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Developing a SAS-Based Digital Literacy Book Guided by Diagnostic Assessment to Enhance Early Childhood Literacy

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ABSTRACT

This study aimed to improve children's cognitive ability to match quantities with numerical symbols through the implementation of Problem-Based Learning (PBL) and Direct Instruction (DI) supported by Number Plate media. The study employed classroom action research based on the Kemmis and McTaggart model, conducted over four meetings from April 13 to 16, 2026. The participants were 12 children in Group B at Kenanga Kindergarten Banjarmasin, consisting of eight boys and four girls. Data were collected through observation, documentation, interviews, and cognitive development assessments and analyzed using qualitative and quantitative descriptive methods. PBL encouraged children to solve simple numerical problems, while DI provided structured guidance and demonstrations supported by concrete learning media. The findings revealed

improvements in teacher activity from 61% to 98%, children's activity from 59% to 83%, and cognitive development achievement from 33% to 92%. By the fourth meeting, children's activity and cognitive development had exceeded the predetermined classical success criterion of 80%. These findings suggest that integrating PBL and DI with Number Plate media can support children's cognitive development, particularly their ability to associate quantities with numerical symbols.

Introduction

Early literacy is widely recognized as the foundation of children's language development, cognitive growth, and future academic achievement. During the early childhood period, children begin to develop essential literacy skills, including letter recognition, phonological awareness, vocabulary acquisition, and emergent reading abilities. These foundational competencies significantly influence children's readiness for formal education and their long-term educational success. Nevertheless, many early childhood education institutions continue to encounter challenges in providing literacy instruction that accommodates children's diverse developmental characteristics and learning readiness. Conventional literacy instruction often applies uniform teaching strategies without considering children's initial literacy profiles, resulting in less effective learning experiences and slower literacy development. Consequently, innovative instructional approaches supported by appropriate assessment

practices are essential to ensure that literacy instruction is responsive to children's individual needs.

Early literacy skills represent the fundamental bedrock of young children's cognitive and language development. While the national *Kurikulum Merdeka* framework highlights individualized, adaptive instruction, early childhood education (ECE) classrooms in Indonesia frequently default to standardized, one-size-fits-all literacy activities. Consequently, developing evidence-based instructional tools that align diagnostic profiling with adaptive literacy media remains a critical priority.

A critical synthesis of existing scholarship reveals significant operational similarities, contrasts, and methodological limitations among previous interventions. On one hand, researchers investigating structured phonics (e.g., Damayanti et al., 2024; Erlin & Saptono, 2025; Quach et al., 2018) demonstrate that the Structural Analytic Synthetic (SAS) method effectively enhances early reading skills by breaking down whole sentences into syllables and letters. However, these studies share a major limitation: *they treat all young learners as an homogeneous group, applying uniform SAS exercises without preliminary diagnostic mapping*. On the other hand, studies focusing on differentiated learning and diagnostic assessment (e.g., Connor et al., 2020; Deunk et al., 2018) prove that data-driven profiling optimizes learning pathways. Yet, these assessment-focused studies rarely provide practical, step-by-step

instructional media that teachers can directly deploy to execute differentiated phonics lessons. Furthermore, while recent technology-enhanced literacy research (e.g., Bautista, 2024; Maureen et al., 2020) confirms that interactive digital media boost reading engagement, most digital tools lack an embedded diagnostic mechanism to guide content adaptation based on individual readiness.

These unresolved issues highlight a clear research gap: the lack of an integrated learning resource that connects initial diagnostic assessment, differentiated instruction, the SAS method, and interactive digital media into a single operational workflow. Previous research evaluated these components in isolation, leaving early childhood teachers without concrete tools to bridge diagnostic data with classroom media execution.

To address this critical gap, this study develops and evaluates a SAS-based Digital Literacy Book guided by diagnostic assessment using the ADDIE Research and Development (R&D) model. The primary novelty of this research lies in embedding diagnostic literacy mapping directly into the digital media design, allowing ECE educators to deliver targeted, differentiated SAS activities tailored to young children's baseline phonological readiness.

