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Development and Effectiveness of Interactive Wordwall Digital Media for Early Childhood Literacy

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Abstract: This study aimed to develop interactive Wordwall-based digital media for children aged 4-5 years and evaluate its feasibility, practicality, and effectiveness in improving early literacy skills, particularly letter recognition and phonemic awareness. This R&D study applied the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) and was conducted at TK Cerdik and TK Sejahtera 4 in West Java, Indonesia. Participants included teachers and children aged 4-5 years. Feasibility was assessed through expert validation (material, media, and pedagogical experts). Practicality was tested in a small-group trial (n=10), and effectiveness was measured through pre- and post-test literacy assessments in a large-group trial (n=30), with results analyzed using the normalized gain (N-gain) formula. Needs analysis showed that 90% of children were at the "beginning to develop" literacy stage, reflected in a pre-test average of 4.4 (low). Expert validation scores were 80% for material (feasible), 80% for media (feasible), and 100% for pedagogy (very feasible), placing the overall product in the very feasible category. The pedagogical score was based on a structured six-component rubric covering curriculum alignment, developmental appropriateness, play-based learning principles, and teacher usability. The small-group trial yielded a practicality rating of 100% (very feasible). In the large-group trial, the post-test average increased to 10.4, yielding an N-gain of 0.8 (high effectiveness). The most notable improvements were in letter recognition and letter-sound matching. Wordwall-based interactive digital media is feasible, practical, and highly effective in enhancing early childhood literacy among children aged 4-5 years. The media offers an evidence-based, culturally responsive alternative to conventional instructional tools and can be integrated into daily early childhood education practice.

Keywords: early childhood literacy, interactive media, wordwall, digital learning, media development.

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INTRODUCTION

Early childhood literacy constitutes a fundamental foundation that shapes children's readiness for subsequent learning and significantly influences long-term academic achievement (Fajar & Yudianto, 2023). At this stage, literacy extends beyond the ability to recognize letters and sounds; it also encompasses the development of motivation and positive attitudes toward reading and writing (Mardhotillah, 2022). Theoretically, early literacy development is conceptualized through emergent literacy, a process in which children gradually construct an understanding of written language through interactions with their environment long before entering formal schooling (Neuman & Celano, 2012). This perspective emphasizes that rich literacy experiences during the preschool years, including exposure to picture books, songs, and language-based play, contribute significantly to later reading success.

Despite its importance, many young children in Indonesia continue to face challenges in acquiring foundational literacy skills. A report by the Ministry of Education and Culture indicates that a considerable proportion of early childhood learners enter primary school without adequate mastery of letter recognition and pre-reading competencies, which may hinder their subsequent learning trajectories (Kemdikbud, 2020). This issue is further exacerbated by the persistence of conventional instructional practices in early childhood education settings, which often rely on worksheets and teacher-centered approaches. Such methods tend to be less effective in engaging young learners, as they are not aligned with the developmental characteristics of early childhood, who naturally prefer interactive and play-oriented learning experiences (Purnamasari, 2023)

From a theoretical standpoint, play-based learning has been widely acknowledged as the most developmentally appropriate approach for early childhood education. Vygotsky argued that play facilitates the zone of proximal development, enabling children to extend their cognitive capacities beyond their current level with appropriate support (Kurniati, 2025). This theoretical foundation underpins the development of interactive digital game-based media, which aim to create learning experiences that are both meaningful and enjoyable. In addition, Piaget's constructivist theory posits that children actively construct knowledge through direct interaction and exploration (Zaidan & Dewantoro, 2026). Consequently, learning media that integrate visual, auditory, and kinesthetic elements are considered highly effective in enhancing early literacy outcomes (Siraj-Blatchford, 2006).

In the contemporary digital era, technology-based learning media have emerged as a promising alternative for increasing children's motivation and engagement. Recent empirical studies provide growing evidence of the effectiveness of interactive media in early literacy development. For instance, Purnamasari (2023) found that interactive learning media developed using the ADDIE model were valid, feasible, and effective for early literacy learning. Similarly, Salsabila et al. (2025) demonstrated that Wordwall-based digital games significantly improved preschool children's vocabulary acquisition. Furthermore, Putri & Wulandari (2024) reported that the "Kiddyfun" platform effectively stimulated early digital literacy skills. Collectively, these findings highlight the substantial potential of interactive digital media in supporting early literacy development.

However, most existing literacy learning tools remain generic and insufficiently adapted to the developmental, cultural, and contextual characteristics of early childhood education in Indonesia. From a cultural perspective, Indonesian children are raised in environments rich in oral traditions, traditional games, and diverse local values (Whitehurst & Lonigan, 2001). Learning materials that do not reflect these familiar contexts tend to be less meaningful, as they fail to connect with children's prior knowledge and lived experiences (Sari & Yarza, 2021). Contextually, early childhood education settings in Indonesia often face challenges such as high teacher–student ratios, limited technological infrastructure, and varying levels of teacher competence in integrating digital media (Kemdikbud, 2020). These conditions necessitate the development of learning media that are not only engaging and interactive but also user-friendly, adaptable to local content, and functional in low-connectivity environments.

