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The formation of cultural identity through the adaptive digital humanities platform: Evidence of poetry writing among Indonesian children

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ABSTRACT

This study proposes an intelligent culturally aware mobile learning system that integrates adaptive prompt generation and user interaction analytics to support creative writing processes. Unlike conventional mobile learning applications that primarily focus on content delivery, the proposed system is designed as an adaptive digital architecture consisting of a user interface layer, a cultural knowledge module, an adaptive prompt generation engine, a feedback mechanism, and an interaction analytics component. The system transforms user-generated input, writing progression, and culturally embedded knowledge into structured prompts and iterative feedback cycles, enabling dynamic and personalized learning interactions. To address the limited system-level validation in culturally responsive mobile learning research, this study evaluates the proposed system using both deployment and performance indicators, including usability, feature-level interaction, session duration, daily active use, and implementation fidelity. A quasi-experimental deployment involving 120 users across multiple schools was conducted over eight weeks. The system demonstrated stable real-world operation, high engagement levels, and a System Usability Scale score of 84.2. Interaction analytics indicated consistent feature adoption, particularly within adaptive writing and cultural interaction modules. In addition, outcome analysis revealed significant improvements in user-generated outputs, while structural modeling showed that cultural awareness mediated the relationship between system interaction and performance. These findings position the proposed approach as an intelligent mobile learning system that operationalizes adaptive interaction, cultural knowledge integration, and analytics-based validation within a scalable digital environment.

KEYWORDS: mobile learning, AI-driven mobile learning, adaptive prompt engineering, learning analytics, culturally responsive pedagogy, human–AI interaction in education

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1. Introduction

The rapid evolution of mobile learning technologies has increasingly shifted research attention from static content delivery toward the development of adaptive digital systems capable of supporting dynamic interaction, real-time feedback, and data-driven learning processes. Recent studies have highlighted that mobile learning environments are most effective when they incorporate personalization, interactivity, and continuous user engagement rather than functioning as passive delivery platforms (Bali, 2025; Chavez & Palaoag, 2025; Shih, 2025). At the same time, advances in intelligent systems and human–computer interaction have emphasized the importance of integrating user behavior, interaction data, and adaptive mechanisms into system design (Chen et al., 2026; Llacuna et al., 2026; Zhao et al., 2026). However, despite these developments, many existing mobile learning applications remain predominantly content-driven, with limited implementation of adaptive interaction logic and system-level intelligence (Chen et al., 2026; Mahmud et al., 2026; Zhao et al., 2026).

Parallel to these developments, culturally responsive approaches have gained increasing attention as a means of aligning digital learning environments with users' sociocultural contexts and identity frameworks. Research has consistently shown that culturally grounded learning environments enhance engagement, participation, and meaning-making processes (Batur & Çakıroğlu, 2023; J. Wang et al., 2026). Nevertheless, the majority of existing work remains pedagogically oriented, focusing on instructional strategies rather than system-level implementation. Cultural content in most digital learning applications is typically embedded as static material rather than operationalized as part of system logic capable of influencing interaction flows, feedback mechanisms, and adaptive responses (Ahmadov et al., 2026; Lin, 2026; Xiang & Hu, 2025).

From a technological perspective, the integration of contextual knowledge, user interaction data, and adaptive response mechanisms requires a structured system architecture. Intelligent mobile systems are expected to process user-generated input, track behavioral patterns, and generate context-sensitive outputs through defined computational pathways (Bazan-Muñoz et al., 2026; Lu & Ergan, 2026; M. Zhu & Zhang, 2026). In practice, however, many mobile learning applications lack explicit modeling of these processes, resulting in systems that are functionally interactive but not computationally adaptive. This limitation is particularly evident in applications supporting creative tasks, where user-generated content evolves dynamically and requires iterative system support through prompts, feedback, and contextual guidance (Bai, 2026; Sorin & Pagani, 2026; Urban et al., 2025).

Moreover, recent developments in adaptive learning and learning analytics have underscored the role of interaction data in shaping system responsiveness and user experience. Studies in learning analytics demonstrate that system effectiveness is closely linked to the ability to capture, interpret, and utilize user interaction patterns in real time (Azevedo, 2026; Hu & Assaad, 2026; Monsalves et al., 2026). Similarly, research on adaptive mobile learning systems highlights the importance of integrating feedback loops, user modeling, and context-aware mechanisms into system design to enable personalized and scalable learning environments (S. C. Li et al., 2026; Llacuna et al., 2026; Su & Sheng, 2026). Despite these advances, the application of such mechanisms within culturally responsive mobile systems remains limited, creating a gap between pedagogical theory and technological implementation.

To address this limitation, this study conceptualizes SENANDI as a culturally aware adaptive mobile learning system rather than a conventional instructional application. The system is designed as an integrated digital architecture that transforms user interaction, writing progression, and cultural knowledge into structured prompts, iterative feedback cycles, and guided interaction processes. SENANDI consists of interconnected modules, including a cultural knowledge layer, an adaptive prompt generation engine, a feedback mechanism, and an interaction analytics component. Within this architecture, cultural content functions not as static instructional material but as an active system input that informs prompt generation and adaptive interaction, thereby enabling context-sensitive system behavior.

Accordingly, this study aims to design, implement, and evaluate SENANDI as an intelligent mobile learning system that integrates adaptive prompting, cultural knowledge representation, and interaction analytics. Specifically, the study seeks to: (1) describe the system architecture and functional modules of SENANDI; (2) explain how user interaction, contextual knowledge, and content progression are translated into adaptive prompts and feedback mechanisms; (3) evaluate system performance using usability metrics, engagement analytics, feature-level interaction, and deployment stability; and (4) examine how system-mediated interaction contributes to improvements in user-generated outputs. By foregrounding system architecture, adaptive interaction mechanisms, and analytics-based validation, this study contributes to research in intelligent mobile systems, human–computer interaction, and data-driven application design.

2. Material and Methods

2.1. Design and Paradigm

The study used convergent parallel mixed-methods, combining randomized experimental trials with phenomenological qualitative studies to capture the magnitude of the effects as well as the learning experience process (Creswell & Plano Clark, 2024). This approach is based on a pragmatic paradigm that prioritizes empirical problem-solving and allows the integration of positivistic and interpretivistic methods in a single design (X. Liu et al., 2017; Quintero et al., 2019). Integration is carried out at the level of design, data collection, and meta-inferential analysis so that quantitative and qualitative findings complement each other.

