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Enhancing Early Literacy: The Effect of Flashcard-Based Learning Media on Consonant Letter Recognition in Early Childhood Education

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ABSTRACT
Visual discrimination of letters with similar graphic forms (e.g., b, d, p, q) presents a significant cognitive challenge in early childhood literacy development. This study investigates the effect of flashcard-based learning media on enhancing consonant letter recognition among young learners. Utilizing a Classroom Action Research (CAR) design spanning two iterative cycles, the intervention involved 15 children aged 4–5 years at a purposively selected early childhood education center in Indonesia. Data were gathered through structured observations, semi-structured teacher interviews, and pedagogical documentation. The findings revealed a progressive improvement in children's letter recognition and visual differentiation capabilities. The mastery rate increased significantly from a baseline of 26.67% in the pre-cycle stage to 53.33% in Cycle I, ultimately achieving 80.00% in Cycle II. The integration of high-contrast, interactive flashcards combined with game-based learning effectively mitigated mirror-letter confusion by reducing cognitive load and enhancing visual retention. Furthermore, the approach stimulated active participation and learning motivation. These results suggest that structured visual media serve as a critical scaffold for early orthographic processing. This study contributes to early childhood pedagogy by providing an empirical framework for addressing specific letter-reversal difficulties through targeted visual stimulation.

Keywords: Early Literacy, Flashcard Media, Consonant Letters, Early Childhood Education, Letter Recognition, Visual Discrimination, Mirror Letters

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1. INTRODUCTION

Early literacy development constitutes a foundational milestone in childhood cognitive growth, directly predicting future academic achievement and reading development. A pivotal component of this developmental stage is letter knowledge and letter-sound correspondence, particularly the acquisition of consonant letters, which serves as a critical prerequisite for grapheme–phoneme mapping, orthographic learning, and fluent decoding skills (Dilgard et al., 2022; Dixon et al., 2023; Y. Li & Wang, 2023). Effective literacy stimulation during early childhood should extend beyond passive rote learning toward structured, meaningful, play-based, and visually or multimodally enriched pedagogical approaches that actively engage children's participation and support literacy development (Fundelius et al., 2023; Rouse & Nicholas, 2025; Sysoev et al., 2022). However, transitioning from abstract phonetic sounds to concrete orthographic representations frequently imposes a heavy cognitive load on young learners, often leading to persistent challenges in early reading readiness.

A critical cognitive hurdle for children aged 4 to 5 years is the visual discrimination of letters characterized by symmetrical shapes or similar graphic forms, commonly referred to as mirror letters, such

as b, d, p, and q. From a cognitive psychology perspective, young learners frequently experience mirror generalization, which is a neurological phenomenon where the brain treats reversed visual stimuli as identical objects (Fernandes et al., 2022; Martínez-García et al., 2022; Resque et al., 2023; Yang et al., 2022). To establish a rigorous empirical baseline, preliminary field observations conducted by the authors in the selected early childhood center revealed that 73.33% of the children exhibited low consonant recognition proficiency, which was primarily manifested in a continuous confusion of reversible letter shapes. This widespread deficit is further exacerbated by the dominance of conventional, worksheet-bound instructional methods and a profound lack of interactive visual scaffolding, which ultimately results in diminished student engagement and low learning motivation during critical literacy sessions.

To mitigate these visual processing difficulties, the integration of structured visual learning media is highly imperative. Flashcard-based learning media are widely recognized as effective cognitive scaffolds because they present orthographic information through concrete and visually salient representations, enabling young learners to process, encode, and retrieve letter and word forms more efficiently than text-only instruction (Lei & Reynolds, 2022; Zakian et al., 2022). Methodologically, flashcard-based instruction functions not merely as a passive visual aid but as a multimodal learning scaffold that engages both visual and verbal (including auditory) processing through dual-coding mechanisms. Combined with systematic repetition and retrieval practice, this approach strengthens memory retention and facilitates the automatization of letter–sound associations during early literacy learning (W. Li et al., 2022; Xodabande et al., 2022; Zung et al., 2022). Grounded in cognitive load theory (O. Chen et al., 2023; Sweller, 2024), the strategic design of colorful and interactive flashcards helps decompose complex orthographic inputs into digestible visual units, which enhances children's focus and task-directed attention.