Furthermore, recent evidence highlights the critical role of diagnostic assessment in identifying children's literacy readiness and enabling teachers to provide timely instructional support. Diagnostic

assessment has been shown to improve instructional decision-making and facilitate differentiated learning that better addresses individual student needs.

Despite these advances, several research gaps remain. Existing studies have generally examined the effectiveness of the SAS method, diagnostic assessment, or digital learning media separately. Limited attention has been given to integrating diagnostic assessment with the SAS method within a differentiated learning framework specifically designed for early childhood education. In addition, most studies have focused primarily on improving beginning reading skills without systematically using diagnostic assessment to map children's literacy profiles before instruction. As a result, teachers often lack practical guidance for designing personalized literacy instruction based on children's actual learning needs. This limitation indicates the necessity of developing an integrated instructional model that combines diagnostic assessment, differentiated instruction, and the SAS method to enhance early literacy development more effectively.

The novelty of this study lies in the integration of diagnostic assessment, the Structural Analytic Synthetic (SAS) method, differentiated learning, and a digital literacy book into a comprehensive instructional model for early childhood education. Unlike previous studies that mainly investigated the effectiveness of instructional methods independently, this research employs diagnostic assessment as

the basis for identifying children's literacy readiness and determining differentiated instructional strategies before implementing the SAS method. In addition, the development of a digital literacy book integrated with diagnostic assessment provides teachers with an innovative instructional resource that supports personalized literacy learning. This integrated approach is expected to contribute both theoretically and practically to improving early literacy instruction in early childhood education.

Therefore, this study aims to identify children's initial literacy profiles through diagnostic assessment, examine the effectiveness of the Structural Analytic Synthetic (SAS) method in improving early literacy skills, and develop a digital literacy book that supports differentiated literacy instruction. The findings are expected to enrich the literature on early literacy education, provide practical guidance for teachers in implementing evidence-based literacy instruction, and support the implementation of the Merdeka Curriculum through adaptive and child-centered learning practices.

Methods

This study employed a Research and Development (R&D) mixed-methods design using the ADDIE model (*Analysis, Design, Development, Implementation, Evaluation*) to construct and evaluate a SAS-based Digital Literacy Book guided by diagnostic assessment. The study was conducted across three Early Childhood Education (ECE) centers in

Cirebon Regency, West Java, Indonesia. A purposive sampling technique was applied based on specific inclusion criteria: institutions implementing the *Kurikulum Merdeka*, willingness of educators to participate in diagnostic profiling, and school digital infrastructure readiness. The primary study participants comprised N = 20 kindergarten children aged 5–6 years (11 girls and 9 boys) and 3 classroom teachers responsible for ECE literacy instruction.

Operationalization of the ADDIE Framework The design and testing of the digital literacy book strictly followed the five sequential phases of the ADDIE framework:

1. **Analysis Phase:**
    - *Needs Assessment:* Conducted classroom observations and semi-structured interviews with the 3 teachers to identify current early literacy instructional bottlenecks. Findings indicated a reliance on uniform worksheets and a lack of preliminary diagnostic mapping.
    - *Diagnostic Profiling:* Administered an initial diagnostic literacy assessment to all $N = 20$ children evaluating four baseline domains: letter recognition, phonological awareness, vocabulary knowledge, and emergent reading interest.
2. **Design Phase:**
    - *Curriculum Mapping:* Designed a differentiated SAS instructional framework aligning diagnostic readiness

profiles with specific SAS phonics stages (sentence \rightarrow word \rightarrow syllable \rightarrow letter \rightarrow syllable \rightarrow word \rightarrow sentence).

- *Media Blueprinting:* Drafted storyboards, interactive audio-visual elements, tactile-digital prompts, and user-interface flows for the interactive digital literacy book.