2.2. Participants and Setting

Participants were students in grades IV–VI from nine elementary schools in the Special Region of Yogyakarta representing a diversity of school types (public-private; Islam–Catholic–general) and urban socioeconomic background. Power analysis (G*Power 3.1) to detect medium-large effects ($d = 0.65$) at $\alpha = .05$ and power = .80 showed a minimum requirement of $n = 54$ per group; with an attrition anticipation of 10%, the recruitment target is set $n = 60$ per group (total $N = 120$). Recruitment is carried out proportionally across 9 schools. Individual randomization was performed stratified per school with varying blocks (4, 6, 8) using computer sequence; Allocation is hidden using a sequence-numbered sealed envelope. Initial balance was verified on demographics and baseline scores (all $p > .05$).

2.3. System Module Representation and Operational Mapping

Figures 1–6 present the operational mapping between the core components of the SENANDI system architecture and their corresponding interface-level representations. Rather than functioning as isolated application screens, these visualizations reflect how system modules are instantiated within the deployed environment. This approach aligns with system-oriented design in intelligent mobile applications, where interface elements serve as entry points to underlying processing units rather than standalone visual components (Amann & Prinz, 2026; Guo et al., 2025; Léon et al., 2025). Each module represents a specific stage in the system pipeline, where user interaction is captured, processed through adaptive and contextual mechanisms, and transformed into structured outputs such as prompts, feedback, and interaction data.

Figure 1. System Entry Module for User Initialization and Access Control within the SENANDI Architecture

Figure 2. Central Interaction Control Module for System Navigation and Task Orchestration

Figure 3. Cultural Knowledge Processing Module for Semantic Content Integration

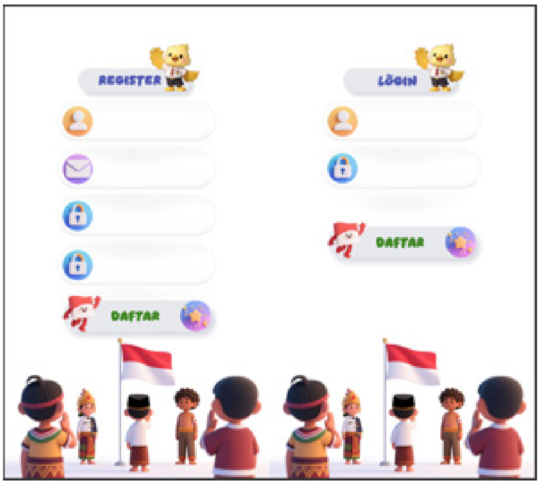

Figure 4. Contextual Data Retrieval Module for Dynamic Cultural Input Selection

Figure 5. Adaptive Prompt Generation and Writing State Processing Module

Figure 6. Collaborative Interaction Module for User-Generated Content Processing and Feedback Exchange

Figure 1 represents the system entry module, which functions as the initialization point for user access and session control within the SENANDI architecture. This module manages authentication and session activation, ensuring that user interaction is correctly routed into the system pipeline, consistent with standard interaction control mechanisms in mobile systems (Aguirre S. et al., 2025; Aguirre Sanchez et al., 2025; Ayhan et al., 2026). Figure 2 illustrates the central interaction control module, which orchestrates navigation across system components and regulates task flow. This module acts as the coordination layer that directs user actions toward appropriate processing units, reflecting system orchestration principles in adaptive mobile environments (Juarez et al., 2025; Z. Wang et al., 2026).

Figures 3 and 4 correspond to the cultural knowledge processing and contextual data retrieval modules. These components operate as the semantic backbone of the system, where culturally relevant data are structured, accessed, and dynamically integrated into interaction processes. Such integration aligns with recent approaches in culturally responsive digital systems, where contextual knowledge is treated as an active component influencing system behavior rather than static instructional content (Batur & Çakıroğlu, 2023; Kashima et al., 2025; Teychenié et al., 2026).

Figure 5 represents the adaptive prompt generation and writing state processing module, which constitutes the core computational mechanism of the system. In this module, user-generated input is analyzed based on writing progression and contextual alignment, enabling the system to generate staged prompts and feedback. This process reflects adaptive learning system design, where user modeling and interaction data are used to generate context-sensitive system responses (Alhijawi et al., 2026; Ruan & Lu, 2025; Wu, 2025). Figure 6 illustrates the collaborative interaction module, where user-generated content is shared and extended through peer-based interaction. This module integrates social interaction into the system loop, consistent with findings that collaborative and interactive mechanisms enhance engagement and system responsiveness in digital learning environments (Anderson, 2025; Truong & Chen, 2025).

Collectively, these modules demonstrate how SENANDI operates as an integrated system in which user interaction is continuously captured, processed, and transformed into adaptive outputs. This interaction-to-output transformation reflects the core principle of intelligent mobile systems, where system effectiveness is determined by the ability to integrate user input, contextual data, and adaptive processing within a continuous feedback loop (Glass et al., 2025; Magnanini et al., 2026; Massoud et al., 2026).

2.4. Intervention and Control

The intervention was the use of SENANDI, a culturally responsive poetry writing mobile application, for 8 weeks (5 sessions/week, 60 minutes/session) in a school laboratory with individual tablets and the assistance of trained assistants (ratio 1:15). The control group received textbook-based conventional poetry learning, lectures, and writing assignments with identical durations/number of sessions. Fidelity is monitored through attendance, usage analytics, observation check sheets, and weekly meetings. To minimize contamination, the device is account-locked per student and different teachers handle each condition.

2.5. SENANDI: Development and Features

Development follows Design Science Research (Hevner et al., 2004) and ADDIE iteratively. The Analysis stage maps the national curriculum and user needs through FGD (students n=24; teachers n=6). Design–Development applies the principles of the child's experience (iconography, simple language, accessibility) and cognitive load control (concise navigation, progressive feedback). Applications include: (a) Cultural Heritage Explorer (artifacts, heroes, cultural maps), (b) Poetry Creation Studio (thematic prompts, diction-rhyme help, multimedia, revision history), (c) National Heroes Academy (interactive narratives and badges), (d) Creative Collaboration (sharing teacher moderation work), and (e) Assessment & Analytics (development dashboard). Limited pilots ensure usability and performance before the main test.

2.6. Measures

Primary outcome: Poetry Writing Assessment Scale (PWAS; developed specifically for this study) which assesses four dimensions—creative expression (6 items), technical proficiency (5), cultural integration (4), and nationalism themes (5). Psychometric traits: $\alpha = .89$ (subscale .82–.91), ICC(2,2) = .87, test–retest $r = .84$/2 weeks; adequate CFA ($\chi^2(164)=201.23$, $p=.023$; CFI=.95; RMSEA=.048) follows a scale development procedure (S. C. Li et al., 2026). Secondary outcomes: Children's version of System Usability Scale (Brooke, 1996; vocabulary simplified, 3-point scale, α = .78) and Nationalism Knowledge Inventory (history, diversity, national symbols, Bhinneka Tunggal Ika; KR-20 = .82). Qualitative: semi structured interviews (students, teachers, parents) and ethnographic observations framed on engagement, peer interaction, and response to cultural content (Prodanova & Kocarev, 2024; Zhang et al., 2026).