Extensive literature has documented the effectiveness of flashcard-based visual learning media in supporting early literacy and vocabulary development. Recent studies indicate that flashcards significantly enhance vocabulary acquisition, strengthen early literacy-related skills, and improve learning outcomes by providing repeated visual exposure and structured retrieval opportunities (Lei & Reynolds, 2022; Zakian et al., 2022). Furthermore, evidence from contemporary literacy research indicates that structured visual-card activities provide repeated exposure to printed word forms, facilitating the consolidation of orthographic representations in long-term memory and improving word recognition through repeated retrieval and systematic practice (Hulme et al., 2022; Jiang & Wu, 2022; Teng, 2023). Contemporary evidence suggests that visually appealing instructional materials support children's intrinsic motivation and engagement, thereby fostering sustained participation in early literacy activities when integrated into structured learning environments (Sysoev et al., 2022; Valentín et al., 2022).

Despite these valuable insights, a notable conceptual gap persists in the existing literature. Most extant studies evaluate flashcards either as a generic tool for holistic vocabulary acquisition or focus heavily on digital-based screen applications. This focus leaves a critical scarcity of empirical evidence regarding how action-oriented, tactile, and game-based flashcard interventions can be deployed to specifically dismantle mirror-letter confusion among 4 to 5-year-olds within under-resourced classrooms. Furthermore, the precise pedagogical mechanism of utilizing physical, high-contrast flashcards to facilitate visual discrimination of symmetrical consonants remains under-explored in early childhood action research.

Consequently, this study addresses this critical literature gap by presenting a targeted, action-based pedagogical framework that focuses explicitly on resolving consonant letter-reversal confusion through optimized flashcard media. Moving away from localized geographical claims, the conceptual novelty of this research lies in its systematic evaluation of how iterative visual discrimination drills, embedded within collaborative games, can scaffold orthographic processing and mitigate mirror-letter errors. The objective of this study is to critically analyze how colorful and interactive flashcard media, utilized through game-based learning, can support children in recognizing, distinguishing, and remembering consonant letters more effectively. By aligning these specific instructional variables, this research offers scalable insights and empirical contributions to the global discourse on innovative literacy strategies and early childhood cognitive scaffolding.

2. METHOD

This study employed a mixed-methods action research design grounded in the contemporary cyclical principles of action research, involving iterative phases of planning, action, observation, and reflection to systematically address immediate instructional challenges and continuously refine teaching practices (Feekery, 2024; Rabgay & Kidman, 2023). The intervention was executed across two complete operational cycles at an anonymized preschool center located in West Java, Indonesia, during the 2025/2026 academic year. The research cohort comprised 15 young learners, consisting of 8 male and 7 female students aged between 4 and 5 years, who were selected via purposive sampling due to their documented difficulties in identifying and differentiating symmetrical consonant letters. To satisfy international ethical mandates regarding research with vulnerable populations, formal administrative clearance was obtained from the

institution prior to the study, and signed informed consent sheets were secured from the parents or legal guardians of all participating children, thereby ensuring absolute anonymity and voluntary participation.

Data collection was operationalized through a concurrent triangulation approach involving structured classroom observations, semi-structured teacher interviews, and pedagogical documentation. The primary diagnostic tool was a structured assessment sheet designed to measure four critical dimensions of early orthographic mastery consisting of letter identification, phonetic pronunciation, visual discrimination of reversible letters such as b, d, p, and q, and matching characters with corresponding images. To guarantee instrument validity, the observation criteria were subjected to a rigorous evaluation by two independent experts in early childhood education, yielding a final Content Validity Index of 0.94. Furthermore, to eliminate subjective bias during classroom evaluations, two trained observers concurrently recorded student performance, and an inter-rater agreement analysis yielded a Cohen's Kappa coefficient of 0.89, which confirms a high level of observational reliability and consensus.

The intervention procedure followed an iterative trajectory where each cycle adapted pedagogical strategies based on empirical data. During the planning phase, lesson plans were aligned with curriculum standards, and high contrast tactile flashcards were developed alongside interactive, game based learning scripts. In the action and observation phases, these colorful visual materials were introduced three times a week in dedicated learning sessions lasting 30 minutes, allowing the researchers to track child media engagement and task directed focus. Quantitative data regarding mastery rates were analyzed using descriptive percentages to measure progress against a predetermined collective success threshold of 75%. Concurrently, qualitative insights extracted from semi-structured teacher interviews and field notes were processed via thematic analysis, utilizing data reduction and pattern synthesis to provide a nuanced understanding of how visual discrimination tools reduce cognitive load and enhance early literacy retention.