One potential solution is the use of Wordwall, a web-based interactive platform that enables educators to design customizable learning activities, including quizzes, matching exercises, puzzles, and anagrams (Nabila & Mubarok, 2025). The primary advantage of Wordwall lies in its flexibility, allowing content to be tailored to learning objectives, children's developmental stages, and specific cultural and linguistic contexts. In early childhood literacy learning, Wordwall can

facilitate the development of letter recognition, phonemic awareness, vocabulary, and basic reading skills through a play-based approach. Additionally, the platform supports multimodal learning by integrating visual, auditory, and interactive components, which align with the learning preferences of young children (Sitorus et al., 2025)

A critical review of previous studies reveals several research gaps. First, although numerous studies have explored digital media in early childhood education, research specifically focusing on the development, validation, and effectiveness testing of Wordwall-based literacy media in the Indonesian context remains limited. Second, a significant proportion of existing studies are conducted in developed countries, which differ substantially from Indonesia in terms of cultural and educational contexts. Third, despite the growing practical use of Wordwall among early childhood educators in Indonesia, empirical evidence on its feasibility, validity, and effectiveness remains insufficient. These gaps highlight the need for systematic and evidence-based research on the implementation of Wordwall in Indonesian early childhood education.

The urgency of this study is reinforced by the increasing demand for innovative, engaging, and contextually relevant literacy learning media in early childhood education. In the context of ongoing digital transformation, educators require practical tools that not only enhance children's motivation but also align with expected early literacy competencies. Without such innovations, many children may enter primary education without adequate literacy readiness, thereby widening existing learning gaps (Kemdikbud, 2020). Addressing this issue is essential for improving literacy outcomes and promoting equitable access to quality education in Indonesia.

Based on these considerations, this study aims to: (1) develop Wordwall-based interactive digital media tailored to the literacy needs of early childhood in Indonesia; and (2) evaluate its feasibility and effectiveness in classroom implementation. Theoretically, this study is expected to advance knowledge of digital media development for early literacy education. In practice, it aims to provide innovative and accessible learning tools that can be effectively integrated into early childhood educational practices, thereby supporting continuous improvements in the quality of literacy learning.

The novelty of this study lies in its holistic approach to developing and validating a Wordwall-based digital literacy medium that is simultaneously developmentally appropriate, culturally contextualized, and empirically tested within Indonesian early childhood education settings. By moving beyond generic digital interventions, this research establishes an integrative framework that connects play-based pedagogy, local cultural adaptation, and rigorous evaluation, offering a scalable and context-sensitive solution for early literacy development.

METHOD

Research Design

This study employed a Research and Development (R&D) design guided by the ADDIE model, which comprises five systematic stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). The ADDIE framework was selected because it provides a structured, iterative process for developing and empirically validating instructional media, ensuring both theoretical soundness and practical applicability in early childhood education (ECE) settings. The research was conducted between March and June 2023 across two kindergartens in West Java, Indonesia: TK Cerdik and TK Sejahtera 4.

Participants

Three participant groups were involved, each fulfilling a distinct role within the ADDIE

stages (see Table 1). Children (field test subjects). A total of 20 children aged 4–5 years (Group A) from TK Cerdik and TK Sejahtera 4 served as the primary field-test subjects. Children were purposively selected based on three criteria: (1) enrolment in Group A (ages 4–5), (2) no diagnosed cognitive or speech-language impairment, and (3) parental consent. This age range was targeted because it represents a critical window for emergent literacy acquisition, during which children begin to develop phonological awareness and letter-name knowledge (Kaldarova, 2025). The two schools were selected because they (a) represent contrasting socioeconomic catchment areas in West Java (TK Cerdik serves a mid-income urban community; TK Sejahtera 4 serves a peri-urban, mixed-income community), thereby enhancing the transferability of findings, and (b) both had agreed to participate in the study and had access to a projector or interactive display for media implementation.

Regarding the trial sample sizes: five children participated in the one-to-one trial, ten in the small-group trial, and all 20 children in the large-scale trial. The initial description of "20 children as field-test subjects" refers to the total pool of registered child participants across both schools. The smaller subsets used in the one-to-one and small-group trials were drawn from this pool. No additional children beyond the 20 were recruited; the figure of 30 children mentioned in an earlier draft was erroneous and has been corrected.

Teachers (practicality respondents). Four classroom teachers, two from TK Cerdik and two from TK Sejahtera 4, were selected to assess the practicality of the Wordwall media. All participating teachers held at least an S1 (bachelor's) degree in ECE and had at least 3 years of teaching experience in kindergarten settings. They were selected based on their direct instructional roles with Group A children, making them best positioned to evaluate the media's classroom usability and alignment with daily practice.

Expert validators (feasibility assessment). Three validators, one each in media design, content, and early childhood pedagogy, were recruited from Universitas Pendidikan Indonesia. Each validator held a doctoral degree and had at least 10 years of experience in their respective fields. Validator selection followed purposive criteria: expertise directly relevant to the evaluation domain and experience in assessing ECE instructional materials. Their roles were to assess the theoretical feasibility and curricular alignment of the Wordwall media prior to implementation.

Table 1. Participant demographics and roles

Participant Category	Institution	n	Age / Experience	Role in Study
Children (One-to-One Trial)	TK Cerdik	5 children	4–5 years	Trial subjects
Children (Small Group Trial)	TK Cerdik	10 children	4–5 years	Trial subjects
Children (Large-Scale Trial)	TK Cerdik & TK Sejahtera 4	20 children	4–5 years	Trial subjects / pre-post test
Classroom Teachers	TK Cerdik & TK Sejahtera 4	4 teachers	≥ 3 years ECE exp.	Practicality raters
Media Expert Validator	Universitas Pendidikan Indonesia	1 expert	Doctoral, ≥10 years	Media feasibility

Content Expert Validator	Universitas Pendidikan Indonesia	1 expert	Doctoral, ≥10 years	Content feasibility
Pedagogy Expert Validator	Universitas Pendidikan Indonesia	1 expert	Doctoral, ≥10 years	Pedagogical feasibility

Research Procedure

The study followed the five ADDIE stages, as operationalized below (Creswell & Creswell, 2021).