3. **Development Phase:**
   - *Media Fabrication:* Produced the digital literacy book prototype using interactive media software, embedding interactive SAS decoding activities, native audio pronunciations, and visual reinforcement.
   - *Expert Validation:* Evaluated the prototype through expert judgment involving early childhood education specialists, literacy pedagogues, and instructional media experts. The evaluation assessed content validity, language appropriateness, interactive design, and pedagogical alignment before classroom testing.
4. **Implementation Phase:**
   - *Classroom Intervention:* Implemented the SAS-based digital literacy book over a 4-week period across the three ECE centers. Teachers utilized the initial diagnostic profiles to deliver differentiated SAS learning tasks, allowing children to

interact individually and in small groups with the digital media.

5. **Evaluation Phase:**
    - *Quantitative Evaluation:* Administered a post-intervention literacy assessment to the N = 20 children using identical rubrics to quantify mean score improvements, evaluated via paired-samples t-test.
    - *Qualitative Evaluation:* Conducted post-implementation interviews with teachers, participant observation logging, and documentation analysis to evaluate program practicality, pedagogical feasibility, and student engagement.

The research was conducted in three Early Childhood Education (ECE) institutions located in Cirebon Regency, West Java, Indonesia. The participants consisted of kindergarten children aged 5–6 years and classroom teachers who implemented literacy instruction during the study. The participants were selected using purposive sampling based on several criteria, including the implementation of the Merdeka Curriculum, teachers' willingness to participate, and the schools' readiness to integrate diagnostic assessment into literacy instruction. The research subjects included children who participated in literacy learning activities and teachers who were responsible for planning and implementing classroom instruction.

The study began with a needs analysis through classroom

observations, interviews with teachers, and literature review to identify existing challenges in early literacy instruction. Subsequently, a diagnostic assessment instrument was administered to determine each child's initial literacy profile, including letter recognition, phonological awareness, vocabulary development, and beginning reading skills. The assessment results served as the basis for designing differentiated literacy instruction using the Structural Analytic Synthetic (SAS) method. Based on the identified learning needs, a digital literacy book was developed to support classroom instruction. The prototype was then evaluated by experts in early childhood education, literacy education, and instructional media to determine its content validity, language appropriateness, presentation quality, and graphical design. Revisions were conducted based on the experts' recommendations before classroom implementation.

Data were collected using diagnostic assessment sheets, classroom observation forms, semi-structured interview guides, documentation, expert validation questionnaires, and children's literacy performance assessments. Classroom observations were conducted throughout the implementation process to evaluate teachers' instructional practices and children's participation during learning activities. Semi-structured interviews were conducted with teachers to obtain comprehensive information regarding the practicality, challenges, and effectiveness of implementing the SAS method integrated with diagnostic assessment.

Documentation included photographs of learning activities, lesson plans, students' learning products, and field notes collected during the research process.

The validity of the research instruments was examined through expert judgment involving specialists in early childhood education and literacy learning. Instrument revisions were carried out according to the experts' recommendations before field implementation. Quantitative data were analyzed using descriptive statistics, including mean scores, percentages, and standard deviations, to describe children's literacy development before and after the intervention. To evaluate the statistical significance and magnitude of improvement in early literacy skills among the participants (N = 20), data were analyzed using a paired-samples t-test alongside Normalized Gain (N-Gain) analysis. The paired-samples t-test determined whether post-intervention mean scores differed significantly from baseline pre-test scores at an alpha level of $\alpha = .05. Additionally, N-Gain scores were calculated to quantify the actual effectiveness and learning enhancement produced by the SAS-based digital literacy book, categorized according to Hake's N-Gain} criteria (High: $g > 0.7$; Medium: $0.3 \leq g \leq 0.7$; Low: $g < 0.3$).

Qualitative data obtained from interviews, observations, and documentation were analyzed using the interactive model proposed by Miles, Huberman, and Saldaña (2014), involving data condensation,

data display, and conclusion drawing. Data credibility was ensured through source triangulation, methodological triangulation, and member checking.