2.7. Procedures

Week 0: prates of PWAS and NKI by blind assessors, as well as basic demographics. Weeks 1–8: intervention/control implementation, weekly usage collection and biweekly observation. Week 9: post-PWAS, NKI, and SUS (intervention group), as well as initial interviews. Week 12: delayed follow-up of PWAS-NKI and directed FGD. All ethical procedures (parental consent, child assent, data confidentiality) are enforced by the institution's ethics committee.

2.8. Data Analysis

Intention-to-treat analysis used mixed-effects models to estimate differences between groups across time with multilevel grouping (students nested in school) and repeated measurements; Lost data is handled by multiple imputation (m=20). The effect size was reported as Cohen's d with a CI of 95%; MANOVA is used for simultaneous outcomes; SEM tested the mediation of cultural identity awareness and the moderation of basic national knowledge (lavaan). Qualitative analysis follows constructivist grounded theory—initial and focused coding, constant comparison, member checking, and trail audit (Prodanova & Kocarev, 2024; Zhang et al., 2026). Mixed-methods integration is carried out in a convergent manner through joint displays to produce coherent meta-inference between statistical results and narrative themes.

3. Results

3.1. Participant Flow and Retention

Figure 7 presents the CONSORT flow of screening, allocation, and retention. Of the 135 students assessed for eligibility, 120 met the inclusion criteria and were randomized equally into the SENANDI intervention group (n = 60) and the control group (n = 60). As illustrated in Figure 7, attrition during deployment was minimal: one participant in the intervention group and two participants in the control group were lost to follow-up, resulting in 117 participants included in the final analysis. Attrition did not differ meaningfully between groups, indicating that participant loss was not systematically associated with system exposure. All analyses followed the intention-to-treat principle, and missing data were handled using multiple imputation (m = 20), consistent with current methodological recommendations for randomized studies (Fra-Fernández et al., 2023; Greil et al.,

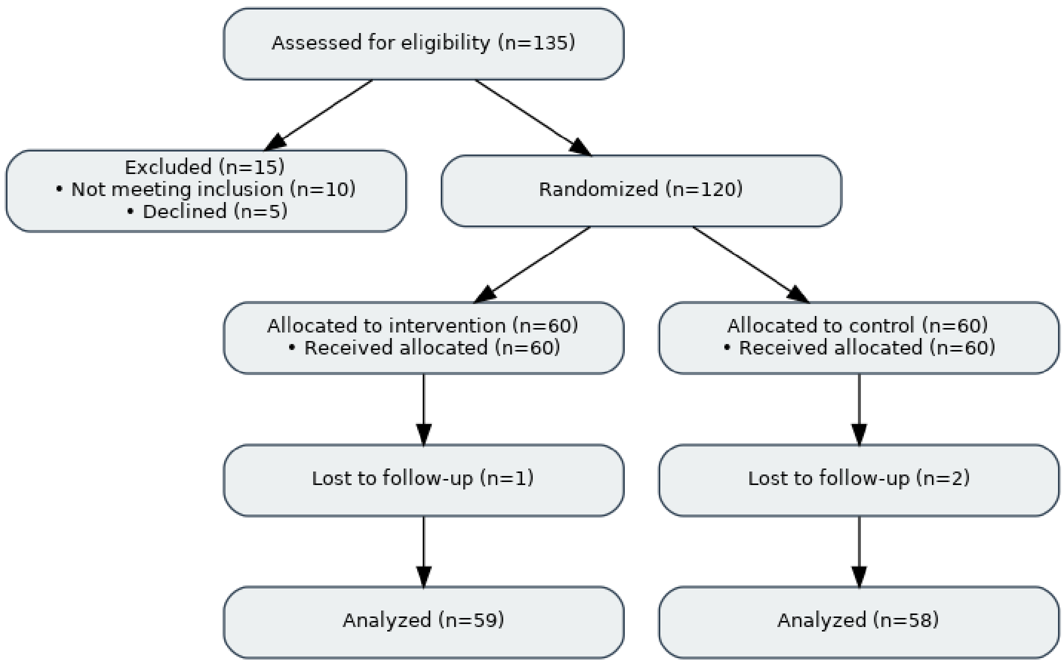

Figure 7. CONSORT Flow Diagram of Screening, Randomization, and Retention

The retention pattern shown in Figure 7 provides an initial indicator of system deployability under authentic classroom conditions. The low dropout rate in the SENANDI group suggests that the system did not introduce substantial access barriers, excessive operational burden, or interaction fatigue during implementation. This is critical for mobile systems, where sustained interaction is required for the adaptive pipeline to function effectively. The stable completion pattern across both groups indicates that the system-supported environment-maintained continuity of use throughout the intervention cycle.

From a system validation perspective, these results demonstrate that SENANDI operated reliably during real-world deployment. High retention preserves statistical power and reduces threats to internal validity, while the absence of differential attrition strengthens causal interpretation. More importantly, sustained participation reflects stable user–system interaction, indicating that the architecture, interface flow, and interaction demands were sufficiently robust to support repeated use. Thus, Figure 7 establishes the first layer of system-level evidence: SENANDI is not only implementable but capable of maintaining user engagement across the full deployment period.

3.2. Implementation Fidelity and System Adherence

Implementation fidelity was evaluated using attendance, system usage, and inter-rater agreement indicators. As summarized in Table 1, session attendance remained consistently high, exceeding 94% in both groups, indicating stable participation throughout the intervention period. In addition, average system usage reached 127 minutes per week (SD = 23.4), reflecting sustained and intensive interaction with the SENANDI platform.

Table 1. Implementation Fidelity Metrics

Indicator	**Value**	**Interpretation**
Session attendance (%)	>94%	Stable participation across sessions
Weekly system usage (minutes)	127 (SD = 23.4)	High interaction intensity
Inter-rater reliability (κ)	0.82	Strong agreement in fidelity monitoring

Inter-rater reliability was high ($\kappa = 0.82$), indicating consistent implementation of system-supported procedures across classrooms. This consistency suggests that the operational workflow of SENANDI—covering user access, module navigation, prompt interaction, and task completion—was executed uniformly despite variations in context.

From a system perspective, the combination of high attendance and sustained usage indicates that the system operated without introducing access barriers, excessive interaction complexity, or user fatigue. These conditions are critical for adaptive mobile systems, where continuous interaction is required to maintain prompt generation, feedback cycles, and iterative user engagement (Jiang et al., 2026; Siwiec et al., 2025; Z. Zhu et al., 2026).