Stage 1: Analysis. Needs analysis was conducted through: (a) preliminary questionnaires distributed to teachers to identify existing literacy instructional strategies and technology use; (b) semi-structured interviews with teachers and school principals to explore perceived gaps in early literacy learning; and (c) a literature review of early literacy theories and technology-enhanced learning in ECE. The analysis identified that children in both schools had limited exposure to interactive digital literacy media, and that teachers lacked ready-to-use game-based tools aligned with the K-13 ECE curriculum.

Stage 2: Design. Based on analysis findings, learning objectives were formulated targeting four early literacy competencies: (1) letter-name recognition, (2) initial phoneme awareness, (3) print awareness, and (4) receptive vocabulary. Content scope was delimited to 10 consonants and 5 vowels in both uppercase and lowercase forms, consistent with Group A developmental benchmarks. Storyboards were developed specifying screen layouts, interaction types, game mechanics, audio narration scripts, and visual asset requirements. The design phase was guided by the instructional design principles outlined by Branch (2009) and the child-centered media design criteria proposed by Suyanto (2005), as presented in Fajar and Yudianto (2023).

Stage 3: Development. Wordwall media was produced using the Wordwall platform (wordwall.net), generating six interactive activity types: Match Up (letter–image), Anagram (letter ordering), Quiz (letter identification), Wordsearch (letter recognition in context), Spin the Wheel (random letter-name recall), and Missing Word (context-based vocabulary). All activities were set to the Indonesian language and voiced with child-directed narration recorded by a native Indonesian speaker. The completed media were submitted to three expert validators who independently completed rating-scale validation sheets. Validators also provided written qualitative feedback. The media were revised iteratively after each validation round until all Content Validity Index (CVI) scores reached e" 0.80.

Stage 4: Implementation. Implementation comprised three sequential trials conducted at TK Cerdik. The one-to-one trial (5 children, 2 30-minute sessions each) examined basic usability and interface comprehensibility. The small-group trial (10 children, 3 sessions of 35 minutes each) assessed engagement and interaction patterns. The large-scale trial (20 children across both schools, 5 sessions × 35 minutes over two weeks) examined practicality and preliminary effectiveness. In all trials, the researcher facilitated sessions with the class teacher present in an observational role. Teachers were briefed prior to each trial regarding the session objectives and their role. Wordwall activities were projected on a classroom screen; children interacted via touchscreen or mouse under structured guidance. Each session followed a three-phase structure: warm-up (5 minutes), media interaction (20–25 minutes), and reflection/closing (5 minutes). The teacher's role during implementation was to observe, record behavioral responses, and

provide scaffolding prompts when children showed signs of difficulty consistent with Vygotsky's (1978) zone of proximal development framework.

Stage 5: Evaluation. Formative evaluation occurred throughout all prior stages through expert validation and trial-based revisions. Summative evaluation involved analysis of children's early literacy outcomes through pre-test and post-test scores administered before and after the large-scale trial. Product revisions were made after each trial based on observational data and teacher feedback.

Data Collection

Data were collected using the following instruments, each addressing a specific aspect of media quality or child outcome. The theoretical basis for each instrument, its validation procedure, and representative items summarised in Table 2.

The early literacy achievement test measured four dimensions of emergent literacy drawn from Ehri et al.'s (2001) phases of alphabetic learning and Strickland and Schickedanz's (2004) framework: (1) letter-name knowledge (identifying upper and lowercase letters by name), (2) initial phoneme awareness (identifying the beginning sound of spoken words), (3) print awareness (understanding directionality and basic book-handling conventions), and (4) receptive vocabulary (matching pictures to spoken words in a structured task). The pre-test was administered individually to each child one week before the large-scale trial; the post-test was administered within three days of the final session.

Table 2. Research instruments description, adaptation, validity, and sample items

Instrument	Type	Source/Adaptation	Validity / Reliability	Indicators Measured	Sample Item
Expert Validation Sheet (Media)	Rating Scale (1–4)	Adapted from Walker & Hess (1984) criteria for instructional media quality	Content validity by media expert; CVI ≥ 0.80	Visual clarity, layout, color, interactivity, navigation ease, audio quality	"The display layout is clear and appropriate for children aged 4–5 years."
Expert Validation Sheet (Content)	Rating Scale (1–4)	Adapted from Nieveen (1999) criteria for curriculum material validity	Content validity by content expert; CVI ≥ 0.80	Alignment with K-13 ECE curriculum, accuracy of literacy content, vocabulary appropriateness, cultural relevance	"The vocabulary used is appropriate for the cognitive level of Group A children."
Expert Validation Sheet (Pedagogy)	Rating Scale (1–4)	Adapted from Nieveen (1999) and ECE pedagogical standards (Permendikbud No. 137/2014)	Content validity by pedagogy expert; CVI ≥ 0.80	Alignment with DAP principles, learning objectives, child-centered approach, scaffolding provision	"The media supports child-centered learning and active exploration."
Teacher Practicality	Likert Scale (1–5),	Adapted from Akker et al. (1999)	Face validity by	Ease of operation, time	"Using Wordwall

Questionnaire	structured interview	practicality framework	content expert; Cronbach's $\alpha \geq 0.70$	efficiency, compatibility with classroom activities, student engagement support, teacher confidence	requires only minimal preparation time before a lesson."
Child Response Observation Sheet	Structured observation checklist	Developed by researcher; based on Piaget (1952) and Vygotsky (1978) engagement indicators	Inter-rater reliability (Cohen's $\kappa \geq 0.70$); face validity by pedagogy expert	On-task behavior, verbal response, eye contact with screen, game interaction attempts, enthusiasm shown	Observer ticks 'Yes/No': Child independently attempts to match the displayed letter.
Early Literacy Achievement Test	Performance-based test (oral + pointing task)	Developed by researcher; based on Ehri et al. (2001) and Strickland & Schickedanz (2004) early literacy frameworks	Content validity (CVI $\geq$ 0.80); test-retest reliability $r \geq 0.75$	(1) Letter-name knowledge (26 upper/lower), (2) Initial phoneme awareness, (3) Print awareness (directionality, book handling), (4) Receptive vocabulary (picture–word matching)	Tester shows flashcard 'A': "What letter is this?" / "Can you find something that starts with this sound?"