The success of the study was evaluated based on several performance indicators, including the validity and practicality of the developed digital literacy book, teachers' ability to implement differentiated literacy instruction based on diagnostic assessment, and improvements in children's early literacy skills following the implementation of the SAS method. The developed learning model was considered effective when expert validation indicated that the instructional materials met acceptable quality standards, teachers demonstrated successful implementation of the learning procedures, and children showed measurable progress in letter recognition, phonological awareness, vocabulary acquisition, and beginning reading skills. These indicators were used to determine the feasibility and educational effectiveness of integrating diagnostic assessment with the Structural Analytic Synthetic method in early childhood literacy instruction.

Result and Discussions

Results

1. Product Development Process and Media Features

The development of the Structural Analytic Synthetic (SAS)-based digital literacy book followed the ADDIE instructional design

framework. The digital media was engineered as an interactive, multi-sensory application designed to facilitate adaptive phonics instruction for early childhood learners.

- Pedagogical Structure: The digital book converts standard text into dynamic, clickable units following the core SAS hierarchy: *Sentence Level \rightarrow Syllable Breakdown \rightarrow Individual Letter-Sound Identification \rightarrow Syllable Re-synthesis \rightarrow Sentence Re-construction*.
- Interactive & Audio-Visual Features: Each page integrates native voiceover audio triggers, animated letter tracing pathways, tactile tap-to-listen phoneme prompts, and visual rewards (such as celebratory animations upon successful decoding).
- Diagnostic Adaptation Interface: The digital book includes a teacher management module where educators can select difficulty pathways based on initial diagnostic profiling (e.g., Tier 1: Phoneme/Letter Focus; Tier 2: Syllable Blending; Tier 3: Fluent Emergent Reading).

2. Expert Validation Results and Revision Process

Prior to field implementation, the digital literacy book prototype was submitted to three expert evaluators: an Early Childhood Education Specialist, a Reading & Literacy Pedagogue, and an Educational Media & Technology Expert.

Table 1. *Expert Validation Scores for the SAS-Based Digital Literacy Book*

Validation Dimension	Evaluated Criteria	Score (%)	Qualitative Category
Content & Pedagogical Validity	Alignment with SAS method, suitability for age 5–6, diagnostic integration	92.5%	Very Valid
Language & Accessibility	Diction clarity, phoneme pronunciation accuracy, story comprehensibility	88.0%	Very Valid
Media Design & Interaction	UI/UX layout, audio-visual feedback, tap-responsiveness, navigation	91.0%	Very Valid
Overall Average	**Overall Media Feasibility Score**	**90.5%**	**Very Valid**

- **Iterative Revision Process Based on Expert Feedback:**
    - *Pedagogical Adjustment:* The Literacy Pedagogue recommended slowing down the default voice speed during the phoneme isolation stage (/b/-/a/-/c/-/a/). The audio playback rate was adjusted to 0.75x speed for clearer phonological discrimination.
    - *Interface Optimization:* The Media Expert suggested enlarging touch targets for children's fine motor capabilities. Button sizes were increased by 25%, and touch-response sensitivity was optimized.

- *Content Refinement:* The ECE Specialist suggested replacing abstract vocabulary words with concrete, highly familiar objects. Abstract terms were replaced with everyday nouns (e.g., *baju*, *bola*, *buku*).

3. Quantitative Findings: Diagnostic Assessment and $N\text{-Gain}$ Analysis

To evaluate the statistical impact of the SAS-based digital book, pre-test and post-test literacy scores of N = 20 children were analyzed. Data satisfied normality assumptions via the Shapiro-Wilk test (W = 0.96, p = .420 for pre-test; W = 0.95, p = .350 for post-test) and homogeneity of variance via Levene's test ($F(1, 38) = 1.12$, $p = .297$).

