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Generative AI Ethno-Digital Comics Enhancing Socio-Cultural Awareness and Value-Based Learning in Elementary Education

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ABSTRACT

Purpose of the study: This study aimed to develop and evaluate an AI-assisted ethno-digital comic using AI Comic Factory to improve elementary students' cultural literacy, character development, and learning engagement in culturally responsive learning contexts.

Methodology: This study employed a Design-Based Research (DBR) approach involving analysis, design, and evaluation phases. Participants consisted of 60 elementary students from Grades IV–VI and 12 students in a preliminary trial from two schools in Banten, Indonesia. Data were collected through expert validation, questionnaires, observations, and field testing, then analyzed using Aiken's V, Cronbach's Alpha, ICC, N-gain, and Cohen's d.

Main Findings: The developed comic demonstrated high validity (Aiken's V = 0.88–0.94) and strong reliability (α = 0.89). Field implementation showed significant improvement in students' socio-cultural awareness (N-gain = 0.70; Cohen's d = 2.02), character development (d = 1.77), and learning engagement (M = 4.34; ICC = 0.89). Emotional and reflective engagement showed greater improvement than behavioral and cognitive engagement. In addition, Technology Acceptance Model (TAM) results indicated very high user acceptance, particularly in behavioral intention (BI = 4.58) and perceived usefulness (PU = 4.52).

Novelty/Originality of this study: This study proposes an AI-assisted ethno-digital story-based learning model integrating generative AI, culturally responsive pedagogy, and DBR to support immersive cultural storytelling and measurable character-based learning outcomes in elementary education.

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1. INTRODUCTION

Artificial intelligence (AI) has transformed education through adaptive learning systems and interactive digital environments; however, the dominance of global digital content simultaneously accelerates cultural homogenization and weakens students' local cultural identity [1]-[3]. This issue becomes increasingly critical among elementary school students aged 6–12, who are in a crucial stage of cognitive, moral, and socio-cultural

development, while excessive exposure to decontextualized digital media reduces opportunities for cultural meaning-making and character internalization [4]-[6]. In Indonesia, this condition is further exacerbated by low literacy achievement and the predominance of teacher-centered instruction. PISA 2022 reported that Indonesia's reading literacy score remained far below the OECD average, indicating weak interpretive and reflective comprehension skills [7]. As illustrated in Figure 1, Indonesia experienced a substantial decline in reading performance between 2018 and 2022, reflecting the growing challenge of contextual literacy in post-pandemic education. National Assessment (AN) findings also revealed that many elementary students experience difficulties in contextual interpretation, inference, and value-based understanding due to the continued dominance of rote and text-based learning approaches [8], [9]. This issue reflects broader global concerns regarding the tension between AI-driven digitalization and the preservation of local cultural identity in primary education.

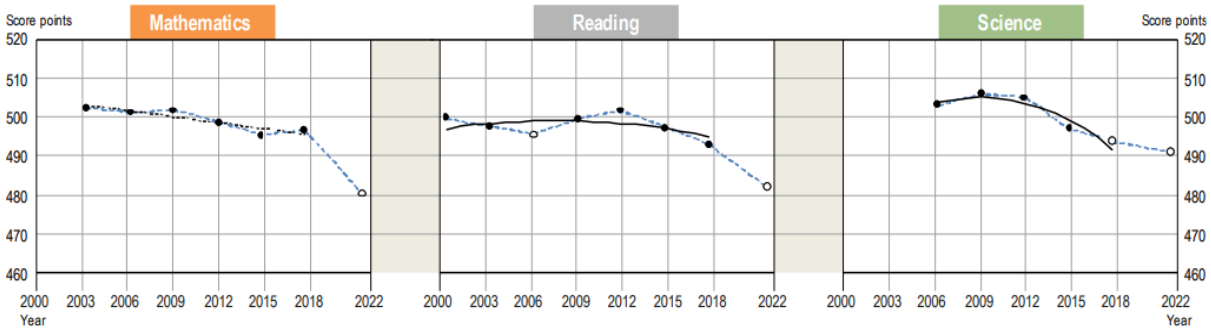

Figure 1. Changes in performance between 2018 and 2022 in the context of pre-2018 performance trends

From a pedagogical perspective, Contemporary elementary students, as digitally immersed learners, tend to prefer visual and interactive learning environments supported by animations, videos, and digital comics [10]-[12]. Studies indicate that multimedia-based and narrative-centered learning environments are more effective in enhancing engagement, motivation, and contextual understanding compared to conventional instructional approaches [13]-[15]. Therefore, AI-assisted digital comics offer strong pedagogical potential to create immersive, adaptive, and culturally relevant learning experiences for primary education. The effectiveness of digital comics is theoretically supported by the Cognitive Theory of Multimedia Learning and Dual Coding Theory, which explain that integrating verbal and visual information improves comprehension, memory retention, and emotional engagement through dual-channel processing [16], [17]. Narrative-based visual learning also facilitates reflective meaning-making and supports character internalization among elementary learners at the concrete operational stage [18]-[20]. Consequently, culturally grounded visual narratives are considered pedagogically appropriate for strengthening cultural literacy and value-based learning in primary schools.

Empirical evidence has consistently shown that digital comics can improve reading engagement and learning motivation, while culture-based learning strengthens local identity awareness and social understanding [21]-[23]. However, previous studies have primarily focused on isolated dimensions such as motivation, literacy, or media usability. The integration of generative AI, local historical narratives, socio-cultural learning, and value-based education within a unified pedagogical framework remains underexplored [24]-[26]. Furthermore, the integration of generative AI with local historical narratives and culturally responsive pedagogy in elementary education remains highly limited. Without culturally responsive AI-supported learning environments, digital transformation in education may further marginalize local cultural knowledge and weaken character-oriented learning among young learners.

