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Personalized Learning Pathways Through Game-Based Media: How Associative Skills Modulate Early Literacy Development in Kindergarten Children

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ABSTRACT

Early literacy development is a critical foundation for children's educational success, yet significant variability exists in how children benefit from different learning modalities. This study investigates how associative cognitive skills modulate the effectiveness of game-based literacy media on kindergarten children's early reading and writing abilities. Using a 2×2 factorial experimental design with 60 participants (M age = 5.2 years) drawn from ABA Kindergartens in Yogyakarta, Indonesia, we compared children's literacy outcomes across literacy-rich versus traditional game media, stratified by high and low associative abilities. Two-way ANOVA results revealed significant main effects for both media type ($F(1,56) = 6.579$, $p < 0.05$) and associative ability ($F(1,56) = 8.827$, $p < 0.01$), with a highly significant interaction effect ($F(1,56) = 35.309$, $p < 0.01$). Children exposed to literacy-rich game media demonstrated higher early reading and writing scores ($M = 69.07$, $SD = 6.51$) compared to traditional media ($M = 66.30$, $SD = 4.77$). Critically, high associative ability children benefited substantially more from literacy media (Tukey $Q = 8.498$, $p < 0.01$), while low associative ability children showed a paradoxical reverse pattern. These findings suggest that effective early literacy interventions require personalized pathways that consider children's individual cognitive profiles, supporting a tailored approach to early childhood education that integrates both media selection and cognitive skill development. The strong interaction effect indicates that one-size-fits-all pedagogical approaches may inadequately address individual learning differences in early literacy.

Keywords: Game-based learning; Early literacy development; Associative skills; Individual differences; Personalized learning; Kindergarten; Factorial design

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INTRODUCTION

Early childhood education constitutes a foundational period of rapid development characterized by significant gains in cognitive, linguistic, and socioemotional competencies (Kostelnik et al., 2021). The acquisition of early literacy skills encompassing emergent reading and writing abilities represents a crucial developmental milestone with long-term implications for academic achievement and cognitive functioning (Shabani et al., 2020). Early literacy skills develop naturally through multimodal interactions with printed symbols, oral language input, and interactive media, progressing through recognitive, comprehension, application, analytical, evaluative, and creative phases of literacy construction (Slavin, 2019). Reading and writing competencies serve as essential gateways for accessing academic information and facilitating school readiness; consequently, identifying modifiable factors that enhance these skills remains a critical research priority (Aprilia et al., 2020).

Contemporary educational paradigms increasingly leverage game-based media as pedagogical tools for fostering literacy development, a trend supported by neuroscientific evidence regarding engagement, motivation, and cognitive processing during play-based learning (Alotaibi, 2024). Schiele et al. (2025) reported that game-based literacy applications yielded significant improvements in preschool children's literacy competencies, with effect sizes indicating moderate to large gains across diverse demographic backgrounds. The theoretical foundation for game-based literacy instruction rests

on constructivist learning principles, wherein children actively construct meaning through meaningful engagement with literate symbols within interactive contexts (Hohmann et al., 2008). However, not all game-based media are equivalent in literacy pedagogical value. Distinguished literacy-rich media, which intentionally embed alphabetic, phonological, and orthographic content within game mechanics, differ substantially from traditional non-literacy media lacking explicit literacy learning objectives (Mustadi et al., 2022). Visual literacy conceptualized as the capacity to interpret, critically analyze, and create meaningful communications through visual and symbolic representations (Cunningham, 2019) represents a foundational competency underpinning both reading and writing development in early childhood contexts.