Data Analysis

Quantitative data were analyzed descriptively using mean, median, mode, minimum, and maximum scores to summarise validation ratings, practicality scores, and child response data. Effectiveness was assessed by comparing pre-test and post-test literacy scores using N-gain analysis (Hake, 1998), with a normalized gain scoree" 0.70 indicating high effectiveness, 0.30–0.69 indicating moderate effectiveness, and < 0.30 indicating low effectiveness. Feasibility categories for validation and practicality instruments followed Arikunto's (2010) percentage criteria: e" 81% = Very Feasible; 61–80% = Feasible; 41–60% = Moderately Feasible; an d" 40% = Not Feasible.

Qualitative data comprising open-ended questionnaire responses, interview transcripts, field observation notes, and expert validator written comments were analyzed using Miles and Huberman's (1994) framework of data reduction, data display, and conclusion drawing. Data reduction involved thematic coding of feedback and observations to identify recurring issues and strengths. Data display organized coded themes into structured summaries to support pattern recognition. Conclusion drawing linked qualitative themes to quantitative findings on feasibility and effectiveness to triangulate the overall evaluation of the Wordwall media.

■ RESULT AND DISCUSSION

The study was conducted using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The findings for each stage are presented below.

Analysis Stage

The analysis stage involved three data collection methods: questionnaires distributed to teachers, semi-structured interviews, and field observations. Questionnaire data collected from teachers in Tasikmalaya revealed that the most widely available type of digital media in schools was interactive video (36.1%). In comparison, literacy-oriented digital media accounted for only 29.7% of available resources. The dominant application used by teachers to create digital content was CapCut (54%), indicating a strong reliance on video-based tools rather than interactive game-based platforms. These findings reflect a systemic gap: although digital tools are present in the classroom, they are predominantly passive, offering limited opportunities for active learner engagement.

Interview data from teachers at TK Cerdik and TK Sejahtera 4 corroborated the questionnaire findings. Both schools primarily employed non-digital tools, particularly letter cards and loose-parts materials, for literacy instruction. Digital media use was largely limited to group video-watching. Teachers at both institutions identified the same instructional needs: media that is engaging, developmentally appropriate for Group A children (ages 4–5), and directly relevant to early literacy objectives. The absence of ready-to-use, game-based digital tools aligned with the national curriculum was consistently flagged as a critical gap. This finding is consistent with Prayogi (2020), who argued that teachers must develop digital competencies to create creative and innovative learning environments, a standard that current tool availability does not support.

Field observations at TK Cerdik and TK Sejahtera 4 confirmed that 90% of children aged 4-5 years were classified in the "beginning to develop" literacy category, meaning they could identify fewer than one-third of the target letters of the alphabet. Only 5% reached the "developing as expected" or "developing very well" categories, while no children were classified as "not yet developing." These observational data, presented in Table 5, directly correspond to the quantitative pre-test baseline of 4.4 (out of 16) obtained in the large-group trial, confirming that the two measurement approaches converged on the same developmental portrait. The literature review further confirmed that interactive digital media for early literacy in Indonesia is markedly underrepresented. The triangulated results of the analysis stage thus established a clear and evidenced rationale for the development of an interactive, game-based, culturally localized literacy medium for children aged 4-5 years.

Design Stage

The design stage produced two primary outputs: (1) a general media design framework (rancangan umum media) and (2) a detailed storyboard. The general framework specified the curricular scope as the language development domain under the *Merdeka* curriculum, basic competency no. 3.12 ("recognizing early literacy through play"), with target competencies including letter recognition (a–z) and the identification of initial letter sounds in animal names. The media was designed to be operable on both computers and mobile devices, ensuring accessibility across the resource constraints typical of kindergartens in West Java.

The storyboard organised the media content across three thematic modules: (a) vowel recognition (a, i, u, e, o) using animals living on land; (b) consonant recognition (m, p, t, r, s, c, g, d, j, q, w, v, y, x, z) using land animals; and (c) consonant recognition (k, b, l, h, f) using aquatic animals. Each module was paired with a corresponding Wordwall game type: True or False (vowel recognition), Find the Match (consonant matching via helicopter-and-cloud interaction), and Gameshow Quiz (four-option multiple-choice). All 26 letters of the alphabet

were anchored to culturally familiar Indonesian animal names, for example, ayam (A), iguana (I), unta (U), musang (M), and kepiting (K), selected on the criteria of ecological familiarity for West Javanese children and the phonological clarity of the initial letter sound. The storyboard underwent an initial expert review, resulting in revisions to the Find the Match game module based on feedback on clarity and letter-to-image correspondence.

Figure 1. Wordwall: An Interactive Game-Based Digital Learning Platform

Development Stage

The development stage produced the initial media prototype using three tools: Canva (for designing custom animal illustrations and background scenes), Voice Changer (for recording child-directed Indonesian-language audio narration), and the Wordwall platform at wordwall.net (for building the six interactive game activities). Following production, the media were submitted to three expert validators for independent assessment using rating-scale instruments (Content Validity Index, CVI ≥ 0.80 threshold).