Although previous studies have reported the positive contribution of digital comics toward students' motivation, literacy engagement, and conceptual understanding, most of these studies remain limited to general multimedia implementation without integrating culturally responsive and AI-assisted pedagogical frameworks [27]-[29]. Existing digital comic research in elementary education predominantly emphasizes usability, visual attractiveness, or cognitive outcomes, while socio-cultural dimensions such as local identity preservation, character internalization, and heritage-based contextual learning are often marginally addressed. Moreover, many AI-based educational studies focus primarily on adaptive assessment systems, automated tutoring, or content generation efficiency rather than on how generative AI can facilitate meaningful cultural learning experiences among young learners [30]-[33]. Consequently, the pedagogical role of AI in supporting culturally grounded narrative learning and value transmission in primary education remains theoretically fragmented and empirically underdeveloped. This indicates a significant research gap regarding the integration of generative AI, ethno-pedagogy, and culturally meaningful digital storytelling within elementary learning environments.

In addition, previous research has rarely positioned local historical narratives as central pedagogical resources within AI-assisted digital learning ecosystems. Most studies involving local culture in education tend to use static folklore or conventional printed materials without adaptive personalization, multimodal interaction, or AI-supported narrative development [34]-[36]. Studies concerning culturally responsive pedagogy also largely

focus on secondary or higher education contexts, leaving elementary learners underrepresented despite their critical developmental stage for identity formation and character education [37]-[39]. Furthermore, limited attention has been given to how AI-generated narrative visualization can support reflective meaning-making, socio-cultural awareness, and value-based learning simultaneously within a single instructional framework. As a result, there remains insufficient empirical evidence concerning the validity, practicality, and effectiveness of AI-assisted ethno-digital comics in promoting contextual literacy and character-oriented learning among elementary school students. Therefore, a more integrative pedagogical model that combines generative AI, local cultural heritage, multimedia learning principles, and character education is urgently needed in contemporary primary education.

The urgency of this study arises from the increasing dominance of globalized AI-driven digital content that potentially marginalizes local cultural identity and weakens contextual character learning among elementary students. At the same time, primary education requires innovative learning environments capable of improving literacy engagement while preserving socio-cultural values and local wisdom. Without culturally responsive AI-based pedagogical interventions, digital transformation in education may further distance young learners from their historical and cultural roots. Integrating Banten Sultanate narratives into AI-assisted ethno-digital comics offers an innovative approach to strengthening contextual literacy, cultural awareness, and value internalization through adaptive visual storytelling. Therefore, this research is important to provide an empirically grounded and pedagogically relevant model for integrating generative AI with heritage-based learning in elementary education.

This study addresses these gaps by developing an AI-assisted ethno-digital comic based on narratives from the Banten Sultanate using AI Comic Factory. Unlike previous studies that position AI merely as a visualization tool, this study positions AI not only as a visualization tool but also as a pedagogical support system for adaptive storytelling and cultural value internalization within heritage-based learning environments. The proposed framework integrates generative AI, multimedia learning, local culture, and value-based learning into a coherent ethno-digital pedagogical system. This study extends culturally responsive digital pedagogy by integrating generative AI into heritage-based narrative learning for character education. Therefore, this study aims to develop an AI Comic Factory-based ethno-digital comic featuring Banten Sultanate narratives adapted to elementary students' characteristics and 21st-century learning demands, while examining its validity, practicality, and effectiveness in supporting socio-cultural awareness, character development, value-based learning, and student engagement in primary education contexts.

2. RESEARCH METHOD

2.1. Research Design

This study employed a Research and Development (R&D) approach using a Design-Based Research (DBR) framework to develop and evaluate an AI-assisted Ethno-Digital Comic for improving cultural literacy and character development among elementary school students. The DBR process was conducted through two iterative cycles consisting of three operational phases: (1) analysis and exploration, (2) design and prototype development, and (3) evaluation and reflection (see Figure 2).

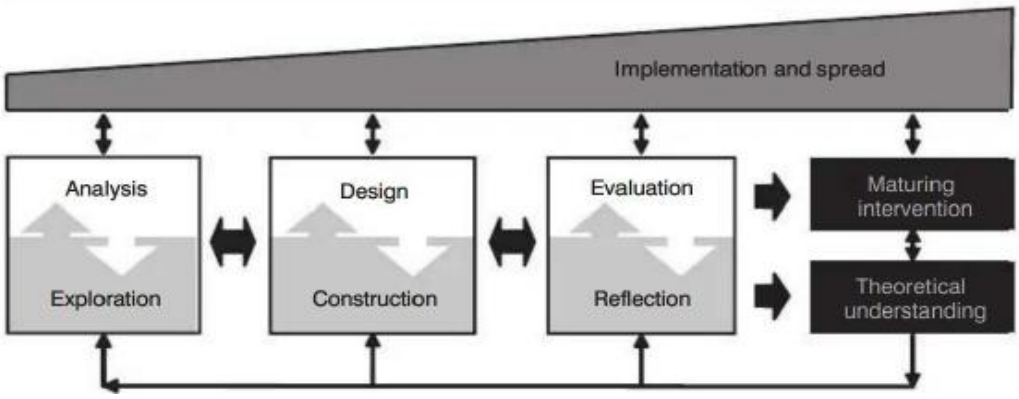

Figure 2. Design-Based Research Process

a. Analysis and Exploration Phase: This phase involved curriculum analysis, classroom observation, teacher interviews, and student characteristic analysis to identify problems related to cultural literacy, character learning, and digital learning practices in elementary schools. Literature related to AI-assisted learning, culturally responsive pedagogy, and digital storytelling was reviewed to formulate the learning framework and media specifications.