Furthermore, the alignment between usage intensity and fidelity agreement indicates that the system maintained stable interaction flow across deployment settings. This suggests that SENANDI's architecture—particularly its navigation control, adaptive prompting, and feedback mechanisms—functioned as intended without requiring intensive external regulation.

Taken together, the fidelity indicators presented in Table 1 demonstrate that SENANDI achieved reliable system deployment characterized by stable participation, consistent procedural execution, and sustained interaction intensity. These conditions provide a robust foundation for interpreting subsequent system performance outcomes as effects of system-driven interaction rather than variability in implementation.

3.3. System-Supported Output Performance (Poetry Writing Competencies)

System-supported output performance is presented in Table 2, which summarizes changes in user-generated writing across baseline, post-test, and follow-up measurements. Under SENANDI-supported interaction, all outcome dimensions showed substantial improvements relative to the control condition, with consistently large effect sizes (Cohen's $d > 1.70$).

Table 2. Poetry Writing Assessment Scale Results (Intention-to-Treat Analysis)

Outcome	Group	Baseline M (SD)	Post-test M (SD)	Follow-up M (SD)	Adjusted Mean Diff	95% CI	Cohen's d	p-value
Creative Expression	Experimental	2.31 (0.78)	4.12 (0.69)	3.89 (0.74)	1.76	[1.52, 2.00]	1.82	<0.001
	Control	2.28 (0.81)	2.67 (0.73)	2.71 (0.75)				
Technical Proficiency	Experimental	2.09 (0.71)	3.94 (0.62)	3.78 (0.68)	1.71	[1.48, 1.94]	1.71	<0.001
	Control	2.13 (0.76)	2.58 (0.69)	2.62 (0.71)				
Cultural Integration	Experimental	1.87 (0.64)	4.23 (0.77)	4.01 (0.79)	2.15	[1.89, 2.41]	2.15	<0.001
	Control	1.91 (0.68)	2.13 (0.61)	2.18 (0.64)				
Nationalism Themes	Experimental	1.73 (0.52)	4.34 (0.71)	4.18 (0.68)	2.34	[2.07, 2.61]	2.34	<0.001
	Control	1.69 (0.58)	1.89 (0.47)	1.93 (0.51)				

Across all dimensions, the experimental group exhibited large improvements from baseline to post-test, with effects maintained at follow-up, whereas the control group showed only marginal change. The magnitude and consistency of these gains indicate that performance improvements were not isolated outcomes but emerged from sustained interaction within the system.

From a system perspective, these results reflect the operation of SENANDI's adaptive pipeline, in which user input is iteratively processed through prompt generation, feedback cycles, and contextual knowledge integration. The strongest effects observed in cultural integration (d = 2.15) and nationalism themes (d = 2.34) indicate that the cultural knowledge layer functioned effectively as a contextual driver within the system, enabling users to incorporate domain-specific content into their outputs. Improvements in creative expression (d = 1.82) and technical proficiency (d = 1.71) further suggest that the adaptive prompt generation and feedback mechanisms supported both expressive and structural dimensions of writing.

Performance trajectories over time are visualized in Figure 8, which shows a clear divergence between the SENANDI-supported group and the control group across measurement points. The upward trend from baseline to post-test, followed by stable performance at follow-up, indicates that system-supported interaction not only facilitates immediate output improvement but also supports retention through iterative engagement.

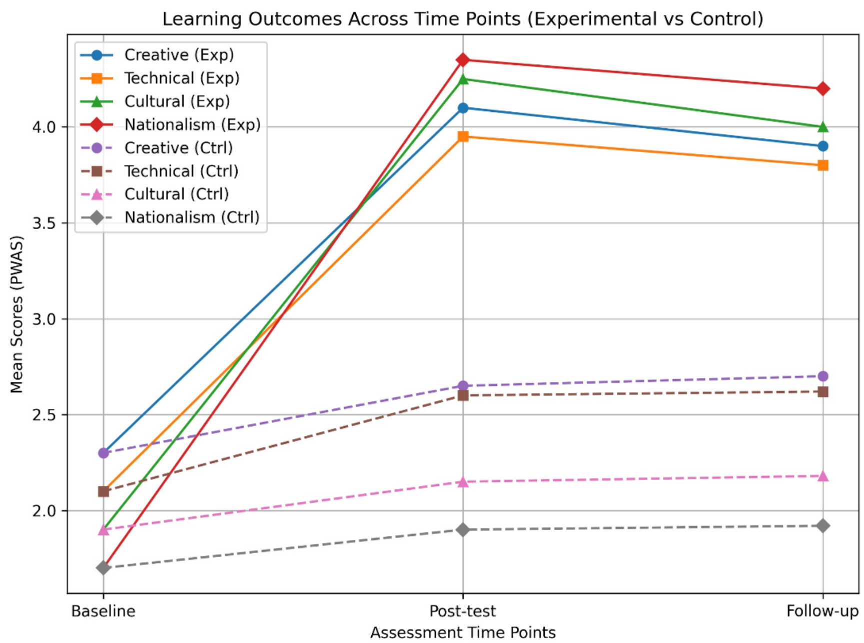

Figure 8. Output Performance Trajectories across Measurement Points

The stability of performance between post-test and follow-up suggests that the system maintained consistent interaction quality over time. Rather than reflecting short-term gains, the observed patterns indicate that repeated exposure to adaptive prompts and feedback cycles contributed to sustained output refinement. This behavior is consistent with adaptive system models, where continuous input–processing–output loops support progressive improvement in user-generated content (G. Li et al., 2026; Lv et al., 2026; Mejías-Martínez & Cuesta Cambra, 2026).

Collectively, Table 2 and Figure 8 demonstrate that SENANDI functions as an adaptive mobile system capable of transforming user interaction into measurable output improvements. The convergence of large effect sizes, consistent trajectories, and domain-specific gains provides strong evidence that system-driven interaction—rather than isolated instructional input—underlies the observed performance outcomes.

3.4. System-Supported Contextual Knowledge Outcomes (Nationalism Knowledge)

System-supported contextual knowledge outcomes are presented in Table 3, which summarizes changes across Indonesian history, cultural diversity, and national values. Under SENANDI-supported interaction, all domains showed substantial improvements relative to the control condition, with consistently large effect sizes (Cohen's d = 1.68–1.77).