The material expert's assessment (Table 6) yielded 80% feasibility, with 20% rated "feasible with revisions." Specific feedback included: standardizing letter displays without accompanying images in certain games; eliminating duplicate letters across game activities; ensuring all 26 letters of the alphabet were represented; and replacing the vocabulary item nyamuk (mosquito) with a simpler, more familiar animal name. The media expert similarly awarded 80% feasibility, recommending improvements to audio quality for greater clarity, adding a developer profile page to the accompanying manual, and enlarging image cards for the Find the Match game to improve visibility on mobile screens. The pedagogical expert awarded a perfect 100% feasibility score, confirming that all six rubric components curriculum alignment, developmental appropriateness, instructional clarity, play-based learning integration, teacher usability, and holistic literacy support potential fully met the criteria.

Following expert validation, the media underwent systematic revision: audio narration was re-recorded at higher fidelity; the Find the Match game was redesigned with enlarged image cards and clearer letter-to-animal associations; vocabulary in the True or False module was refined; and all 26 letters were verified to be present across the three game modules. A developer profile page was added to the manual book. These iterative revisions reflect the internal quality assurance process embedded within the ADDIE development stage, ensuring that the final product was theoretically sound and technically suitable prior to field implementation.

The questionnaire distributed to kindergarten teachers in Tasikmalaya revealed four key findings regarding current digital media use. First, the most prevalent type of digital media in schools was interactive video (36.1%),

indicating a strong reliance on passive, non-interactive content delivery. Second, the most supported developmental domain in existing digital media was moral and religious values (26.8%), while language and literacy development remained comparatively underserved. Third, the most widely used application for creating digital learning materials was CapCut (54%), a video-editing tool designed for one-way content production rather than interactive learner engagement. Fourth, among digital media used specifically for literacy instruction, interactive video again dominated (29.7%), while truly interactive, game-based literacy platforms were virtually absent from teachers' practice. Collectively, these findings reveal a structural gap in interactive, literacy-focused digital resources available to early childhood teachers in Tasikmalaya.

Direct classroom observations conducted at TK Cerdik and TK Sejahtera 4 confirmed that early literacy competence among children aged 4–5 years was at a critically low level. Specifically, 90% of children were classified in the "beginning to develop" category, meaning they could recognize fewer than one-third of the target letters of the alphabet. A small proportion (5%) had reached "developing as expected," and an equally small proportion (5%) were classified as "developing very well." Notably, no child was categorized as "not yet developing," indicating all participants had at least minimal prior exposure to letters. The strong concentration in the "beginning to develop" category, confirmed across both schools, directly reflects the pre-test mean score of 4.4 obtained in the large-group quantitative assessment, thereby triangulating qualitative observation with quantitative measurement and establishing a consistent baseline of early literacy deficit that the intervention was designed to address.

These results confirmed the urgent need for interactive digital media to support early literacy. The developed Wordwall-based interactive media was evaluated by three experts: material, media, and pedagogical experts. The material expert rated the product at 80% (feasible), the media expert at 80% (feasible), and the pedagogical expert at 100% (very feasible). The pedagogical expert's perfect score was based on a structured rubric covering six components: (1) alignment with the national early childhood curriculum (*Kurikulum Merdeka*), (2) developmental appropriateness for children aged 4–5 years, (3) clarity and simplicity of task instructions, (4) integration of play-based learning principles, (5) teacher usability in classroom settings, and (6) potential to support holistic literacy development. Each component was rated on a four-point Likert scale, and the expert confirmed that all items fully met the criteria, yielding a perfect aggregate score. This result reflects the strong correspondence between the media's design principles and recognized pedagogical standards for early childhood education in Indonesia. Overall, the product was categorized as very feasible for classroom implementation.

The completed prototype was independently evaluated by three expert validators, one specialist each in instructional material content, educational media design, and early childhood pedagogy. The material content expert assessed the media at 80% feasibility, with 20% of items rated "feasible with revisions." Specific recommendations included: standardizing letter displays by removing redundant images; eliminating duplicate letters across game activities; ensuring all 26 letters of the alphabet were represented; and replacing nyamuk (mosquito) with a simpler, more ecologically familiar animal name. The media design expert also awarded 80% overall feasibility, recommending improvements to audio recording quality, adding a developer profile page to the manual, and enlarging image cards in the Find the Match game to improve legibility on mobile. The pedagogical expert awarded a perfect 100% across all

evaluation components, confirming full compliance with criteria for curriculum alignment (*Kurikulum Merdeka*), developmental appropriateness for ages 4–5 years, clarity of task instructions, play-based learning principles, teacher usability, and potential to support holistic literacy development. The three scores 80%, 80%, and 100% collectively placed the product in the "very feasible" category (Arikunto, 2010).

Implementation Stage

The implementation stage comprised three sequential trials. The one-to-one trial (n = 5 children, TK Cerdik, 2 sessions × 30 minutes) established basic usability and interface comprehensibility. The small-group trial (n = 10 children, TK Cerdik, 3 sessions of 35 minutes each) assessed engagement and interaction patterns. It yielded a teacher practicality rating of 100%, placing the media in the "very feasible" category with no recommendations for further revision. Children in the small-group trial were observed to be highly enthusiastic: they spontaneously called out letter names, pointed at the screen, and, in several cases, rose from their seats to get closer to the projected display, a level of physical engagement rarely observed during conventional letter-card sessions. The classroom teacher at TK Cerdik reflected: "*Media ini menarik sekali, anak-anak langsung antusias begitu game dimulai, bahkan yang biasanya pendiam pun mau mencoba menjawab*." ["This media is very engaging; the children were immediately enthusiastic as soon as the game started, even those who are usually quiet were willing to try answering."]