b. Design and Prototype Development Phase: The Ethno-Digital Comic was developed using AI Comic Factory through storyboard preparation, historical narrative construction of the Sultanate of Banten, integration of character values, and AI-assisted visual generation. The prototype combined narrative text, illustrations, dialogue, and interactive elements. The product was then validated by subject matter experts, media experts, and pedagogical experts using a 5-point Likert scale covering content accuracy, visual quality, language, interactivity, and pedagogical suitability. Validation results were used for iterative revisions.
c. Evaluation and Reflection Phase: The revised product was implemented through small-scale trials and field implementation. Evaluation focused on usability, practicality, cultural literacy improvement, character development, student engagement, and technology acceptance. Reflection results from each cycle were used to refine the product and improve instructional implementation.

2.2. Participants and Research Setting

The study was conducted in three elementary schools in Serang Regency, Banten, Indonesia. Participants consisted of 3 subject matter experts, 3 media experts, 6 teachers, and 60 students from Grades IV–VI selected using purposive and simple random sampling techniques. Expert selection was based on expertise in primary education, educational technology, and local culture studies, while students were selected randomly to represent different cognitive developmental levels. An additional 12 students and 2 teachers participated in the small-scale formative evaluation (see Table 1).

Table 1. Research participants and product trial

Participant	n	Main Criteria	Role
Content Experts	3	Experts in primary/history education and local culture	Validate content and cultural accuracy
Media Experts	3	Experts in educational technology and AI-based media	Evaluate design, interactivity, and usability
Elementary Teachers	6	Grades IV–VI teachers with teaching experience	Assess pedagogical practicality
Grade IV Students	20	Aged 9–10 years	Practicality and initial response testing
Grade V Students	20	Aged 10–11 years	Cultural literacy evaluation
Grade VI Students	20	Aged 11–12 years	Character and narrative comprehension evaluation
Small-Scale Trial	12 students + 2 teachers	Purposively selected based on literacy and digital skills	Evaluate readability, navigation, engagement, and media clarity
Field Implementation	60 students + 6 teachers	Grades IV–VI students in authentic classroom settings	Evaluate effectiveness, engagement, and usability

The product trial was conducted through two DBR stages: (1) small-scale formative evaluation and (2) field implementation. The small-scale trial was conducted in two sessions (2 × 90 minutes) to evaluate narrative comprehension, visual clarity, language readability, navigation, and student engagement. The field implementation was conducted in four meetings (2 × 35 minutes/session) using AI Comic Factory–based Ethno-Digital Comics through orientation, cultural narrative exploration, reflection, and discussion activities. Data were collected through observations, questionnaires, interviews, pretest–posttest, and documentation. Quantitative data were analyzed using N-Gain, while qualitative data were analyzed thematically through triangulation and member checking to ensure validity and credibility.

2.3. Development Procedures

This study followed an iterative Design-Based Research (DBR) cycle consisting of several operational stages. The process began with a needs analysis through classroom observations, teacher interviews, and curriculum review to identify problems related to cultural literacy and character learning. Based on these findings, storyboards and historical narratives of the Sultanate of Banten were designed and transformed into AI-assisted Ethno-Digital Comic prototypes using AI Comic Factory. The initial prototype was then validated by subject matter, media, and pedagogical experts, followed by revisions based on expert feedback. Subsequently, a small-scale formative evaluation was conducted to identify usability and instructional limitations, which informed further product refinement. The revised product was then implemented in field testing involving elementary school students to evaluate practicality, effectiveness, student engagement, and technology acceptance. Finally, reflection and iterative refinement were conducted to produce a valid, practical, and effective AI-assisted culturally responsive learning medium.

2.4. Research Instruments and Data Collection

Data were collected using methodological and source triangulation through document analysis, expert validation, questionnaires, tests, observations, interviews, and instructional documentation. The instruments were developed based on construct alignment principles to ensure consistency among research objectives, theoretical constructs, indicators, data sources, and measurement procedures. Instrument development was conducted through four stages: (1) identification of theoretical constructs and indicators related to cultural literacy, character education, student engagement, and technology acceptance; (2) preparation of the instrument blueprint; (3) expert validation; and (4) readability and empirical testing before implementation. Document analysis included curriculum documents, teaching modules, local history references, storyboards, flowcharts, and narrative designs of the Ethno-Digital Comic to ensure alignment between the learning media, instructional objectives, students' cognitive characteristics, and the cultural context of the Sultanate of Banten.

The research instruments consisted of: (1) expert validation questionnaires assessing content accuracy, cultural appropriateness, pedagogical relevance, language clarity, visual quality, interactivity, and AI-assisted storytelling integration using a 5-point Likert scale; (2) teacher and student response questionnaires measuring practicality, usability, attractiveness, engagement, perceived usefulness (PU), perceived ease of use (PEOU), attitude toward use (AOT), navigation, and learning motivation; (3) cultural literacy and narrative comprehension tests in pretest–posttest form evaluating cultural interpretation, narrative understanding, contextual reflection, inference, and character value comprehension; (4) structured observation sheets examining participation, interaction, collaboration, emotional engagement, attention, and character internalization through inter-rater agreement procedures; (5) structured interviews with teachers exploring instructional effectiveness, usability, implementation barriers, and classroom applicability; and (6) instructional documentation supporting qualitative findings and data triangulation. Before implementation, all instruments underwent content validation using Aiken's V and empirical validity testing using Pearson Product–Moment correlation involving 30 respondents outside the main sample, with all items declared valid (r-count > r-table; $p < 0.05$). Reliability testing using Cronbach's Alpha produced a coefficient of 0.900, indicating very high internal consistency and reliability.