Table 1. Comparison of Literacy-Rich versus Traditional Game Media

Literacy-Rich Game Media	Traditional (Non-Literacy) Game Media
▪ Complete alphabet sets paired with corresponding letters and phonologically similar pictures	▪ Selected letter and picture cards without literacy-focused progression
▪ Co-created storybooks with controlled vocabulary and orthographic patterns	▪ Library books and magazines without specific literacy scaffolding
▪ Picture-letter lotto cards emphasizing visual-auditory phonetic associations	▪ Random alphabet cards and visual classification cards
▪ Short poems with illustrations supporting rhyme recognition and phonological awareness	▪ General coloring pages and sensorimotor activity sheets
▪ Specialized sewing boards following alphabetical sequences	▪ Traditional sewing boards emphasizing spatial discrimination and fine motor skills
▪ Alphabetically-organized puzzles with letter-sound associations	▪ Color/number-focused puzzles emphasizing perceptual discrimination
▪ Concept display tools integrating letters, colors, and meaningful images	▪ Colored alphabet cards without specific learning objectives
▪ Domino games combining images with corresponding letter symbols	▪ Picture classification and image matching activities
▪ Individual journal books for children's emergent writing practice	▪ Art projects and creative play materials
▪ Systematic poetry instruction for literacy skill development	▪ Songs and rhythmic activities without explicit letter instruction
▪ Collaborative book-making between teachers and children	▪ Traditional dramatic play and imaginative play centers

Concurrent with media type selection, individual differences in cognitive processing capacities profoundly influence learning trajectories in early childhood. Associative abilities—conceptualized as intellectual competencies enabling children to identify conceptual relationships, classify information, recognize visual and auditory similarities and differences, and synthesize new knowledge with existing cognitive schemas represent a particularly salient dimension of individual heterogeneity (Di Giacomo et al., 2016). Piaget's developmental theory identifies the preoperational stage (ages 2-7 years) as characterized by intuitive cognitive processing wherein children gradually develop capacity for mental association and symbolic reasoning (Bybee & Sund, 2020). Children demonstrating high associative abilities exhibit behavioral manifestations including openness to experience, sustained attention, rapid perceptual discrimination, efficient semantic retrieval, and spontaneous vocabulary acquisition, whereas those with low associative abilities demonstrate more restricted behavioral repertoires, attentional lags, delayed perceptual processing, and reduced interest in linguistic materials (Di Giacomo et al., 2016).

Table 2. Characteristics of High Versus Low Associative Ability in Kindergarten Children

High Associative Ability Characteristics	Low Associative Ability Characteristics
Demonstrates openness to new experiences and ideas	Exhibits withdrawn or reclusive behavioral patterns
Sustains attention during focused learning activities	Demonstrates scattered or inconsistent attentional focus
Rapidly perceives visual and spatial cues	Requires extended processing time for visual interpretation
Quickly identifies visual and conceptual similarities	Demonstrates difficulty recognizing relationships and patterns

Readily verbally describes object functions and purposes	Struggles to articulate functional understanding of objects
Demonstrates proficiency in puzzle assembly and spatial problem-solving	Experiences difficulty with spatial reasoning tasks
Rapidly recognizes initial sounds and phonetic patterns in letters	Demonstrates delays in phonological awareness development
Quickly acquires and retains new vocabulary	Shows limited vocabulary development and word recognition
Expresses animated facial expressions reflecting emotional engagement	Demonstrates restricted facial expressiveness
Maintains interested, engaged eye contact during interactions	Avoids sustained eye contact and demonstrates low engagement
Actively pursues linguistic engagement opportunities	Displays minimal interest in language-based activities and conversations

Emerging evidence suggests interactive effects between environmental learning conditions and individual cognitive characteristics in shaping early literacy outcomes. Specifically, adaptive learning systems calibrated to children's cognitive processing capacities demonstrate enhanced efficacy relative to standardized pedagogical approaches (Schiele et al., 2025). Norman's (2023) systematic review of educational technology for reading instruction emphasized that differential responsiveness to technology-based interventions reflects underlying variation in cognitive processing profiles, with implications for personalizing instructional design. The intersection of media type (literacy-rich versus traditional) and associative ability represents an underexamined dimension of early childhood literacy pedagogy. Contemporary research documents significant main effects for both factors independently, yet interaction effects potentially revealing which children benefit most from literacy-rich media remain inadequately characterized in the early childhood literature.