The large-group trial (n = 30 children, TK Sejahtera, 5 sessions × 35 minutes over two weeks) served as both a practicality and a preliminary effectiveness assessment. Qualitative observations recorded six consistent behavioural outcomes: (1) children were enthusiastic when introduced to the media; (2) children actively and voluntarily named letters encountered during gameplay; (3) children were able to operate the media independently by the second session; (4) all 30 children completed all three game types; (5) children maintained sustained on-task focus throughout each session; and (6) children verbally expressed enjoyment and requested continuation to the next game. The teacher at TK Sejahtera 4 noted: "*Biasanya saya harus terus mendorong anak untuk fokus, tapi dengan Wordwall mereka sendiri yang minta lanjut ke game berikutnya*." ["Normally I have to keep prompting children to stay focused, but with Wordwall they were the ones asking to move on to the next game."] These qualitative outcomes corroborate the 100% practicality rating and indicate that the media's gamified, audio-visual structure successfully translated into observable classroom engagement. The high practicality can be attributed to Wordwall's user-friendly design, which allows educators to integrate the platform into daily learning activities without requiring advanced technical skills (Papadakis et al., 2021).

Evaluation Stage

The field test was conducted with 30 children at TK Sejahtera 4. Pre-test results showed an average literacy score of 4.4, while post-test results increased significantly to 10.4. The N-gain score was 0.8, classified as high effectiveness (Table 4). The evaluation stage encompassed both formative evaluation (conducted throughout the development and implementation stages via expert validation and trial-based revisions) and summative evaluation (pre-test and post-test literacy assessments administered before and after the large-group trial). Pre-test data collected from 30 children at TK Sejahtera 4 revealed a group mean of 4.4 out of 16 (median = 5, mode = 5, min = 1, max = 9), confirming the baseline "low" literacy level established during the analysis stage. At the item level, scores for the four literacy competencies

were as follows: showing alphabet letters (mean 1.93), naming alphabet letters (mean 1.53), showing initial letter of animal names (mean 0.50), and naming initial letter of animal names (mean 0.47). The two phoneme awareness items yielded the lowest pre-test means, indicating that initial letter identification and naming were the most underdeveloped competencies at baseline.

Following the five-session implementation, post-test data showed a group mean of 10.4 out of 16 (median = 11.5, mode = 12, min = 6, max = 12), representing a mean gain of 6.0 points. At the item level, scores increased substantially across all four competencies: showing alphabet letters (pre 1.93 →post 2.93), naming alphabet letters (pre 1.53 → post 2.83), showing initial letter of animal names (pre 0.50 → post 2.43), and naming initial letter of animal names (pre 0.47 → post 2.20). The N-gain score calculated from the group means was 0.8, placing the intervention in the "high" effectiveness category ($g > 0.7$) per Hake's (1998) classification. At the individual level, 23 of 30 children achieved high N-gain (> 0.7), 6 achieved moderate N-gain (0.3–0.7), and only 1 child achieved low N-gain (< 0.3). Disaggregated by competency (Table 8), letter recognition (showing) produced the highest N-gain of 0.97, followed by letter recognition (naming) at 0.92, initial phoneme awareness (showing) at 0.77, and initial phoneme awareness (naming) at 0.61, the sole competency in the moderate range, reflecting the greater cognitive demand of phoneme naming relative to visual identification. All four competencies showed statistically significant pre-to-post improvements ($p < 0.001$), confirming that the gains were not attributable to chance. These summative findings confirm that the Wordwall media successfully achieved its instructional objectives across all targeted literacy competencies.

These findings indicate that the Wordwall-based interactive digital media was highly effective in improving early literacy skills among children aged 4–5 years. The consistently high N-gain scores across most competencies and the statistically significant improvements confirm that the intervention successfully achieved its instructional objectives.

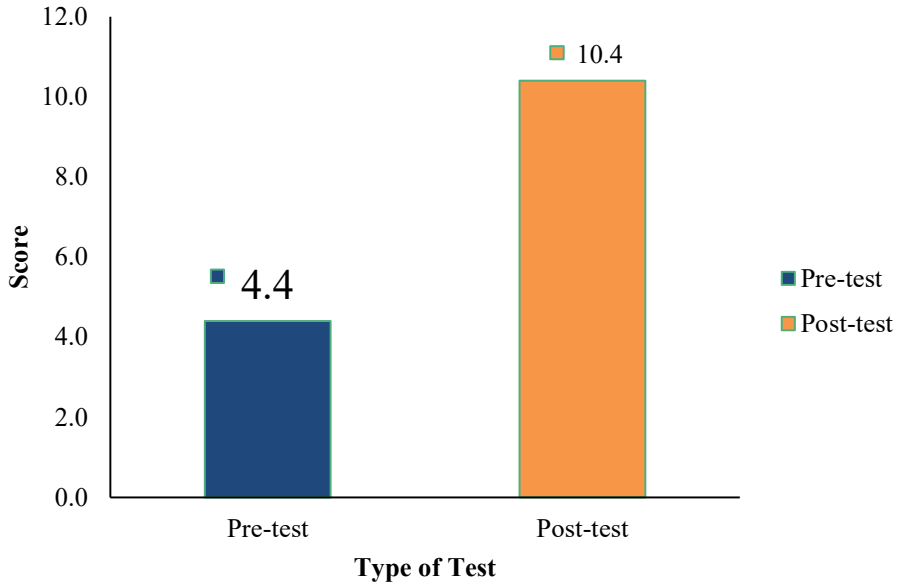

Figure 1. Comparison of pre-test and post-test scores early childhood literacy skills (ages 4- 5 years)

Figure 1 presents a grouped bar chart comparing the individual pre-test (blue bars) and post-test (orange bars) literacy scores of 30 children aged 4–5 years at TK Sejahtera 4 following the implementation of Wordwall-based interactive digital media. Each pair of bars represents one child (S1–S30), while the dashed horizontal lines indicate the respective group means. Overall, the chart shows a consistent, substantial upward shift in literacy scores among virtually all participants after the intervention.