2.6. Data Analysis Techniques

Quantitative and qualitative data were analyzed integratively within the Design-Based Research (DBR) reflection cycle to evaluate the validity, practicality, effectiveness, student engagement, and technology acceptance of the AI-assisted Ethno-Digital Comic. Quantitative data obtained from expert validation, questionnaires, and pretest–posttest assessments were analyzed using IBM SPSS Statistics version 29. Content validity was examined using Aiken's V to determine the relevance and appropriateness of each instrument item. Media feasibility was calculated using percentage-based analysis:

$$P = \frac{f}{N} \times 100\% \qquad \ldots(1)$$

where Prepresents the feasibility percentage, $f$is the obtained score, and $N$is the maximum possible score. Instrument reliability was evaluated using Cronbach's Alpha coefficient, with a minimum acceptable threshold of 0.70 indicating satisfactory internal consistency. Inter-rater consistency from observational data was further analyzed using the Intraclass Correlation Coefficient (ICC). The effectiveness of the learning media in improving students' cultural literacy and character development was analyzed using the Normalized Gain (N-Gain) formula:

$$g = \frac{Posttest - Pretest}{Maximum\ Score - Pretest} \qquad \ldots(2)$$

The N-Gain results were interpreted using three categories: low ($g < 0.30$), moderate ($0.30 \leq g < 0.70$), and high ($g \geq 0.70$). To strengthen the interpretation of learning effectiveness, effect size analysis was conducted using Cohen's d.

Questionnaire data related to technology acceptance, including perceived usefulness (PU), perceived ease of use (PEOU), attitude toward use (AOT), and behavioral intention (BI), were analyzed descriptively using mean and standard deviation scores. Qualitative data obtained from classroom observations, interviews, and field notes were analyzed thematically through data reduction, coding, categorization, interpretation, and conclusion drawing. The trustworthiness of qualitative findings was ensured through methodological triangulation, source triangulation, and member checking. The product was considered successful based on four indicators: validity, practicality, effectiveness, and student engagement. Validity was achieved when expert evaluation results reached the "valid" category based on Aiken's V and feasibility percentage analysis. Practicality was determined through positive teacher and student responses regarding usability, readability, navigation, and implementation efficiency. Effectiveness was indicated by moderate-to-high N-Gain scores and positive effect sizes in students' cultural

literacy and character development outcomes. Student engagement was identified through increased participation, interaction, emotional involvement, and reflective responses during the implementation process. The overall evaluation results were interpreted comprehensively through triangulation of quantitative and qualitative findings within the DBR reflection cycle.

3. RESULTS AND DISCUSSION

3.1. Results of the Analysis and Exploration Phase

The findings indicate a substantial pedagogical gap between conventional text-based instruction and students' needs for culturally contextualized digital learning (see Tables 3). The dominance of teacher-centered instruction and limited integration of interactive media suggest that current learning practices have not fully supported active knowledge construction or contextual cultural literacy development. Consistent with multimedia learning theory and culturally responsive pedagogy, students demonstrated a strong preference for visual–interactive storytelling media that facilitate emotional engagement and contextual meaning-making.

Table 3. Integrated Results of Classroom Observation, Teacher Interviews, and Students' Needs Analysis

Dimension	Quantitative Results	Category	Teacher Interview Findings	Students' Needs Analysis
Teacher-centered instructional practices	Teacher-Centered Instruction Dominance = 78.4% (SD = 6.12); Students' Verbal Participation = 21.6% (SD = 4.87)	Very High–Low	"Most of the teaching process still relies on lectures and textbooks." (Teacher SD-2)	Students preferred more interactive and participatory learning environments
Use of text-based learning media	Use of Text-Based Media = 83.3% (SD = 5.21)	Very High	"History learning materials are still text-based, with no visual support to help students understand the stories." (Teacher SD-3)	Interest in culture-based visual–interactive learning media: M = 4.42; SD = 0.61; 88.4% (Very High)
Limited integration of interactive digital media	Use of Interactive Digital Media = 16.7% (SD = 3.95)	Very Low	"We do not yet have interactive digital media that specifically engagingly presents local history." (Teacher SD-1)	Preference for interactive digital storytelling media: M = 4.05; SD = 0.69; 81.0% (Very High)
Weak cultural reflection and contextual learning	Cultural Reflective Activities = 18.5% (SD = 4.11); Contextualized Learning = 24.3% (SD = 5.02)	Very Low–Low	"Cultural discussions are rarely conducted due to time constraints and lack of learning media." (Teacher SD-4)	Ease of understanding cultural narratives through visual illustrations: M = 4.18; SD = 0.73; 83.6% (Very High)
Limited collaborative and higher-order thinking activities	Students' Collaborative Interaction = 27.8% (SD = 4.74); Higher-Order Thinking Activities = 19.6% (SD = 3.88)	Low–Very Low	"Students rarely ask questions or engage in discussions during history lessons." (Teacher SD-2)	Students preferred interactive narrative-based learning that supports active engagement
Low integration of local cultural narratives	Integration of Local Culture in Learning = 22.4% (SD = 4.36)	Low	"Illustrations of local culture are very limited in the available textbooks." (Teacher SD-6)	Students demonstrated strong interest in culturally grounded visual storytelling media

These findings are aligned with previous studies emphasizing that digital narrative media can improve students' motivation and cultural understanding in elementary education contexts. The results imply the urgency of developing AI-assisted culturally grounded learning environments that combine visual storytelling, local narratives, and reflective learning activities. The novelty of this study lies in integrating AI-generated storytelling with Banten Sultanate cultural narratives as an immersive pedagogical approach for elementary cultural literacy learning.