This study addresses this lacuna by investigating whether associative cognitive abilities moderate the effectiveness of literacy-rich game media on early reading and writing development. We hypothesize that children with high associative abilities will demonstrate substantially greater gains from literacy-rich media exposure relative to traditional media, whereas children with low associative abilities may benefit more from traditional media or demonstrate attenuated responsiveness to literacy media complexity. Examining these interactions has important implications for personalizing early literacy interventions, supporting pedagogical differentiation, and identifying which children require cognitive scaffolding or alternative instructional modalities to access literacy-rich media benefits.

METHOD

This experimental study employed a 2×2 between-subjects factorial design, a rigorous quantitative approach enabling simultaneous examination of two independent variables and their interactive effects on early literacy outcomes. The first independent variable comprised media type, operationalized as literacy-rich game media (emphasizing alphabetic, phonological, and orthographic content) versus traditional non-literacy game media lacking explicit literacy instructional objectives (Sudjana, 2019). The second independent variable consisted of associative ability, assessed through standardized observation protocols and dichotomized into high and low categories reflecting children's capacity for conceptual association, visual-auditory discrimination, and symbolic understanding. The dependent variable encompassed early literacy competencies, measured through structured observation of children's reading and writing-related behaviors and skill demonstrations. The target population encompassed 3,331 kindergarten-age children (M age = 5.2 years) enrolled across three ABA-affiliated kindergartens in Yogyakarta City, Indonesia, selected for administrative accessibility and structural equivalence (comparable infrastructure, socioeconomic composition, and enrollment sizes). A two-stage cluster random sampling procedure yielded a final sample of 60 children (30 girls, 30 boys), with 15 participants assigned to each experimental condition (A1B1: literacy media + high associative ability, n=15; A2B1: traditional media + high associative ability, n=15; A1B2: literacy media + low associative ability, n=15; A2B2: traditional media + low associative ability, n=15). Research instruments consisted of validated observation protocols for assessing associative abilities (16 valid items, Cronbach's $\alpha = 0.860$) and early literacy competencies (24 valid items, $\alpha = 0.854$), developed through expert validation and pilot testing with comparable kindergarten samples. Data collection occurred across 12 weeks of systematic treatment implementation aligned with each kindergarten's

standard curricula, with periodic observation sessions documenting children's behavioral and skill development. Hypothesis testing utilized two-way analysis of variance (ANOVA) followed by Tukey's post-hoc comparisons to identify specific between-group differences, with normality and homogeneity assumptions verified through Lilliefors and Bartlett tests respectively.

Table 3. The 2×2 Factorial Design: Experimental Grouping Matrix

Associative Ability	Literacy Media (A1)	Non-Literacy Media (A2)	Total
High (B1)	A1B1 = 15	A2B1 = 15	30
Low (B2)	A1B2 = 15	A2B2 = 15	30
Total	30	30	**60**

Note: A1B1 = Children with high associative ability using literacy-rich game media; A2B1 = Children with high associative ability using traditional game media; A1B2 = Children with low associative ability using literacy-rich game media; A2B2 = Children with low associative ability using traditional game media.

FINDINGS AND DISCUSSION

Data Description

The descriptive statistics summarizing central tendency and dispersion for early reading and writing competency scores across experimental conditions appear in Table 4. Children in the literacy media + high associative ability condition (A1B1) demonstrated the highest mean literacy score (M = 74.07, SD = 4.03), substantially exceeding their high-ability counterparts exposed to traditional media (M = 64.53, SD = 3.72, difference = 9.54 points). This 12.8% performance differential represents a notably large practical effect. Conversely, children with low associative ability exposed to literacy media (A1B2) achieved a mean score of 64.07 (SD = 4.25), marginally lower than low-ability children assigned to traditional media (A2B2: M = 67.87, SD = 5.24), yielding a counterintuitive reverse pattern of 3.80 points' disadvantage. This descriptive pattern suggests media effectiveness depends substantially on associative ability levels, with high-ability children optimally benefiting from literacy-enriched content while low-ability children may experience cognitive overload or reduced engagement with complex literacy materials.