3. RESULTS

3.1. Pre-Intervention Baseline of Children's Consonant Orthographic Skills

Prior to the implementation of the flashcard intervention, a comprehensive baseline assessment was conducted to evaluate the initial consonant orthographic skills of the participant cohort. The quantitative diagnostic data obtained during this pre-cycle stage demonstrated that a substantial majority of the children experienced severe difficulties in processing and recognizing consonant symbols. Out of the 15 children observed, only 4 individuals, representing 26.67% of the class, managed to achieve the benchmarks for the categories of Developing as Expected or Developing Very Well. The remaining 11 children, constituting 73.33% of the cohort, remained clustered within the lower diagnostic bands of Not Yet Developed and Starting to Develop. To provide a nuanced diagnostic overview, the initial performance was disaggregated across four distinct cognitive indicators, which are presented in Table 1.

Table 1. Pre-Cycle Baseline of Consonant Orthographic Skills by Cognitive Indicator

Cognitive Indicators	Not Yet Developed [BB] (%)	Starting to Develop [MB] (%)	Developing as Expected [BSH] (%)	Developing Very Well [BSB] (%)
Letter Identification	40.00	33.33	20.00	6.67
Phonetic Pronunciation	46.67	26.67	20.00	6.67
Visual Discrimination (b, d, p, q)	60.00	20.00	13.33	6.67
Picture-Letter Matching	46.67	26.67	20.00	6.67
Mean Cohort Performance	48.33	26.67	18.33	6.67

Note. Collective mastery percentage reflects the 26.67% baseline success rate.

The quantitative layout in Table 1 underscores that the lowest performance occurred within the third indicator, which specifically measured the visual discrimination of the reversible letters b, d, p, and q. In this category, 60.00% of the children were classified as Not Yet Developed, indicating a profound vulnerability to spatial orientation alterations in graphic symbols.

Qualitative field observations gathered during the pre-cycle sessions provided deeper behavioral context to these numerical deficits, revealing consistent patterns of mirror-letter confusion. When children were presented with conventional black-and-white worksheets, they frequently displayed cognitive hesitation and high error rates during identification tasks. A recurrent behavioral pattern observed was the spatial inversion error, where children routinely pointed to the letter d when explicitly asked to identify b, or conversely mixed up the vertical descenders of p and q.

Furthermore, this visual disorientation directly impaired their phonological processing capabilities. Because the children could not stabilize the visual structure of the grapheme in their working memory, they struggled to generate the correct phonetic pronunciation, often producing vocal hesitations or silent lapses. Classroom observations also indicated that the conventional, non-interactive teaching methods utilized prior to the intervention failed to maintain child engagement, which was manifested in short attention spans, rapid boredom, and a generalized lack of voluntary participation during early literacy activities.

3.2. Quantitative Mastery Progression Across Iterative Action Cycles

The implementation of flashcard based learning media over two iterative action cycles resulted in a systematic, upward trajectory in children's consonant orthographic skills. Quantitative tracking across the intervention periods demonstrated a steady shift from the initial deficient baseline toward the targeted educational proficiency threshold. The comparative dataset, which consolidates the cohort progression from the pre-intervention stage through the completion of Cycle II, is structured comprehensively in Table 2 to highlight the evolutionary gains within each specific cognitive dimension.