The iterative development results demonstrate that integrating AI Comic Factory within the DBR framework significantly improved visual consistency, cultural representation, and pedagogical quality across development cycles (see Tables 4). The progressive increase in cultural accuracy, emotional expression, and visual engagement confirms that AI-assisted prompt engineering can support the development of culturally responsive instructional media. To clarify the role of artificial intelligence in the development process, this study conceptualizes AI not as a black-box content generator, but as an adaptive instructional design tool embedded within an iterative Design-Based Research (DBR) cycle. The AI operates through structured prompt engineering, where each prompt functions as an instructional optimization strategy that translates pedagogical objectives, cultural narratives, and character values into visual storytelling instructions. Within this framework, AI-assisted prompt engineering serves as a mechanism for instructional refinement, enabling systematic alignment between learning objectives and generated visual outputs. The iterative refinement process is implemented through cycles of evaluation, prompt adjustment, and visual regeneration, in which each regenerated output is assessed based on cultural accuracy, narrative coherence, emotional expression, and pedagogical relevance (see Figure . Furthermore, AI refinement is positioned as adaptive content generation, where feedback from expert validation and student learning needs is continuously integrated into subsequent prompt iterations. Visual regeneration is therefore not merely a technical re-rendering process but represents iterative pedagogical enhancement aimed at improving cultural representation, cognitive engagement, and emotional immersion in learning materials.

Table 4. Integrated Design, Iterative Development, Expert Validation, and Revision Results

Component	Focus/Aspect	Core Findings and Development Process	Statistical/Validation Evidence	Improvement Outcomes/ Category
Narrative and Cultural Mapping Structure	Episode 1 – Establishment of the Banten Sultanate and the role of Sultan Maulana Hasanuddin	Religiosity; demonstrates prayerful attitudes and appreciation of spiritual values; Understanding (C2); reflection on the spiritual meaning embedded in historical development	—	Episode 1
	Episode 2 – Maritime trade in the Sunda Strait and global interactions	Nationalism; identifies regional contributions to the economic development of the Indonesian archipelago; Analysis (C4); discussion of cultural identity and local economic systems	—	Episode 2
	Episode 3 – Diplomatic relations between the Banten Sultanate and other sultanates (Aceh, Ottoman Empire)	Tolerance; demonstrates respect for cultural diversity and differences; Analysis (C4); analysis of intercultural conflict and cooperation	—	Episode 3
	Episode 4 – Leadership of Sultan Ageng Tirtayasa	Leadership; demonstrates decision-making abilities in collaborative group work; Evaluation (C5); case study on ethical leadership	—	Episode 4
	Episode 5 – Conflict between Banten and the VOC (17th-century colonialism)	Integrity; demonstrates honesty and responsibility in ethical reasoning; Evaluation (C5); ethical dilemma analysis in colonial history	—	Episode 5
	Episode 6 – Cultural heritage of Banten	Mutual cooperation; collaborates effectively in group-based cultural assignments; Creation (C6);	—	Episode 6

Component	Focus/Aspect	Core Findings and Development Process	Statistical/Validation Evidence	Improvement Outcomes/ Category
	(architecture, traditions, arts)	social reflection and cultural preservation activities		
Iterative AI Visual Development Process	Iteration I	Design of the main character and historical visual identity; 18 prompts; 42 visual regenerations; revisions on Sultan character design, traditional attire, and facial expressions	Character representation was inconsistent across panels; cultural details insufficiently accurate	Character consistency improved to 81.4% based on expert agreement
	Iteration II	Cultural background consistency and visual narrative coherence; 24 prompts; 57 visual regenerations; revisions on Banten harbor setting, mosque environment, and historical social context	Several settings did not accurately reflect the authentic historical context of the 16th century	Cultural representation accuracy increased from 76.2% to 91.3%
	Iteration III	Emotional expression refinement and visual narrative flow; 21 prompts; 49 visual regenerations; revisions on character expressions, panel transitions, and visual lighting	Emotional expression and visual narrative flow were insufficient to support students' emotional immersion	Visual engagement score increased to 94.6%, and readability reached 92.8%
Expert Evaluation Across Iterations	Character Consistency	Iterative expert evaluation across DBR cycles	Iteration I = 72.5%; Iteration II = 84.1%; Iteration III = 93.4%	Progressive improvement
	Cultural Accuracy	Iterative expert evaluation across DBR cycles	Iteration I = 69.8%; Iteration II = 91.3%; Iteration III = 94.1%	Progressive improvement
	Emotional Expression	Iterative expert evaluation across DBR cycles	Iteration I = 74.2%; Iteration II = 82.7%; Iteration III = 95.2%	Progressive improvement
	Narrative Readability	Iterative expert evaluation across DBR cycles	Iteration I = 78.4%; Iteration II = 86.5%; Iteration III = 92.8%	Progressive improvement
	Visual Engagement	Iterative expert evaluation across DBR cycles	Iteration I = 76.1%; Iteration II = 88.4%; Iteration III = 94.6%	Progressive improvement
Expert Validation Results	Content and Historical Feasibility (γ_1 = -0.84; γ_2 = 0.73)	Validation of historical and content feasibility	Number of Items = 5; Mean = 4.71; SD = 0.42; Aiken's V = 0.91; ICC = 0.87; Cronbach's Alpha = 0.89; Percentage = 94.2%	Highly Valid
	Cultural Accuracy (γ_1 = -0.79; γ_2 = 0.65)	Validation of cultural representation accuracy	Number of Items = 4; Mean = 4.64; SD = 0.47; Aiken's V = 0.89; ICC = 0.85; Cronbach's Alpha = 0.87; Percentage = 92.8%	Highly Valid
	Visual Quality and Interactivity	Validation of visual quality and interactivity	Number of Items = 6; Mean = 4.78; SD = 0.39; Aiken's V =	Highly Valid