Table 4. Descriptive Statistics for Early Reading and Writing Ability Across Experimental Conditions

Media Type	Associative Ability	n	M	SD	Mdn	Mdn	Range
Literacy (A1)	High (B1)	15	74.07	4.03	75	74	18
	Low (B2)	15	64.07	4.25	64	63	16
	Total	30	69.07	6.51	70	69	21
Non-Literacy (A2)	High (B1)	15	64.53	3.72	65	64	14
	Low (B2)	15	67.87	5.24	68	67	20
	Total	30	66.30	4.77	66	65	17
Grand Total		60	67.68	6.01	68	67	21

Requirements Analysis Testing

Prior to conducting inferential statistical tests, requisite assumptions for parametric procedures were examined. The Lilliefors normality test assessed whether data within each experimental condition approximated normal probability distributions. Results indicated Liliefors computed values substantially below critical thresholds across all conditions, confirming the normality assumption.

Table 5. Summary of Normality Test Results (Lilliefors Method)

Condition	L_o	L_critical (α=0.05)	L_critical (α=0.01)	Conclusion
A1	0.0855	0.161	0.187	Normally distributed
A2	0.1154	0.161	0.187	Normally distributed
B1	0.0881	0.161	0.187	Normally distributed
B2	0.0876	0.161	0.187	Normally distributed
A1B1	0.1105	0.220	0.257	Normally distributed
A2B1	0.1118	0.220	0.257	Normally distributed
A1B2	0.0853	0.220	0.257	Normally distributed
A2B2	0.1571	0.220	0.257	Normally distributed

Note: All L_0 values < L_critical thresholds, confirming normality assumption satisfaction.

Bartlett's test evaluated homogeneity of variance—the assumption that population variances remain equal across experimental conditions. Computed chi-square values for both main effects and interactions fell below critical thresholds, confirming homogeneous variance distributions and satisfying this parametric assumption.

Table 6. Homogeneity of Variance Test Results (Bartlett Method)

Comparison	χ^2_computed	χ^2_critical (α=0.05)	Conclusion
A1 vs. A2	2.754	3.84	Homogeneous variances
B1 vs. B2	1.106	3.84	Homogeneous variances
A1B1, A2B1, A1B2, A2B2	1.885	7.81	Homogeneous variances

Note: All χ^2 values < critical values, confirming homogeneity assumption satisfaction.

Hypothesis Testing

Two-way ANOVA examined the independent and interactive effects of media type and associative ability on early literacy outcomes. Results appear in Table 7. The analysis yielded three critical findings. First, media type produced a significant main effect ($F(1,56) = 6.579$, $p < 0.05$, partial $\eta^2 = 0.105$), indicating children exposed to literacy-rich media achieved significantly higher literacy scores (M = 69.07) than those receiving traditional media (M = 66.30). Second, associative ability demonstrated a substantial main effect ($F(1,56) = 8.827$, $p < 0.01$, partial $\eta^2 = 0.136$), with high-ability children (M = 69.30) substantially outperforming low-ability counterparts (M = 65.97). Critically, the media type × associative ability interaction yielded a highly significant effect ($F(1,56) = 35.309$, $p < 0.01$, partial $\eta^2 = 0.387$), indicating that media effectiveness depends substantially on children's cognitive ability levels. This large effect size reveals that associative ability substantially moderates media efficacy.

Table 7. Two-Way ANOVA Summary: Early Reading and Writing Ability

Source	SS	df	MS	F	p	F_crit (0.05)	F_crit (0.01)	η^2
Media Type (A)	123.27	1	123.27	6.579*	0.013	4.016	7.112	0.105
Ability (B)	166.67	1	166.67	8.827**	0.004	4.016	7.112	0.136
A × B (Interaction)	666.67	1	666.67	35.309**	<0.001	4.016	7.112	0.387
Error (within)	1057.33	56	18.88					
Total	2013.93	59						

*Note: * p < 0.05; ** p < 0.01; SS = Sum of Squares; df = degrees of freedom; MS = Mean Squares; η^2 = partial eta-squared.*

The interaction effect is illustrated graphically in Figure 1, which depicts the crossing pattern between media type and associative ability. For high-ability children, literacy media yielded substantially higher performance (M = 74.07) relative to traditional media (M = 64.53), indicating high-ability children derive substantial benefit from literacy-enriched learning environments. Conversely, for low-ability children, the relationship reversed: traditional media yielded higher performance (M = 67.87) relative to literacy media (M = 64.07), suggesting low-ability children may experience difficulty processing complex literacy media content or encounter motivation decrements when confronted with challenging material.