Table 2. Comparative Mastery Rates Across Iterative Action Cycles

Cognitive Indicators	Pre-Cycle Mastery (%)	Cycle I Mastery (%)	Cycle II Mastery (%)	Net Gain (%)
Letter Identification	26.67	60.00	86.67	+60.00
Phonetic Pronunciation	26.67	46.67	73.33	+46.66
Visual Discrimination (b, d, p, q)	20.00	46.67	80.00	+60.00
Picture-Letter Matching	33.33	60.00	80.00	+46.67
Overall Cohort Mastery Success Rate	26.67	53.33	80.00	+53.33

Note. Mastery denotes the percentage of children achieving the categories of Developing as Expected (BSH) or Developing Very Well (BSB). The pre-determined success threshold was established at a minimum collective rate of 75.00%

The empirical distribution in Table 2 reveals that the overall cohort mastery rate experienced a substantial linear surge, rising from 26.67% in the pre-cycle baseline to 53.33% at the conclusion of Cycle I. Although this intermediate phase demonstrated marked educational progress, it remained below the necessary 75.00% benchmark because several learners still faced lingering challenges with complex letter typographies. Following targeted pedagogical adjustments in the subsequent phase, the final assessment in Cycle II documented a conclusive mastery rate of 80.00%, thereby successfully surpassing the established institutional success criterion and validating the efficacy of the visual intervention.

Granular analysis of the individual parameters reveals that the most drastic growth occurred within Indicator 1 (Letter Identification) and Indicator 3 (Visual Discrimination of b, d, p, q), which both achieved a net percentage gain of 60.00%. The sharp upward trajectory in visual discrimination is particularly noteworthy, as it jumped from a critical baseline of 20.00% to 46.67% in Cycle I, before culminating at 80.00% in Cycle II. This specific statistical acceleration demonstrates that the introduction of high contrast, interactive flashcards directly addressed the core neurological challenge of spatial reversal errors, successfully enabling the children to systematically isolate and identify the distinctive structural contours of highly symmetrical graphemes.

Conversely, Indicator 2 (Phonetic Pronunciation) required a longer developmental timeline and exhibited a more gradual progression. This phonetic domain advanced moderately from 26.67% to 46.67% in the first cycle, eventually securing a final mastery rate of 73.33% in the second cycle. The slower developmental pace of this indicator stems from the fact that phonetic pronunciation demands a higher order cognitive operation, requiring children to not only decode the visual structure of a letter symbol but also coordinate the appropriate vocal motor response. This trend suggests that while visual recognition can be rapidly accelerated through structured tactile card stimulation, the automated integration of grapheme to phoneme matching requires sustained, repetitive linguistic drills over a more extended instructional duration.

3.3. Qualitative Artifacts of Learning Engagement and Behavioral Shifts

To complement the quantitative milestones, qualitative datasets derived from semi-structured teacher interviews and field observations were synthesized to capture the behavioral transformations occurring within the classroom environment. The qualitative evidence provided a deeper look into how the children navigated their initial learning difficulties. The classroom teacher offered critical insights during the post-intervention interview regarding the evolution of student attention spans and task-directed focus:

"*During the pre-cycle phase, instructional delivery was heavily impeded by rapid cognitive fatigue and frequent off-task behaviors, as the children would typically disengage from the black-and-white worksheets within the first five minutes of the literacy lesson. Following the deployment of the high-contrast flashcards within peer-centered games, we observed a remarkable extension in their concentration span. The children remained actively immersed for the full duration of the thirty-minute session, demonstrating a complete turnaround in their learning discipline without requiring constant behavioral redirection from the teaching staff.*"

This pedagogical reflection confirms that the visual and interactive properties of the flashcard media acted as a strong external anchor for child attention, effectively converting an unengaging classroom environment into a highly focused learning space.

Concurrently, the systematic analysis of pedagogical field notes revealed profound emotional and motor shifts when the children interacted with the colorful media during collaborative group games.

Emotionally, the initial anxiety, cognitive hesitation, and frustration associated with distinguishing mirror letters like b, d, p, and q were gradually replaced by expressions of high enthusiasm and self-confidence. The field notes recorded a distinct drop in visual hesitation; children who previously withdrew from literacy tasks began to smile, raise their hands voluntarily, and cheer enthusiastically when their peers successfully isolated the correct consonant shapes.

In terms of motor responses, the tactile nature of the physical flashcards stimulated active bodily involvement that helped reinforce learning. Instead of remaining sedentary and passive, the young learners actively leaned forward, reached out to grasp the physical cards, and utilized deliberate hand gestures to trace the vertical loops and stems of the target letters. This somatic engagement indicates that combining physical manipulation with vibrant visual stimulation creates a powerful multi-sensory learning experience, which successfully stabilizes the cognitive mapping of symmetrical consonants in early childhood learners.