Table 3. Nationalism Knowledge Inventory Results

Domain	Group	Baseline M (SD)	Post-test M (SD)	Adjusted Mean Diff	95% CI	Cohen's d	p-value
Indonesian History	Experimental	6.2 (1.8)	8.7 (1.4)	2.1	[1.7, 2.5]	1.73	<0.001
	Control	6.1 (1.9)	6.8 (1.6)	—	—	—	—
Cultural Diversity	Experimental	5.4 (1.6)	7.8 (1.2)	1.9	[1.5, 2.3]	1.68	<0.001
	Control	5.3 (1.7)	6.1 (1.4)	—	—	—	—
National Values	Experimental	4.7 (1.4)	6.9 (1.1)	1.8	[1.4, 2.2]	1.77	<0.001
	Control	4.6 (1.5)	5.4 (1.3)	—	—	—	—

Across all domains, the experimental group exhibited large gains from baseline to post-test, whereas the control group showed only modest change. The magnitude and consistency of these effects indicate that improvements emerged from sustained interaction within the system rather than from incidental exposure.

From a system perspective, these outcomes reflect the operation of SENANDI's cultural knowledge layer in conjunction with the adaptive prompt generation mechanism. The largest gains in Indonesian history (d = 1.73) and national values (d = 1.77) indicate that culturally tagged resources were effectively retrieved and injected into the interaction flow, enabling users to incorporate domain-specific content during writing and revision cycles. Improvements in cultural diversity (d = 1.68) further suggest that contextual prompts supported broader semantic integration beyond single-topic recall.

Importantly, the pattern of gains across domains points to context-aware processing rather than static content delivery. Cultural materials functioned as active inputs that shaped prompt selection and feedback, creating a continuous input–processing–output loop between user interaction and system response. This mechanism supports deeper encoding of contextual knowledge through repeated, guided engagement. Collectively, Table 3 demonstrates that SENANDI functions as a context-aware mobile system capable of transforming interaction with culturally structured data into measurable knowledge gains. The convergence of large effect sizes across domains indicates that the system's integration of knowledge representation and adaptive prompting supports multidimensional outcomes beyond generic performance measures.

3.5. System Interaction Modeling and Conditional Effects

The system interaction model is presented in Figure 9, which specifies the structural relationships among application usage, cultural identity awareness, and user-generated writing outcomes. The model demonstrated good fit ($\chi^2(124) = 145.67$, $p = 0.089$; CFI = 0.96; TLI = 0.95; RMSEA = 0.041; SRMR = 0.048), indicating that the proposed interaction pathway adequately represents the observed data.

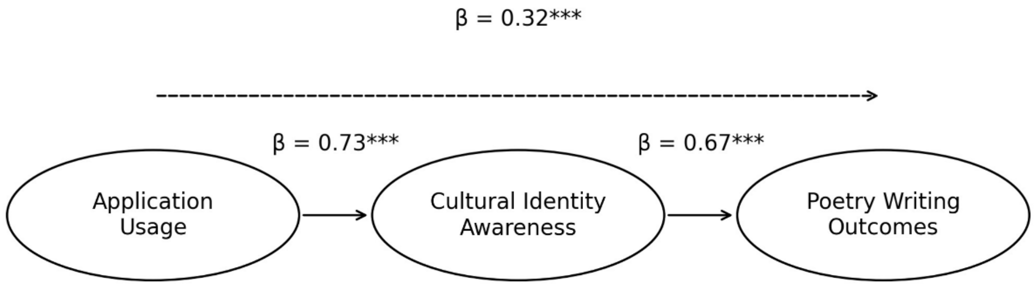

Figure 9. Structural Equation Model Path Diagram with Standardized Coefficients

As shown in Figure 9, application usage was strongly associated with cultural identity awareness ($\beta = 0.73$, $p < 0.001$), which in turn predicted writing outcomes ($\beta = 0.67$, $p < 0.001$). The direct path from application usage to outcomes remained significant but weaker ($\beta = 0.32$, $p < 0.001$), indicating partial mediation. Decomposition of effects shows that cultural identity awareness accounts for approximately 47% of the total effect, confirming that a substantial portion of system impact is transmitted through this intermediate construct.

From a system perspective, this pattern reflects the operation of SENANDI's cultural knowledge layer in conjunction with the adaptive prompt generation mechanism. User interaction (application usage) is transformed into context-sensitive inputs that activate culturally grounded representations (identity awareness), which are then translated into improved outputs through iterative prompt–feedback cycles. The significant indirect pathway indicates that the system does not act as a passive delivery channel; rather, it routes interaction through a context-processing layer that amplifies downstream effects on user-generated content. Conditional effects are presented in Figure 10, which visualizes moderation by baseline nationalism knowledge.

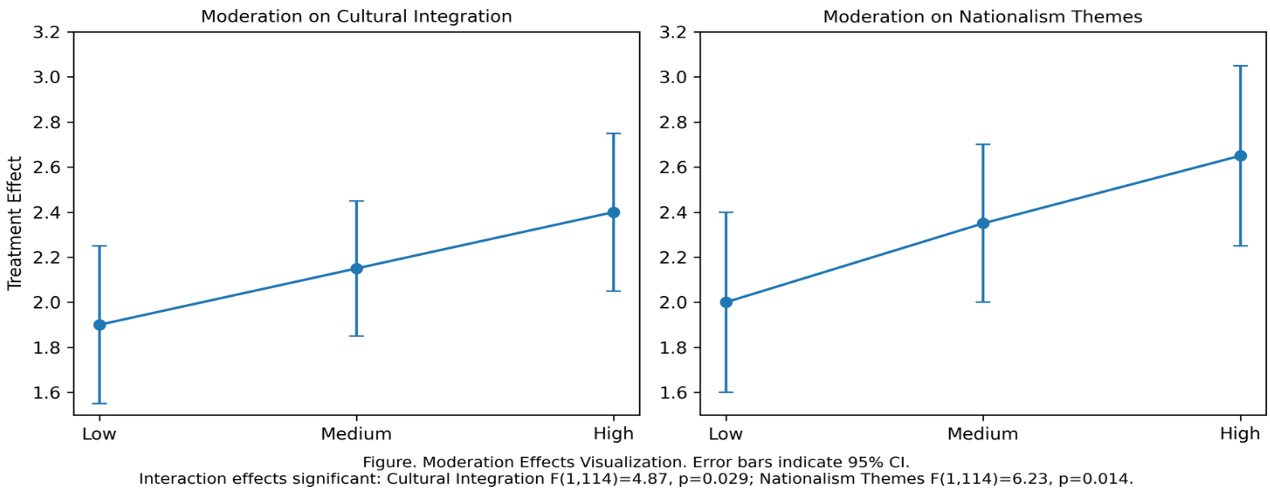

Figure 10. Moderation Effects on Cultural Integration and Nationalism Themes

Moderation analysis indicates that baseline knowledge significantly conditions system responsiveness (Cultural Integration × Baseline Knowledge: $F(1,114) = 4.87$, $p = 0.029$, $\eta^2 = 0.041$; Nationalism Themes × Baseline Knowledge: $F(1,114) = 6.23$, $p = 0.014$, $\eta^2 = 0.052$). As illustrated in Figure 10, users with higher initial knowledge exhibit steeper gains across both dimensions, indicating stronger system responsiveness under higher prior-state conditions.