Component	Focus/Aspect	Core Findings and Development Process	Statistical/Validation Evidence	Improvement Outcomes/ Category
	(γ_1 = -0.92; γ_2 = 0.88)		0.94; ICC = 0.91; Cronbach's Alpha = 0.92; Percentage = 95.6%	
	Language Quality (γ_1 = -0.68; γ_2 = 0.54)	Validation of language readability	Number of Items = 4; Mean = 4.58; SD = 0.51; Aiken's V = 0.88; ICC = 0.83; Cronbach's Alpha = 0.86; Percentage = 91.7%	Highly Valid
	Pedagogical Alignment (γ_1 = -0.81; γ_2 = 0.70)	Validation of pedagogical appropriateness	Number of Items = 5; Mean = 4.67; SD = 0.44; Aiken's V = 0.90; ICC = 0.86; Cronbach's Alpha = 0.88; Percentage = 93.5%	Highly Valid
	AI-Assisted Storytelling Integration (γ_1 = -0.88; γ_2 = 0.79)	Validation of AI-assisted storytelling integration	Number of Items = 4; Mean = 4.75; SD = 0.41; Aiken's V = 0.93; ICC = 0.89; Cronbach's Alpha = 0.90; Percentage = 94.8%	Highly Valid
	Overall (γ_1 = -0.82; γ_2 = 0.72)	Overall validation results	Number of Items = 28; Mean = 4.69; SD = 0.44; Aiken's V = 0.91; ICC = 0.87; Cronbach's Alpha = 0.89; Percentage = 93.8%	Highly Valid
Revision Traceability Matrix Based on Expert Feedback	Complexity of narrative dialogue	Subject matter and pedagogy experts; 66.7% (6/9 experts)	Historical dialogue overly lengthy and abstract for students at the concrete operational stage	Student readability score increased from 71.2 to 87.5 (+22.9%)
	Cultural reflection	Pedagogical experts; 55.6% (5/9 experts)	Cultural values not explicitly reflected at the end of the episode	Student reflective engagement index increased from 68.4 to 81.1 (+18.6%)
	Visual quality and contrast	Media experts; 44.4% (4/9 experts)	Several panels exhibited low contrast and unclear facial expressions	Visual clarity score increased from 74.6 to 86.3 (+15.7%)
	Interface navigation	Media experts and teachers; 33.3% (3/9 experts)	Students experienced difficulty navigating panels and reflection features	Usability score increased from 69.8 to 84.5 (+21.1%)

These findings support multimedia learning theory, which emphasizes that integrated visual–verbal representations enhance comprehension and emotional immersion among elementary learners. Compared with previous digital comic studies that mainly focus on motivation or literacy, this study extends the field by embedding measurable character indicators, contextual reflection, and AI-assisted historical visualization within a culturally grounded narrative structure. The findings imply that AI can function not only as a content-generation tool but also as a

pedagogical mediator supporting reflective and contextual learning. The innovation of this study is reflected in the integration of AI storytelling, local cultural heritage, and character-based instructional design into a single ethno-digital learning ecosystem.