Table 2. *Inferential Statistics and N-Gain} Score Comparison (N = 20)*

Assessment Phase	Mean (M)	SD	Mean Diff.	t-value	df	p-value	Mean N-Gain	Category
Pre-test	54.35	8.12	-28.15	-14.62	19	< .001	0.62	Medium-High
Post-test	82.50	6.45						

The paired-samples t-test confirmed a statistically significant increase in literacy proficiencies from pre-test (M = 54.35, SD = 8.12) to post-test (M = 82.50, SD = 6.45), $t(19) = -14.62$, $p < .001$. The calculated Normalized Gain score (N-Gain = 0.62) reflects medium-to-high

instructional effectiveness in developing phonological awareness, letter recognition, and emergent sentence decoding.

4. Qualitative Findings: Observations, Interviews, and Documentation

- Classroom Observation Narratives:

Over the 4-week implementation, qualitative observations tracked a transition from initial learner hesitation to self-directed interaction. During Week 1, children with low diagnostic scores showed frustration when attempting letter sound associations on paper. When introduced to the digital literacy book in Week 2, the multi-sensory feedback (visual highlight + native audio) allowed children to self-correct phoneme errors without constant teacher intervention. By Week 3, field logs noted that 85% (n = 17) of the children independently navigated the sentence-to-letter decomposition modules and re-synthesized words correctly.

- Representative Teacher Interview Quotations:

Post-implementation interviews with all 3 classroom teachers highlighted high practical utility, particularly regarding differentiated instruction:

"In previous years, I taught the SAS method on a blackboard to the entire class simultaneously. Children who lacked basic letter-sound knowledge quickly lost attention. The diagnostic assessment helped me map exact student gaps, while the digital book allowed children to practice SAS decoding at their own pace. The audio prompts act like an assistant teacher." (Teacher A, Interview Data)

"The digital format makes the analytic-synthetic steps concrete. Children love tapping the syllables to hear how 'I-ba' joins to become 'Iba'. It transformed a drill-heavy reading session into a playful activity." (Teacher C, Interview Data)

- Documentation and Student Artifacts:

Analysis of diagnostic profile cards, weekly anecdotal logs, and student activity sheets confirmed significant skill progression. Baseline diagnostic profiles indicated that 12 out of 20 children started in the "Emergent/Beginning" tier (struggling with phoneme blending). Post-intervention documentation showed that 15 out of 20 children achieved the "Proficient" tier, demonstrating fluent syllable blending and basic sentence decoding on both digital and print media.

Discussion

The empirical findings demonstrate that optimizing the Structural Analytic Synthetic (SAS) method through initial diagnostic assessments and interactive digital media exerts a highly significant positive effect on young children's early literacy development ($t(19) = -14.62, p < .001, N\text{-Gain} = 0.62$). Beyond confirming general literacy improvements, these results provide critical insights into *why* and *how* an integrated model outperforms conventional literacy instruction in early childhood education (ECE) settings.

Mechanism of Action: Why the Integrated Model Outperforms Earlier Approaches

Traditional SAS implementations often fail when applied as a one-size-fits-all classroom activity because children enter preschool with vastly different levels of phonological readiness. In standard non-differentiated SAS instruction, children lacking basic phoneme isolation skills experience cognitive overload when tasked with breaking down full sentences into words and syllables. The integrated model evaluated in this study overcomes this structural limitation through a two-fold synergistic mechanism:

1. *Targeted Cognitive Load Reduction:* Initial diagnostic profiling allows teachers to identify each child's precise baseline readiness across four core domains (letter recognition, phonological awareness, vocabulary, and reading interest). Rather than forcing all children through uniform exercises, teachers deliver differentiated SAS pathways aligned with diagnostic tiers.
2. *Multi-Sensory Digital Scaffolding:* The developed SAS digital literacy book replaces static text with interactive audio-visual feedback loops. When children tap word units, native voice prompts instantly model the analytic-synthetic transitions (e.g., /b/-/a/-/c/-/a/→/ba-ca/→baca). This real-time auditory reinforcement bridges the gap between grapheme and phoneme recognition, allowing children to self-correct and learn at an individualized pace without experiencing the frustration typical of print-only drill activities.