4. DISCUSSION

4.1. Cognitive Mechanisms of High-Contrast Flashcards in Mitigating Mirror-Letter Confusion

The remarkable quantitative leap in overall cohort mastery, which escalated from a baseline of 26.67% to a final rate of 80.00%, requires a profound evaluation through the lens of cognitive psychology and neuro-developmental frameworks. The primary mechanism underlying the effectiveness of physical, high-contrast flashcards is their capacity to provide repeated visual discrimination of letter forms, thereby supporting the inhibition of the neurological phenomenon of mirror generalization. During early childhood, the human visual system naturally treats mirror-symmetrical objects as identical regardless of orientation, an evolutionarily adaptive property that inadvertently causes young learners to confuse reversible graphemes such as b, d, p, and q until stable orthographic representations are established (Fernandes et al., 2022; Resque et al., 2023; Yang et al., 2022). By presenting these letters not as uniform monochrome prints but through vibrant, high-contrast visual arrangements, the flashcards acted as an artificial perceptual scaffold that forced the brain to inhibit mirror generalization and recognize spatial orientation as a defining feature of the symbol.

This cognitive breakthrough can be robustly explained by Dual-Coding Theory (Bi, 2021; Mehta et al., 2026; Wooten & Cuevas, 2024), which posits that information is processed more effectively when it simultaneously activates independent visual and verbal channels within human working memory. Conventional worksheet-based instruction often emphasizes text-focused activities with limited multimodal support, providing fewer opportunities for children to integrate visual-orthographic and phonological information during early decoding and orthographic learning (Y. Li & Wang, 2023; Verhoeven et al., 2022). In contrast, the implementation of tactile flashcard media facilitated a multisensory, dual-coding learning routine. When children were presented with colorful flashcards, the visual features of the letter supported visuospatial processing, while the teacher's simultaneous articulation of the corresponding phoneme activated verbal–phonological processing. The integration of visual and auditory information strengthened letter–sound associations and enhanced memory encoding during early literacy learning (W. Li et al., 2022; O'Brien et al., 2022; Zung et al., 2022). This parallel cognitive activation created dual memory traces, allowing children to cross-reference visual structures with auditory cues, thereby drastically accelerating the stabilization of grapheme-phoneme correspondences.

Furthermore, the design and interactive nature of the flashcards directly aligned with the principles of Cognitive Load Theory (Sweller, 2020), which emphasize minimizing unnecessary mental effort during complex learning tasks. Because novice learners possess a highly limited working memory capacity, learning becomes less effective when they must process abstract or poorly organized linguistic information without adequate instructional support. Visually organized flashcards help reduce extraneous cognitive load by presenting information in a simple and salient format, thereby allowing more cognitive resources to be devoted to letter–sound learning and orthographic processing (Buchner et al., 2022; H.-C. Chen et al., 2022; Greenberg & Zheng, 2022). Symmetrical consonant recognition naturally imposes a high intrinsic cognitive load because children must simultaneously calculate vertical alignments, loop directions, and phonetic values.

The high-contrast, interactive flashcards were designed to reduce extraneous cognitive load by presenting the target consonant in a visually salient format with minimal irrelevant visual information. This simplified presentation directed children's attention toward the critical orthographic features of the letter, thereby facilitating visual discrimination and orthographic processing (Baxter et al., 2022; Chang et al., 2022; Jiang & Wu, 2022; Skulmowski & Xu, 2022). By utilizing bold outlines and localized color accents to distinguish the structural variations of letters, such as coloring the right loop of b differently from the left loop of d, the media effectively directed the child's selective attention toward the critical point of contrast. Consequently, mental processing capacity was preserved, allowing the young learners to dedicate their remaining cognitive resources toward long-term memory consolidation and visual discrimination, which explains the rapid drop in letter reversal errors documented by the end of Cycle II.