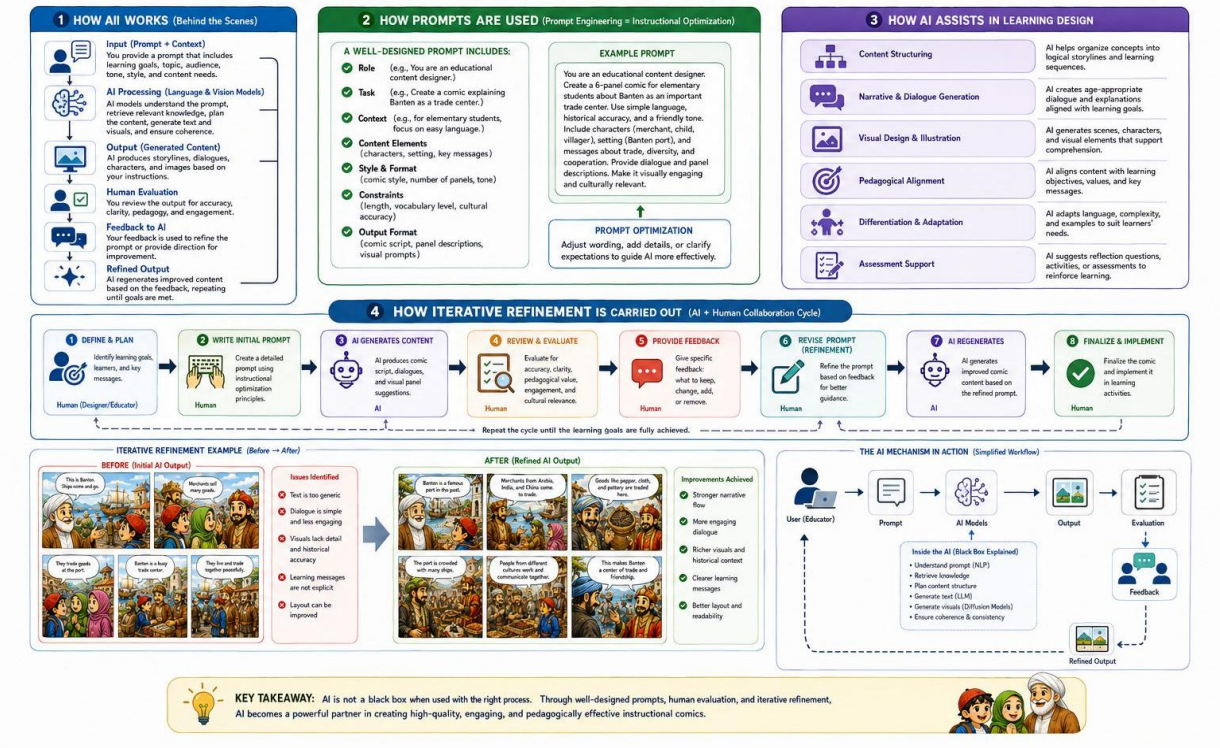

Figure 3. AI Mechanisme in Instructional Comic Design

3.2. Small-Scale Formative Evaluation (Limited Trial Results)

The limited trial findings indicate that the AI-assisted Ethno-Digital Comic generated high levels of behavioral, emotional, cognitive, and reflective engagement among elementary students (see Table 5). Emotional and reflective engagement showed the greatest improvement, suggesting that culturally embedded visual narratives facilitate deeper emotional connection and reflective meaning-making.

Table 5. Integrated Results of Student Engagement in the Limited Trial Across Learning Sessions

Dimension (Indicators)	Session (Mean ± SD)	Improvement Statistics (Δ Mean; % Gain; Mean ± SD)	95% CI	Statistical Results	Category (Effect Interpretation)
Behavioral Engagement (Sustained Attention and Participation)	I: 4.21 ± 0.71 II: 4.58 ± 0.63	+0.37; 8.8%; 4.58 ± 0.63	4.18–4.98	t/z = 3.82; p = 0.003**; Cohen's d = 1.10; ICC = 0.91; Percentage = 91.6%	Very High (Large Effect)
Emotional Engagement (Enthusiasm, positive response, cultural curiosity)	I: 4.08 ± 0.74 II: 4.44 ± 0.71	+0.36; 8.1%; 4.44 ± 0.71	4.00–4.88	t/z = 3.44; p = 0.005**; Cohen's d = 0.99; ICC = 0.89; Percentage = 88.8%	Very High (Large Effect)
Cognitive Engagement (Cultural Interpretation and Contextual Meaning-Making)	I: 3.94 ± 0.77 II: 4.31 ± 0.68	+0.37; 9.4%; 4.31 ± 0.68	3.89–4.73	t/z = 3.67; p = 0.004**; Cohen's d = 1.05; ICC = 0.90; Percentage = 86.2%	Very High (Large Effect)
Reflective Participation (Critical cultural value reflection)	I: 3.61 ± 0.88 II: 4.02 ± 0.84	+0.41; 11.4%; 4.02 ± 0.84	3.50–4.54	t/z = -2.98; p = 0.002**; Cohen's d = 0.86; ICC = 0.92; Percentage = 80.4%	High (Large Effect)
Overall Average (AI-Assisted Student Engagement)	I: 3.96 ± 0.78 II: 4.34 ± 0.72	+0.38; 9.6%; 4.34 ± 0.72	3.89–4.79	Cohen's d = 1.55; ICC = 0.91; Percentage = 86.8%	Very High (Moderate–High)

These findings align with narrative immersion theory, which posits that emotionally engaging stories enhance attention, empathy, and interpretive thinking. Similar trends have been reported in previous studies on digital storytelling; however, this study uniquely integrates AI-generated visual narratives with local cultural heritage and character education. Pedagogically, the findings suggest that culturally contextualized AI-assisted storytelling can foster immersive and reflective learning experiences beyond conventional text-based instruction. The novelty lies in positioning AI-generated comics as reflective cultural learning media rather than merely visual entertainment tools. Based on Table 5, all revisions were carried out iteratively in the second cycle of the Design-Based Research through a formative refinement approach (see Figure 4). The effectiveness of these revisions was analyzed using a comparative prototype evaluation by comparing usability, readability, visual clarity, and student engagement scores between the initial prototype and the revised version. The evaluation results indicate that all aspects demonstrated a significant improvement following the revision process informed by expert feedback.