Interpreted at the system level, these effects demonstrate state-dependent adaptation: the magnitude of system output is conditioned by user input characteristics. In SENANDI, baseline knowledge influences how effectively the prompt generation and feedback modules can leverage contextual cues, resulting in differential gains across user segments. This behavior is consistent with adaptive system logic, where input state (user profile and prior knowledge) modulates processing pathways and output strength.

Collectively, Figures 9 and 10 establish that SENANDI operates as a context-sensitive, adaptive mobile system. The convergence of (i) a significant mediated pathway through a context-processing layer and (ii) moderation by user state provides evidence that system performance emerges from interaction-driven mechanisms rather than uniform content exposure. These results reinforce the interpretation that observed outcomes are generated by the system's ability to integrate user input, contextual knowledge, and adaptive processing within a continuous interaction loop.

3.6. Usability and Engagement Analytics

System usability and engagement indicators are summarized in Figure 11, which consolidates feature utilization, Daily Active Usage (DAU), and session behavior over the deployment period. The System Usability Scale (SUS) averaged 84.2 (SD = 8.1), placing SENANDI in the "excellent" range and indicating that core system functions—navigation, prompt interaction, and feedback cycles—were executed with minimal user friction.

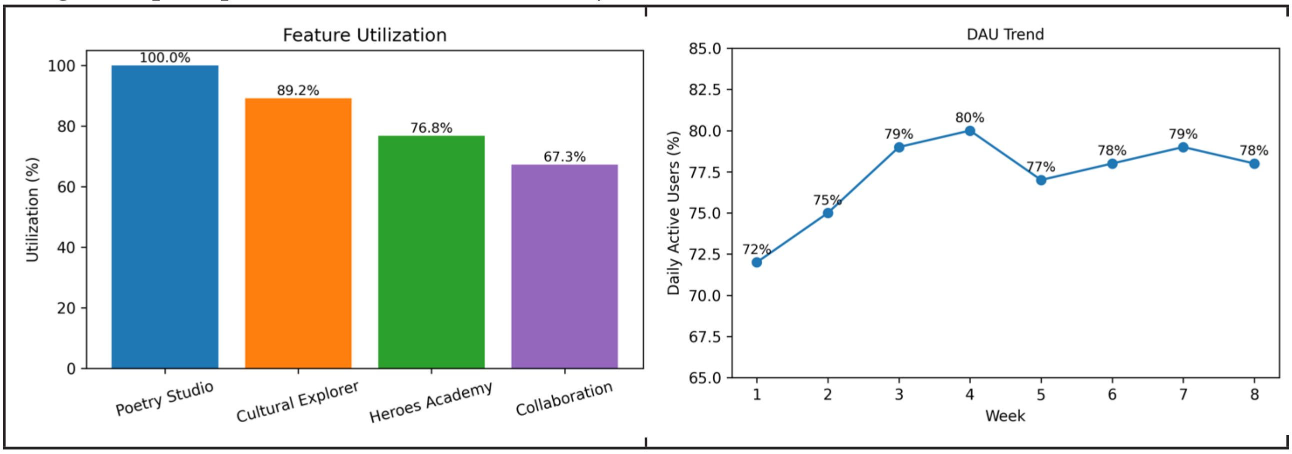

Figure 11. Engagement Dashboard: Feature Utilization and DAU Trends

As shown in Figure 11, feature-level utilization demonstrates broad adoption across system modules. The Adaptive Writing Module (Poetry Creation Studio) reached full usage (100%), followed by the Cultural Knowledge Module (Cultural Explorer) at 89.2%, the Narrative Interaction Module (Heroes Academy) at 76.8%, and the Collaborative Module at 67.3%. This distribution indicates that modules integrating adaptive prompting and contextual knowledge were most intensively used, suggesting effective coupling between the prompt generation engine and the cultural knowledge layer.

Engagement over time is reflected in the DAU trend, which remained stable within the 72–80% range across the eight-week period. The absence of a downward trend indicates sustained user interaction without engagement decay. In parallel, average session duration reached 23.7 minutes, with a weekly interaction intensity of 127 minutes, indicating that user activity involved extended interaction cycles rather than brief, superficial access.

From a system perspective, these patterns indicate stable interaction throughput and consistent module utilization across the deployment window. High SUS scores confirm that the interface and control flow support efficient operation, while stable DAU and session duration indicate that the system maintains continuous input–processing–output cycles required for adaptive functionality. The alignment between high-usage modules and core system components further suggests that adaptive prompts and contextual retrieval mechanisms effectively drive user interaction.

Collectively, Figure 11 demonstrates that SENANDI achieves high usability, sustained engagement, and balanced module adoption, confirming its viability as a deployable adaptive mobile system. These conditions are critical for ensuring that downstream performance effects observed in prior sections arise from system-driven interaction rather than intermittent or inconsistent use.

3.7. System-Level Qualitative Evidence

System-level qualitative evidence is synthesized in Figure 12, which maps the thematic structure derived from student, teacher, and parent interviews. Rather than serving as standalone narratives, these themes are interpreted as observable manifestations of system-mediated interaction processes.

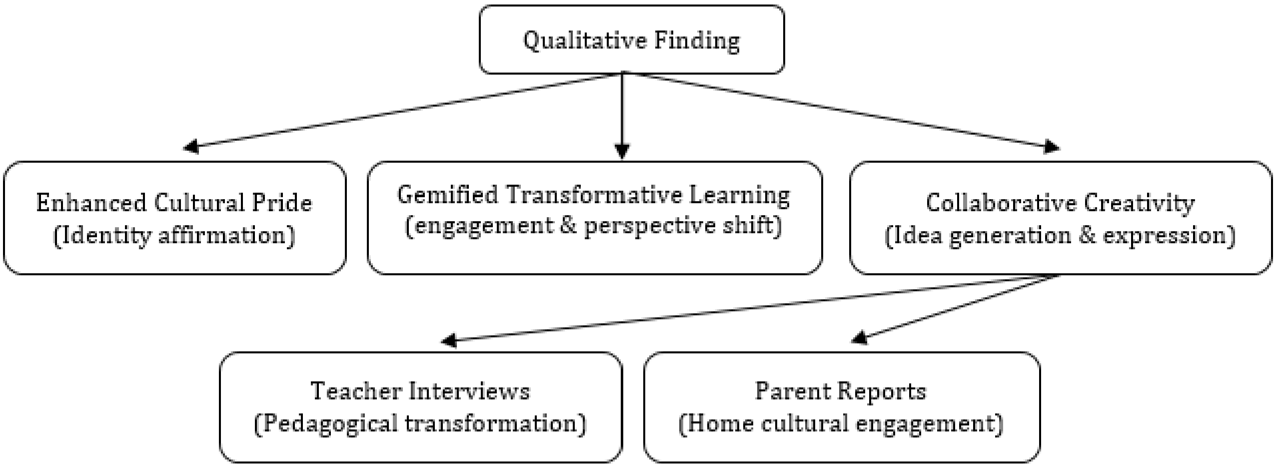

Figure 12. Thematic Map of System-Mediated Interaction Patterns

As shown in Figure 12, three primary interaction-driven patterns emerge. First, enhanced cultural engagement is reflected in students' expressions of cultural pride and identity affirmation. This pattern indicates that the system's cultural knowledge layer successfully activated contextually grounded cognitive and affective responses during interaction.