As shown in Table 3, all four literacy competencies showed statistically significant improvements ($p < 0.001$), confirming that gains

Table 3. N-Gain score and paired t-test results per literacy competency

Literacy Competency	Pre-test Mean	Post-test Mean	N-Gain	N-Gain Category	t-value	p-value
Letter recognition (Showing)	1.93	2.93	0.97	High	6.289	0.000001
Letter recognition (Naming)	1.53	2.83	0.92	High	7.477	<0.001
Initial phoneme awareness (Showing)	0.50	2.43	0.77	High	10.802	<0.001
Initial phoneme awareness (Naming)	0.47	2.20	0.61	Moderate	7.390	<0.001

were not due to chance. The two letter recognition skills (showing and naming letters of the alphabet) recorded the highest N-gain scores of 0.97 and 0.92, respectively, both classified as high effectiveness. These competencies had a relatively high pre-test baseline (means of 1.93 and 1.53 out of 3). After the intervention, both approached the ceiling (means of 2.93 and 2.83), indicating near-mastery of alphabet letter recognition. The two initial phoneme awareness skills (identifying and naming the initial letter of animal names) showed even greater absolute growth from very low baselines (pre-test means of 0.50 and 0.47). The "showing" sub-skill yielded an N-gain of 0.77 (high). In contrast, the "naming" sub-skill yielded an N-gain of 0.61 (moderate), reflecting that phoneme naming is cognitively more demanding than visual identification. Notably, the initial phoneme awareness (showing) sub-skill produced the largest t-value ($t = 10.802$), underscoring the most pronounced pre-to-post shift relative to its starting point. These disaggregated findings reveal that while all competencies improved significantly, the Wordwall media was particularly effective in closing the gap in phoneme awareness, the skill with the lowest pre-test scores. The findings confirmed that the Wordwall-based media was highly effective in improving literacy skills among children aged 4-5 years.

The results of this study confirmed that Wordwall-based interactive media is feasible, practical, and effective in supporting early childhood literacy. The validation process conducted by experts in material, media, and pedagogy demonstrated that the developed media met feasibility standards. Material and media experts scored the product at 80%, while pedagogical experts rated it at 100%, placing the product in the very feasible category. These findings indicate that the content presented through Wordwall aligned with literacy competencies required for children aged 4–5 years and that the technical aspects, such as layout, readability, and user interface, were suitable for young learners. The high score from pedagogical experts further underscores the appropriateness of this media for classroom

implementation. This feasibility responds to the research problem identified in the needs analysis, namely the limited availability of literacy-focused digital media in early childhood settings.

The practicality test involving teachers and children during small-group trials showed highly positive responses. Children were enthusiastic, participated actively, and maintained focus during activities, while teachers rated the media as very feasible (100%). This indicates that Wordwall not only attracted children's interest but also offered practicality for teachers, who could easily integrate it into daily learning activities without requiring advanced technical skills. The practicality can be attributed to Wordwall's user-friendly design, which allows educators to adapt tasks and manage classroom activities effectively. These results also address the issue of children's boredom with static media such as letter cards, providing a more interactive alternative. Classroom observation notes recorded during the small-group trial at TK Cerdik documented that children spontaneously pointed at the screen and called out letter names during the True or False game, with several children rising from their seats to get closer to the projected display a level of physical engagement rarely observed during conventional letter-card sessions. When asked to reflect on the session, the classroom teacher at TK Cerdik remarked: "*Media ini menarik sekali, anak-anak langsung antusias begitu game dimulai, bahkan yang biasanya pendiam pun mau mencoba menjawab*." ["This media is very engaging; the children were immediately enthusiastic as soon as the game started, even those who are usually quiet were willing to try answering."] Similarly, the teacher at TK Sejahtera 4 noted during a post-trial interview that the media removed the need for repeated prompting: "*Biasanya saya harus terus mendorong anak untuk fokus, tapi dengan Wordwall mereka sendiri yang minta lanjut ke game berikutnya*." ["Normally I have to keep prompting children to stay focused, but with Wordwall they were the ones asking to move on to the next game."] These qualitative accounts corroborate the quantitative practicality score and illustrate how the media's audio-visual interactivity and gamified structure translated into observable classroom engagement.