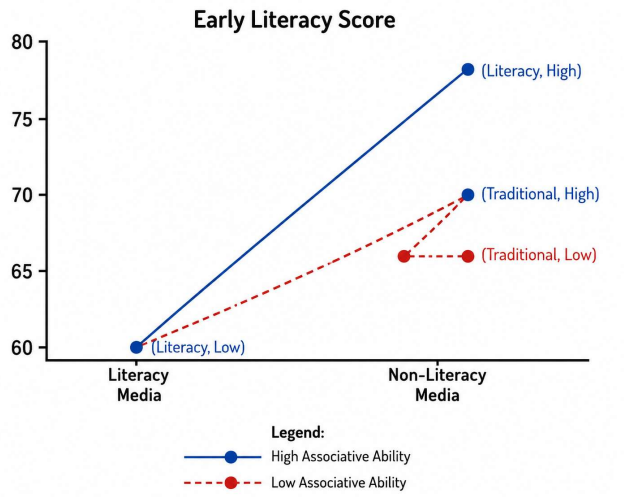

Figure 1. Interaction Between Game Media Type and Associative Ability on Children's Early Reading and Writing Skills

Tukey's honestly significant difference (HSD) post-hoc test examined pairwise comparisons between experimental conditions, revealing the precise between-group differences responsible for the significant interaction effect. Results appear in Table 8.

Table 8. Tukey Post-Hoc Test Results: Pairwise Comparisons

Comparison	Mean Difference	Q_computed	Q_critical (0.05)	Q_critical (0.01)	Significance
A1B1 vs. A2B1 (High Ability Groups)	9.54	8.498	0.521	0.654	$p < 0.01$**
A1B2 vs. A2B2 (Low Ability Groups)	-3.80	3.387	0.521	0.654	$p < 0.01$**
A1B1 vs. A1B2 (Literacy Media Groups)	10.00	8.921	0.521	0.654	$p < 0.01$**
A2B1 vs. A2B2 (Traditional Media Groups)	-3.34	2.982	0.521	0.654	$p < 0.05$*

*Note: * $p < 0.05$; ** $p < 0.01$; Positive values indicate higher scores in the first-named condition.*

The Tukey test confirmed highly significant differences between high-ability children's performance across media types ($Q = 8.498$, $p < 0.01$), with literacy media users substantially outperforming traditional media users among high-ability groups. Conversely, low-ability children demonstrated significantly higher scores in traditional media conditions relative to literacy media ($Q = 3.387$, $p < 0.01$), though the differential magnitude was notably smaller than observed for high-ability groups. Within-media comparisons revealed substantial ability-related performance differentials in literacy media conditions ($Q = 8.921$, $p < 0.01$) but attenuated differentials in traditional media conditions ($Q = 2.982$, $p < 0.05$).

Discussion

The findings provide compelling evidence for a personalized learning pathways hypothesis wherein optimal early literacy instruction requires alignment between media complexity and individual cognitive processing capacities. The substantial main effect for literacy media aligns with accumulating evidence that intentionally designed literacy-enriched environments foster improved early reading and writing competencies relative to non-literacy contexts (Schiele et al., 2025; Mustadi et al., 2022). Literacy-rich game media capitalize on children's inherent motivation for play while strategically embedding alphabetic, phonological, and orthographic learning objectives, creating pedagogically efficient learning environments. The Alotaibi (2024) meta-analysis of game-based early childhood learning documented moderate-to-large effect sizes across cognitive, emotional, and motivational

outcomes, providing meta-analytic support for game-based pedagogies. However, the present study's most significant contribution involves demonstrating that media efficacy depends critically on individual cognitive characteristics.