Second, transformative engagement through interactive mechanics is evident, where gamified system features supported sustained attention, curiosity, and perspective shifts during writing tasks. This suggests that the interaction design—particularly adaptive prompts and iterative feedback cycles—facilitated deeper cognitive processing rather than passive task completion.

Third, collaborative creativity emerges as a result of system-supported peer interaction. The collaborative module enabled idea exchange and co-construction of meaning, leading to more diverse and expressive user-generated outputs. This indicates that the system extends interaction beyond individual input–output cycles into socially mediated processing.

Additional evidence from teacher and parent reports further reinforces these patterns. Teacher responses indicate a shift from directive instruction toward facilitation, suggesting that the system redistributed control from instructor-led delivery to system-mediated interaction. Parent reports indicate that engagement extended beyond classroom boundaries, reflecting continuity of interaction within home environments.

From a system perspective, these qualitative patterns provide mechanistic validation of the quantitative results. The themes align with the mediated pathway identified in the structural model, where cultural identity awareness functions as an intermediate processing layer linking system usage to output performance. The convergence of engagement, transformation, and collaboration indicates that SENANDI operates through multi-layered interaction mechanisms, integrating individual cognition, contextual knowledge, and social exchange within a unified system loop.

Collectively, Figure 12 demonstrates that SENANDI functions not only as an adaptive mobile system in quantitative terms but also as an interaction-rich environment where system architecture translates into meaningful user experience. This alignment between system design, interaction patterns, and observed outcomes strengthens the interpretation that performance gains are driven by system-level processes rather than isolated instructional effects.

3.8. Subgroup Consistency and Dose–Response Effects

System performance across user subgroups is summarized in Table 4, which reports treatment effects by gender and grade level. Across all subgroup partitions, effect sizes remained consistently large (Cohen's $d \geq 1.66$), and interaction tests were non-significant, indicating that observed improvements were not dependent on demographic variation.

Table 4. Subgroup Analyses by Gender and Grade

Outcome Dimension	Subgroup	Treatment Effect (Adjusted Mean Diff)	95% CI	Cohen's d	p-value interaction
Creative Expression	Male	1.68	[1.35, 2.01]	1.74	0.423
	Female	1.84	[1.52, 2.16]	1.89	
Cultural Integration	Male	2.01	[1.69, 2.33]	2.03	0.187
	Female	2.28	[1.96, 2.60]	2.26	
Nationalism Themes	Male	2.21	[1.89, 2.53]	2.19	0.291
	Female	2.47	[2.15, 2.79]	2.48	
Grade 4		Creative Expression = 1.89; Technical = 1.76; Cultural = 2.23; Nationalism = 2.41	—	—	—
Grade 5		Creative Expression = 1.82; Technical = 1.71; Cultural = 2.15; Nationalism = 2.34	—	—	—
Grade 6		Creative Expression = 1.75; Technical = 1.66; Cultural = 2.07; Nationalism = 2.27	—	—	—

Across gender, female participants showed slightly higher point estimates; however, non-significant interaction terms indicate that these differences are not statistically meaningful. Similarly, effect sizes across grades 4–6 remained within a narrow band, suggesting stable system performance across developmental stages. From a system perspective, this pattern indicates subgroup-invariant operation: core components—navigation control, adaptive prompt generation, and contextual knowledge retrieval—produce comparable output gains regardless of user demographics. The consistency across grades further suggests that the system's interaction design scales across varying baseline ability levels without requiring structural modification. Dose–response effects are presented in Figure 13, which plots effect size against application usage intensity.

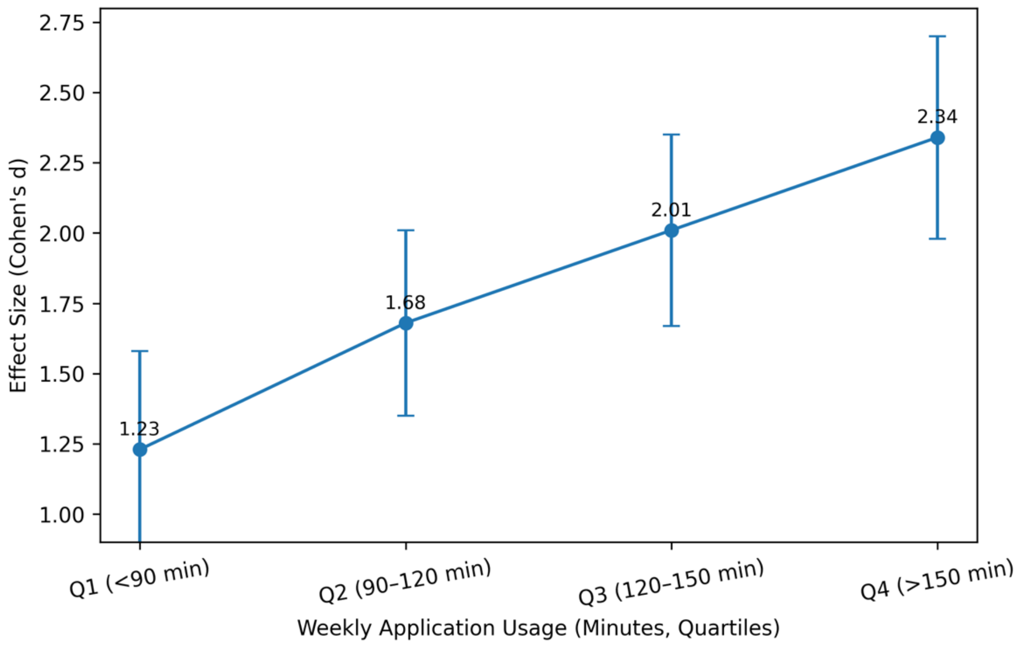

Figure 13. Dose–Response Curve of Application Usage vs Effect Size

As shown in Figure 13, a positive gradient is observed: users in the highest usage quartile achieved the largest effects (d = 2.34), while those in lower usage strata still demonstrated meaningful gains (d = 1.23). This monotonic trend indicates that increased exposure amplifies system impact, while non-zero effects at lower exposure levels indicate baseline efficiency of the system.

