; Supervision, Sumartiningsih Indah; Project Administration, Wiwik Sulistyawati.

All authors have read and agreed to the published version of the manuscript

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