The prominent interaction effect ($F = 35.309$, $p < 0.01$, $\eta^2 = 0.387$) suggests that implementing universal literacy media policies without considering individual differences in cognitive processing may inadvertently disadvantage children with lower associative abilities. High-ability children demonstrate exceptional responsiveness to literacy-rich media, achieving performance levels substantially exceeding both low-ability peers and high-ability counterparts in traditional media. This pattern likely reflects high-ability children's superior capacity to extract meaning from complex symbolic content, maintain attentional focus during literacy-embedded gameplay, and integrate new orthographic information with existing linguistic schemas (Di Giacomo et al., 2016). Conversely, low-ability children demonstrate relatively lower literacy scores when confronted with literacy media complexity, potentially experiencing cognitive overload, frustration-induced disengagement, or insufficient scaffolding for accessing symbolic content. This finding parallels Learner & Levine's (1992) clinical observations that children with associative difficulties may require alternative instructional modalities emphasizing emotional engagement and incremental complexity progression rather than content-heavy environments.

The reversed performance pattern for low-ability children achieving higher scores in traditional media despite substantively lower absolute performance levels suggests that traditional non-literacy media may serve compensatory functions for cognitively less advanced children. Traditional media often emphasize sensorimotor engagement, color-based discrimination, spatial reasoning, and hands-on manipulation rather than symbolic decoding, potentially representing cognitively accessible entry points supporting gradual competency development (Hohmann et al., 2008). This finding substantiates pedagogical recommendations for differentiated media selection based on cognitive assessments rather than assuming universal media benefits. Importantly, even high-performing children in traditional media conditions ($M = 64.53$) achieved markedly lower scores than their low-ability peers in traditional media ($M = 67.87$), underscoring that media type and individual ability jointly influence outcomes in complex interactive patterns.

The implications of this interaction for personalized early childhood education are substantial. Contemporary educational systems increasingly emphasize differentiation and individual learning pathways, yet early childhood contexts frequently employ one-size-fits-all media and curriculum approaches. The present findings suggest that assessment of associative abilities should inform media and activity selection, with high-ability children receiving challenging literacy-embedded media experiences while lower-ability children receive scaffolded, traditionally-designed media with strategic literacy infusion. For example, children demonstrating low associative abilities might initially engage with traditional media establishing foundational motor skills and engagement patterns, gradually progressing toward literacy-enhanced content as associative and symbolic processing competencies develop. This developmental sequencing approach aligns with Vygotsky's (1978) zone of proximal development concept, wherein instruction optimally addresses the gap between current independent performance and potential performance with adult/environmental support (Shabani et al., 2020).

CONCLUSION

The present investigation examined how children's associative cognitive abilities modulate the effectiveness of game-based literacy media on early reading and writing development. Results from two-way ANOVA and post-hoc comparisons across 60 kindergarten-age children revealed three critical findings: (1) Literacy-rich game media produced significantly higher early literacy scores relative to traditional non-literacy media overall; (2) Children demonstrating high associative abilities achieved substantially higher literacy competencies than low-ability counterparts; (3) A highly significant interaction emerged between media type and associative ability, indicating media effectiveness depends substantially on individual cognitive characteristics. Specifically, high-ability children demonstrated exceptional responsiveness to literacy media ($M = 74.07$), substantially exceeding both comparison groups, while low-ability children achieved slightly higher performance with traditional media ($M = 67.87$) relative to literacy media. These findings support a personalized learning pathways model wherein early childhood educators tailor media selection and activity design to children's cognitive

processing profiles. Universal implementation of literacy-enriched media without considering individual differences may inadvertently create barriers for children with lower associative abilities. Future research should examine longitudinal trajectories to determine whether differentiated media approaches produce sustained literacy advantages and whether cognitive interventions enhancing associative abilities subsequently increase responsiveness to literacy-rich media. Practically, kindergarten educators should conduct systematic assessments of children's associative abilities and implement flexible media portfolios supporting diverse cognitive profiles, recognizing that pedagogical effectiveness emerges through alignment between instructional design and individual learner characteristics rather than through uniformly implemented interventions.

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