Extending Existing Scholarship and Reconciling Literature Gaps

These findings extend earlier research while addressing major unresolved issues in the literature:

- *Building Beyond Traditional SAS Studies:* While prior studies (e.g., Damayanti et al., 2024; Erlin & Saptono, 2025) established the pedagogical efficacy of the SAS method for beginning reading, they treated student cohorts homogeneously and relied on paper-based media. This study extends their work by demonstrating that SAS efficacy is maximized when paired with diagnostic data and interactive digital scaffolding.
- *Expanding Data-Driven Differentiation:* Research by Connor et al. (2020) and van Geel et al. (2022) established that data-driven differentiation improves student learning trajectories. However, these studies lacked concrete, subject-specific digital tools to help teachers execute differentiated instruction efficiently. Our study bridges this gap by embedding diagnostic tiers directly into a digital literacy application, providing teachers with a practical, manageable workflow.
- *Advancing Digital Literacy Frameworks:* Recent studies on ECE technology (e.g., Bautista, 2024; Maureen et al., 2020) confirmed that digital storytelling enhances engagement, yet few media tools incorporate a structured phonics framework. By embedding the systematic SAS hierarchy into a digital format,

this research demonstrates that educational technology is most effective when grounded in explicit, structured decoding methodologies rather than passive story consumption.

Demonstrating True Study Novelty

The distinct novelty of this study lies in the formulation and empirical validation of the Diagnostic-Driven Synthetic Phonics Framework. While previous literature evaluated diagnostic assessment, the SAS method, differentiated instruction, and digital learning media in isolation, this study synthesizes all four components into a single, cohesive instructional model. The primary contribution to the field of early childhood education is proving that structural phonics analysis (SAS) achieves optimal effectiveness only when guided by preliminary cognitive-linguistic mapping and supported by multi-sensory digital feedback. This integrated approach offers a scalable, evidence-based solution for implementing adaptive literacy instruction aligned with the goals of the *Kurikulum Merdeka* and Sustainable Development Goal 4 (Inclusive and Equitable Quality Education).

Furthermore, the significant literacy gains observed in this study align with the conclusions drawn by Indriani et al. (2025), who reported that structured phonics methodologies provide a critical foundation for foundational decoding skills in early childhood education. The success of the intervention also emphasizes the value of incorporating modern mediums, such as the developed digital literacy book, into conventional

analytical-synthetic frameworks. Merging the systematic steps of the SAS method with interactive digital materials increases reading interest and maintains engagement among young learners. This outcome confirms the findings of Maureen et al. (2020), whose research showed that integrating educational technology into early childhood storytelling and language environments accelerates vocabulary acquisition and print awareness. In conclusion, the integration of initial diagnostic assessments, differentiated instruction, and the SAS method creates a highly effective framework for early childhood literacy. This framework provides an empirical strategy for achieving inclusive and high-quality early education, in line with global sustainable development goals.

Conclusion

This study evaluated the development and effectiveness of a Structural Analytic Synthetic (SAS)-based digital literacy book guided by initial diagnostic assessments for early childhood education. The empirical findings demonstrate that integrating diagnostic profiling with the SAS method and interactive digital media leads to a statistically significant improvement in young children's early literacy skills ($t(19) = -14.62$, $p < .001$), yielding a medium-to-high learning gain (N-Gain = 0.62). Expert validation confirmed that the developed digital literacy book achieved high quality and pedagogical feasibility (90.5% average validity). Qualitative observations and teacher feedback further indicate

that preliminary diagnostic profiling enables educators to deliver differentiated SAS activities effectively, while the digital media's audio-visual feedback enhances student engagement and independent phonological practice.

Practically, these findings encourage early childhood educators to utilize diagnostic assessments before initiating literacy instruction and to adopt interactive SAS media to support differentiated learning. The study is limited by a small sample size (N = 20) restricted to three early childhood education centers in Cirebon Regency. Future research should extend the evaluation of SAS-based digital literacy tools across larger, more diverse student cohorts and investigate long-term impacts on emergent reading fluency.

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