4.2. Game-Based Learning Scaffolding as a Catalyst for Visual Retention

The notable enhancement in student engagement and the positive behavioral modifications detailed within the qualitative findings cannot be decoupled from the structural integration of a game-based learning framework. When flashcard activities were transformed from mechanical drills into collaborative, peer-oriented games, they fostered children's intrinsic motivation by supporting the basic psychological needs of autonomy, competence, and relatedness, as proposed by Self-Determination Theory. Such game-based and socially interactive learning environments promote sustained engagement and active participation in early literacy activities (Qiao et al., 2022). Traditional early literacy practices that rely predominantly on passive worksheet-based activities may provide limited support for children's basic psychological needs for autonomy, competence, and relatedness. According to Self-Determination Theory, insufficient support for these needs is associated with lower intrinsic motivation, reduced classroom engagement, and a greater likelihood of off-task behavior during literacy instruction (Guay, 2022; Lyons, 2024; Svrcek & Abugasea Heidt, 2022).

By embedding the high-contrast flashcards within gamified mechanics, such as speed-matching rounds or cooperative letter-hunts, the instructional design successfully fostered a sense of volitional autonomy and collective play among the young learners. This motivational shift explains why the concentration span of the cohort extended to fill the entire thirty-minute session without behavioral breakdowns or the need for constant teacher intervention. Furthermore, from a Vygotskian perspective, the playful structure functioned as an interactive scaffolding mechanism within the children's Zone of Proximal Development, where peer interaction and rule-guided gameplay supported children in achieving literacy skills that would have been difficult to accomplish independently (Ferguson et al., 2022; Rigopouli et al., 2025; Rubtsov et al., 2022; Sarmiento-Campos et al., 2022; Sysoev et al., 2022).

In addition to boosting motivational parameters, the joyful pedagogical environment played a critical neuro-cognitive role by lowering the children's affective filter and reducing cognitive anxiety during literacy tasks. Contemporary research suggests that children's literacy and orthographic development are shaped not only by cognitive processes but also by socio-emotional functioning, where stress, anxiety, and emotional regulation influence reading performance and learning outcomes (Dixon et al., 2023; Gotlieb et al., 2022; Y. Li & Wang, 2023). When young children face persistent difficulties with highly symmetrical graphemes like b, d, p, and q, conventional, high-stakes evaluation methods often induce heightened performance anxiety. This emotional stress hyper-activates the amygdala, creating a psychological block that compromises working memory efficiency and diverts neural resources away from the prefrontal cortex where visual discrimination and orthographic decoding take place.

By embedding the flashcard activities within a supportive, low-stakes game format, the researchers successfully minimized this affective barrier, effectively dismantling the children's fear of failure. The resulting reduction of emotional stress allowed the children's cognitive processing units to operate at maximum efficiency, liberating working memory capacity to focus entirely on visual orientations and graphic configurations. Consequently, this stress-free cognitive environment catalyzed the automation of symbolic letter recognition, enabling rapid, fluent grapheme-to-phoneme translation because the young learners were no longer mentally paralyzed by spatial reversal confusion.

4.3. Comparative Synthesis with Global Early Literacy Trajectories

The achievement of an 80.00% overall cohort mastery rate in this study is consistent with contemporary evidence on orthographic learning and extends current international findings on early literacy development (Y. Li & Wang, 2023). Furthermore, letter-reversal phenomena, particularly the persistent confusion of visually similar or orientation-sensitive graphemes during early childhood, are recognized as a common developmental neurocognitive challenge across languages and writing systems (Carioti et al., 2021; Fischer & Luxembourger, 2021). Empirical investigations in North America and Europe indicate that mirror-letter errors are common among preschool children learning the Latin alphabet because several letters possess visually confusable orientations, making mirror discrimination a normal developmental challenge during early literacy acquisition (Alabood et al., 2024; Patro et al., 2025; Soares et al., 2021). Similarly, contemporary evidence suggests that although mirror-letter discrimination develops naturally with increasing literacy experience, explicit and systematic literacy instruction substantially accelerates the inhibition of mirror generalization, thereby reducing persistent letter-confusion errors and supporting more efficient reading development (Resque et al., 2023; Torres et al., 2021).

Even in East Asian educational systems, where children acquire either logographic or highly structured phonetic scripts, successful reading acquisition depends on the development of robust visual-orthographic processing, making spatial and orthographic analysis a critical milestone in early reading readiness (Georgiou et al., 2022; Ju et al., 2022; Y. Li & Wang, 2023). By comparing the 80.00% mastery achieved through this action research with these global benchmarks, it becomes evident that structured visual stimulation is a universally scalable solution for cross-linguistic orthographic challenges.