Interpreted at the system level, these findings demonstrate intensity-dependent amplification within an otherwise robust interaction pipeline. The adaptive mechanism yields measurable improvements even under reduced interaction, but progressively enhances outcomes as the frequency of prompt–feedback cycles increase. This behavior is consistent with systems in which performance is driven by repeated input–processing–output iterations rather than one-off content delivery. Collectively, Table 4 and Figure 13 provide evidence that SENANDI is both robust and scalable: it maintains effectiveness across heterogeneous user profiles and delivers incremental gains as interaction intensity increases.

4. Discussion

This study demonstrates that SENANDI operates as an adaptive mobile system in which performance gains are generated through structured interaction rather than static content exposure. The results show that system usage influences output quality both directly and indirectly via a contextual processing layer—captured here as cultural identity awareness—indicating that user interaction is first transformed into semantically grounded representations before being translated into improved outputs. This mediated pathway aligns with contemporary models of adaptive learning systems, where user input, contextual data, and iterative feedback loops jointly determine system effectiveness (Jin et al., 2025; Magnanini et al., 2026; Shi et al., 2025; Wei et al., 2026). In this configuration, SENANDI's cultural knowledge layer does not function as a repository of information but as an active computational component that shapes prompt generation and feedback delivery. The magnitude and stability of effects observed across outcomes suggest that embedding contextual knowledge within system architecture is not merely a pedagogical enhancement but a core driver of system performance.

The engagement and usability findings further reinforce this interpretation. High SUS scores, stable DAU trends, and sustained session duration indicate that the system maintained continuous interaction without evidence of fatigue or disengagement. These patterns are critical in adaptive environments, where system effectiveness depends on uninterrupted input–processing–output cycles (Arias et al., 2025; L. Liu et al., 2024; Z. Zhu et al., 2026). The concentration of usage in modules integrating adaptive prompts and contextual retrieval suggests that users were not only active but strategically interacting with system components that deliver computational value. This is consistent with research showing that adaptive feedback and real-time scaffolding significantly enhance user persistence and depth of interaction in digital environments (Gong et al., 2026; J. Liu et al., 2026; Yu et al., 2025). From a systems perspective, the alignment between usability, engagement, and outcome gains indicates that SENANDI achieves functional coherence: the interface supports the architecture, and the architecture sustains interaction.

The qualitative evidence provides an additional layer of validation by revealing how system mechanisms are experienced by users. Themes of cultural engagement, transformative interaction, and collaborative creativity map directly onto the system's core components: the cultural knowledge layer, the adaptive prompt engine, and the collaborative module. Rather than serving as peripheral observations, these themes explain how the system's computational processes are internalized by users during interaction. This correspondence between qualitative patterns and structural modeling strengthens the claim that system performance is mechanism-driven. Recent work on culturally responsive digital systems similarly emphasizes that contextual alignment enhances both engagement and meaning-making, particularly when cultural elements are operationalized within interaction design rather than presented as static content (Batur & Çakıroğlu, 2023; Sakvand et al., 2026; Watson et al., 2026). In SENANDI, cultural content becomes actionable through prompts and feedback, enabling users to iteratively refine outputs within a culturally grounded interaction space.

Subgroup and dose–response analyses extend these findings by demonstrating that system performance is both robust and adaptive. The absence of significant subgroup interactions indicates that the system operates consistently across demographic profiles, while the positive dose–response gradient shows that increased interaction intensity amplifies outcomes. This dual pattern—baseline effectiveness combined with intensity-dependent amplification—is characteristic of scalable adaptive systems (Mbasso et al., 2026; Song et al., 2024). It suggests that SENANDI can deliver meaningful gains under varying usage conditions while still benefiting from sustained engagement. Importantly, the moderation effect observed in the structural model indicates that baseline user state conditions system responsiveness, supporting the interpretation that SENANDI implements state-dependent adaptation. Such behavior is consistent with recent advances in user modeling and context-aware systems, where system outputs are dynamically adjusted based on prior knowledge and interaction history (Lee & Hsieh, 2026; Lou et al., 2025).

Taken together, these findings position SENANDI within a class of intelligent mobile systems that integrate contextual knowledge, adaptive interaction, and user-dependent processing into a unified architecture. The study contributes to the field by demonstrating that culturally grounded constructs can be operationalized as system components, not merely as instructional themes, and that doing so enhances both interaction quality and output performance. Future research should extend this model by incorporating finer-grained interaction analytics, longitudinal tracking of adaptive pathways, and cross-domain validation to test generalizability beyond literary contexts. Additionally, integrating machine learning–based user modeling may further refine prompt generation and feedback precision. By advancing from content-centered applications to interaction-driven systems, this line of work opens new directions for designing mobile environments that are both technically robust and contextually responsive.

5. Conclusion

This study demonstrates that SENANDI functions as an adaptive and context-aware mobile system in which user interaction is systematically transformed into measurable performance outcomes. The findings consistently show that system-supported interaction—through adaptive prompts, contextual knowledge integration, and iterative feedback cycles—produces substantial improvements across writing competencies and culturally grounded knowledge domains. Structural modeling further confirms that system effectiveness operates through a mediated mechanism, where cultural identity awareness functions as a critical processing layer linking system usage to output quality. In addition, stable engagement patterns, high usability, and consistent performance across subgroups indicate that the system operates reliably under real-world conditions, supporting both robustness and scalability.

The implications of this study extend beyond conventional mobile learning applications by demonstrating that culturally embedded constructs can be operationalized as active system components rather than passive instructional content. However, this study is limited by its focus on a single domain and a relatively bounded deployment context. Future research should examine cross-domain applicability, incorporate more granular interaction analytics, and explore the integration of machine learning–based user modeling to enhance adaptive precision. By advancing from content-centered design toward interaction-driven system architecture, this study provides a foundation for developing mobile systems that are not only technically robust but also contextually responsive and pedagogically meaningful.

Statements

Author Contributions. Anang Sudigdo: conceptualization, methodology, supervision, writing – review & editing. Eko Suroso: conceptualization, supervision, project administration, writing – review & editing. Onok Yayang Pamungkas: data curation, formal analysis, writing – original draft preparation. Daru Tunggul Aji: software, validation, visualization, field study. Rochmad Novian Inderanata: investigation, project administration, resources, field study. Edi Jatmiko: funding acquisition, supervision, writing – review & editing. Nani Darheni: data collection, formal analysis, writing – review & editing. Nailul Mukorobin: data collection, validation, resources, field study.

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