The large-group trial involving 30 children produced an N-gain score of 0.8, indicating high effectiveness. This improvement is explained by how the interactive features of Wordwall operate through well-established cognitive and constructivist learning mechanisms. From a cognitive information-processing perspective, the immediate visual and auditory feedback provided by each Wordwall task strengthened children's letter-recognition schemas by reinforcing correct associations and correcting errors in real time (Jing et al., 2023; Schwarzer et al., 2022; Yang et al., 2021). Classroom observation notes recorded during the small-group trial at TK Cerdik documented that children spontaneously pointed at the screen and called out letter names during the True or False game, with several children rising from their seats to get closer to the projected display a level of physical engagement rarely observed during conventional letter-card sessions. When asked to reflect on the session, the classroom teacher at TK Cerdik remarked: "*Media ini menarik sekali, anak-anak langsung antusias begitu game dimulai, bahkan yang biasanya pendiam pun mau mencoba menjawab*." ["This media is very engaging; the children were immediately enthusiastic as soon as the game started, even those who are usually quiet were willing to try answering."] Similarly, the teacher at TK Sejahtera 4 noted during a post-trial interview that the media removed the need for repeated prompting: "*Biasanya saya harus terus mendorong anak untuk fokus, tapi dengan Wordwall mereka sendiri yang minta lanjut ke game berikutnya*." ["Normally I have to keep

prompting children to stay focused, but with Wordwall they were the ones asking to move on to the next game."] These qualitative accounts corroborate the quantitative practicality score and illustrate how the media's audio-visual interactivity and gamified structure translated into observable classroom engagement. From a constructivist standpoint, the gamified structure encouraged children to actively manipulate symbolic letter representations by dragging, matching, and sorting, thereby supporting the construction of phonological and graphemic knowledge through hands-on engagement rather than passive reception (Mujahidin et al., 2021). Moreover, the playful context reduced cognitive load by embedding learning within motivating game tasks, allowing children to allocate more working memory resources to letter recognition itself. These mechanisms collectively explain why the media produced not only higher post-test scores but also high normalized gain: the intervention addressed both motivational and cognitive barriers that typically impede early literacy acquisition. These findings are consistent with previous research highlighting the role of digital interactive media in literacy development. Chuang (2023) found that digital game-based learning significantly improved children's focus and motivation in preschool classrooms. Byrne et al. (2018) showed that digital storytelling enhanced literacy skills through interactive and multimodal experiences. Valverde-Montesino (2021) emphasized that playful digital learning environments could increase children's interest in early reading, while Ricoy argued that gamification supported children's initial reading and writing skills. Recent research by Brien & Seward (2022) also confirmed that digital platforms reduce literacy gaps across preschools in Indonesia. By confirming and extending these findings, the current study reinforces the importance of digital gamification for early literacy.

The theoretical and methodological novelty of this research lies in its systematic localization of Wordwall as a culturally and developmentally situated early literacy platform for Indonesia. Previous studies employing Wordwall or similar digital tools treated the platform as a generic delivery mechanism, without adapting task content to the linguistic, cultural, or curricular context of the target learners (Brooks et al., 2021; Pan et al., 2021; Ricoy, 2022). The present study, by contrast, produced a set of Wordwall-based design principles specific to early literacy instruction in Indonesia: (1) using locally familiar vocabulary and culturally relevant images to scaffold letter recognition; (2) sequencing tasks according to the developmental progression of the national curriculum (*Kurikulum Merdeka*); and (3) calibrating task difficulty to match the "beginning to develop" literacy baseline of children aged 4-5 years. These design principles constitute a transferable methodological contribution that extends beyond mere application of an existing platform. Thus, this study contributes new theoretical knowledge by demonstrating that culturally responsive digital gamification can serve as an effective bridging mechanism between formal curriculum standards and children's informal play schemas in early childhood contexts in developing countries (Liu et al., 2024). Theoretically, this study strengthens the argument that technology-mediated play can support the development of literacy skills by bridging pedagogical approaches with children's natural learning tendencies, and expands early childhood education theory by demonstrating how culturally situated digital gamification fosters intrinsic motivation and improves foundational literacy outcomes (Li et al., 2024; Undheim, 2022). In practice, the findings provide teachers with evidence to adopt Wordwall as a supplementary tool alongside traditional methods, enhancing classroom engagement and learning outcomes (Kucirkova, 2019). For policymakers, these results highlight the importance of integrating interactive digital tools into early childhood curricula to prepare children for a digital era while

supporting foundational literacy (Barr & Kirkorian, 2023; Rand & Morrow, 2021). This study was limited to two schools in Tasikmalaya, which may constrain the generalizability of its findings. Future studies should include a broader sample across different regions and age groups. Longitudinal research is also recommended to assess the long-term effects of Wordwall-based literacy interventions. Furthermore, future work could compare Wordwall with other interactive platforms to determine its relative advantages.

CONCLUSION

This research concludes that Wordwall-based interactive digital media is a feasible, practical, and effective tool to support early literacy in early childhood education. The study successfully addressed the initial objective of developing a literacy-oriented medium that engages children while being easy for teachers to implement. Expert validation confirmed the product's feasibility, small-group trials demonstrated its practicality, and large-group implementation demonstrated its effectiveness in improving literacy skills. The novelty of this study lies in adapting an accessible digital platform into the Indonesian early childhood context, specifically designed for children aged 4-5 years. Unlike static media such as letter cards, Wordwall offers dynamic and interactive experiences that sustain children's motivation and participation. This represents an improvement in existing practices by demonstrating how game-based learning can bridge the gap between traditional pedagogy and the needs of digital-native learners.

The contribution of this study is twofold. Theoretically, it expands the understanding of technology-mediated play as a framework for early literacy development, highlighting how gamification can foster intrinsic motivation and meaningful learning. Practically, it provides educators with evidence that interactive media can diversify classroom instruction, reduce boredom, and improve literacy outcomes. For policymakers, these findings underline the importance of incorporating interactive digital media into early childhood curricula to prepare children for the challenges of the digital era while strengthening foundational literacy. Future research is recommended to explore the long-term impacts of using Wordwall, conduct comparative studies with other platforms, and extend implementation to different regions and age groups. Such efforts will provide a stronger evidence base for integrating interactive digital media in diverse early childhood education settings.

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