Furthermore, the findings of this study contribute to contemporary discussions in early literacy research by demonstrating that structured instructional support can substantially enhance children's

orthographic development during the early stages of reading acquisition. The consistent improvement observed across the intervention reflects the principle that limitations in visual processing can be effectively compensated through well-designed pedagogical scaffolding, with the integration of high-contrast flashcards and collaborative educational games providing external support that facilitated accurate letter discrimination and recognition. At the same time, the marked increase in learning outcomes over the two intervention cycles suggests that mirror-letter reversal should not be viewed solely as a developmental phenomenon that resolves automatically with age. Instead, the findings indicate that systematic, engaging, and targeted instructional experiences can accelerate the refinement of visual-orthographic processing, reducing persistent letter-reversal errors and promoting more efficient reading readiness. These results reinforce the perspective that early orthographic development is a dynamic and responsive cognitive process that can be significantly strengthened through purposeful educational intervention rather than relying exclusively on natural maturation.

4.4. Pedagogical Implications, Critical Limitations, and Future Research Directions

The practical implications of this study offer vital insights for the optimization of early literacy curricula, particularly within the context of developing nations where instructional resources are frequently constrained. By demonstrating that tactile, cost-effective media can systematically dismantle complex orthographic challenges, this research provides a scalable framework for educators to transition away from traditional, worksheet-heavy methodologies toward active, multi-sensory learning models. This approach encourages curriculum planners to integrate structured visual discrimination drills and game-based mechanics into national early childhood education frameworks, thereby establishing robust early reading readiness without relying on expensive digital infrastructure. However, despite these positive contributions, several critical limitations must be explicitly acknowledged. The study was restricted to a relatively small sample size consisting of only 15 children within a single educational center, which inherently constrains the immediate generalizability of the quantitative metrics to broader, more diverse student populations. Furthermore, the instructional intervention was conducted over a highly compressed timeframe, leaving the long-term cognitive durability and retention of the eliminated letter-reversal errors unexamined over extended academic periods.

To address these limitations and advance the scholarship of early childhood cognitive scaffolding, future investigations should focus on expanding both the demographic scale and the technological scope of similar interventions. Researchers are encouraged to execute longitudinal studies with larger, randomized sample groups across multi-centered regional environments to validate the cross-cultural efficacy of visual discrimination tools. Most notably, a promising avenue for subsequent research lies in the integration of emerging instructional technologies, specifically the deployment of augmented reality applications to bridge the gap between abstract symbolic configurations and concrete spatial awareness. Future studies could investigate how interactive augmented reality frameworks can be leveraged not only for advanced letter and orthographic recognition but also for complex spatial reasoning tasks, such as geometric visualization and spatial geometry research in early education. By shifting from physical cards to immersive digital scaffolds, future inquiries can further decode the precise neurological pathways that govern visual retention and cognitive load reduction in young learners.

5. CONCLUSION

This study demonstrates the significant pedagogical value of physical, high-contrast flashcard media integrated within game-based learning frameworks to resolve persistent orthographic challenges in early childhood education. The systematic implementation of this visual intervention successfully mitigated mirror-letter confusion among young learners, facilitating a profound shift from a deficient literacy baseline toward targeted orthographic proficiency. On a conceptual level, this research yields vital theoretical contributions by reinforcing the validity of dual-coding and cognitive load frameworks, proving that early orthographic processing is a highly malleable construct that can be actively accelerated through structured visual stimulation and cooperative gameplay. Practically, the study offers a scalable, low-cost instructional model that empowers educators, particularly in resource-constrained educational settings, to build robust foundations for reading readiness and sustainable early literacy development.

Nevertheless, the scope of these findings is bounded by certain boundaries, most notably the small sample size of fifteen participants within a single educational center and the compressed instructional timeline of the action cycles. These constraints inherently limit the immediate cross-cultural generalizability and the evaluation of long-term cognitive retention regarding the eliminated letter-reversal errors. To address these critical limitations, future research directions should focus on expanding the demographic scale through multi-center longitudinal studies to validate the scalability of this model. Furthermore, subsequent investigations should explore the integration of emerging instructional technologies, such as utilizing interactive augmented reality applications to examine advanced orthographic automation and complex spatial reasoning tasks in early childhood pedagogy.

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