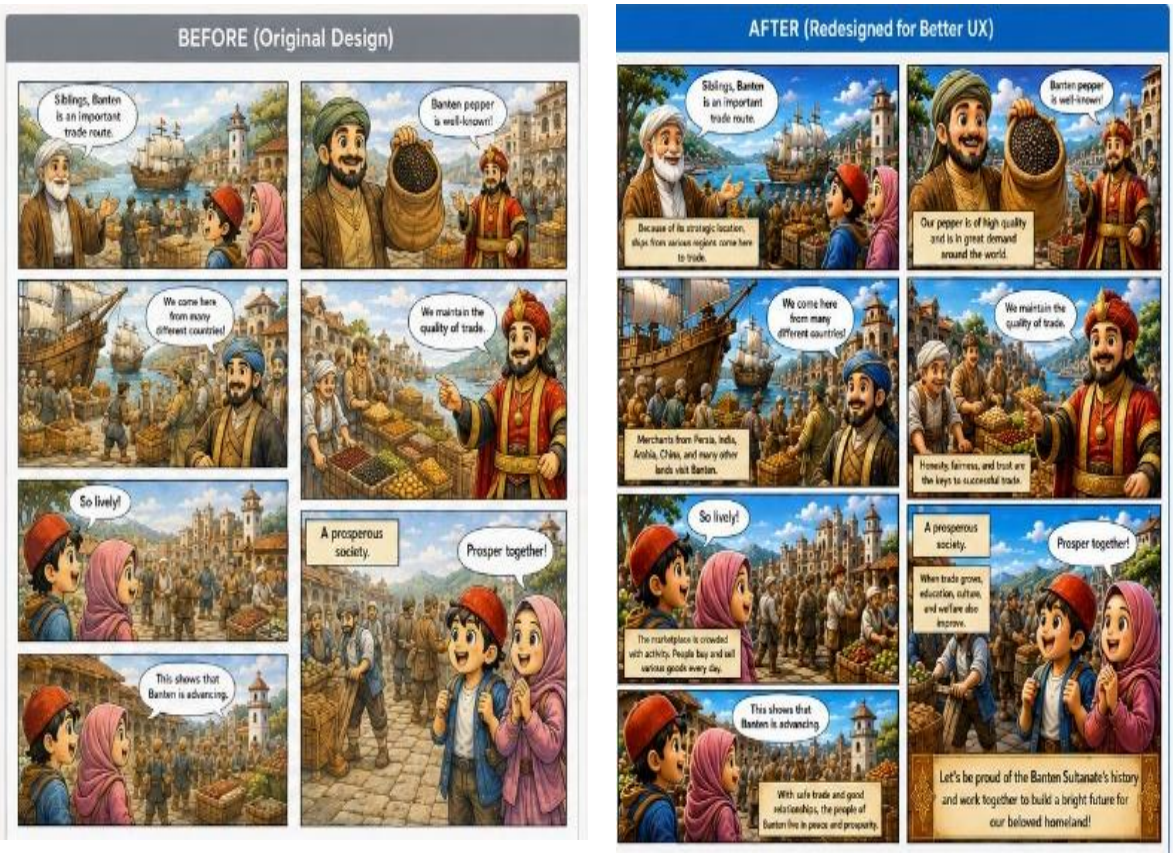

Figure 4. Before–After Panel Comic Revision and Design-Based Research (DBR) Revision Cycle Diagram

The figure 4 illustrates an iterative Design-Based Research (DBR) framework for developing AI-assisted ethno-digital comics through five interconnected stages: analyze and explore, design and develop, implement and produce, evaluate and reflect, and revise and improve. The process begins with identifying learners' needs, cultural contexts, and educational goals, followed by designing culturally relevant comic narratives and visual elements aligned with learning objectives. The developed comics are then implemented and evaluated based on usability, engagement, clarity, and learning impact through feedback from users and stakeholders. The evaluation results are continuously used to revise and improve the comic content, visuals, and pedagogical alignment to enhance educational effectiveness. Overall, this framework aims to produce meaningful, engaging, and culturally responsive digital comics that support literacy, character education, and socio-cultural awareness among elementary students. Based on Table 5, the findings indicate that the use of AI-assisted ethnonarrative learning not only enhances students' attention toward learning but also strengthens their affective and reflective engagement through culturally contextualized and immersive learning experiences (see Figure 3).

3.3. Media Practicality Evaluation Results

The technology acceptance and user experience results demonstrate very high levels of perceived usefulness, behavioral intention, and cultural connectedness toward the AI-assisted learning media (see Tables 6). These findings indicate that students and teachers perceived the Ethno-Digital Comic as both pedagogically meaningful and technologically accessible.

Table 6. Results of Technology Acceptance, User Experience (UX), and Pedagogical Engagement Evaluation

Evaluation Dimension	Construct / Indicator	Number of Items	Mean ± SD	Reliability and Validity Index	Percentage (Category)
TAM	PU	4	4.52 ± 0.48	0.91; 0.72; 0.89	90.4% (Very High)
	Perceived Ease of Use (PEOU)	4	4.36 ± 0.55	0.89; 0.69; 0.87	87.2% (High)
	Attitude Toward Using (ATU)	3	4.47 ± 0.50	0.88; 0.71; 0.85	89.4% (Very High)
	Behavioral Intention to Use (BI)	3	4.58 ± 0.46	0.90; 0.74; 0.88	91.6% (Very High)
	User Satisfaction (US)	3	4.49 ± 0.49	0.89; 0.70; 0.86	89.8% (Very High)
	System Quality (SQ)	3	4.28 ± 0.57	0.86; 0.66; 0.84	85.6% (High)
	Overall Mean (TAM)	20	4.45 ± 0.51	0.89; 0.70; 0.87	89.0% (Very High)
UX	Visual Attractiveness	—	4.68 ± 0.39	—	93.6% (Very High)
	Navigation Accessibility	—	4.24 ± 0.58	—	84.8% (High)
	Interface Clarity	—	4.37 ± 0.51	—	87.4% (High)
	Interaction Responsiveness	—	4.41 ± 0.47	—	88.2% (Very High)
	System Stability	—	4.29 ± 0.56	—	85.8%
	Overall Mean (UX)	—	4.40 ± 0.50	—	88.0% (Very High)
Pedagogical Engagement	Emotional Engagement	—	4.48 ± 0.46	—	89.6% (Very High)
	Narrative Immersion	—	4.56 ± 0.42	—	91.2% (Very High)
	Reflective Participation	—	4.29 ± 0.49	—	85.8% (High)
	Cultural Connectedness	—	4.61 ± 0.41	—	92.2% (Very High)
	Collaborative Interaction	—	4.34 ± 0.53	—	86.8% (High)
Overall Mean (Pedagogical Engagement)		—	4.46 ± 0.46	—	89.2% (Very High)

In line with the Technology Acceptance Model (TAM), perceived usefulness emerged as a major factor influencing positive attitudes toward media use. Compared with previous educational technology studies that primarily emphasize usability, this study highlights the importance of integrating emotional immersion and local cultural narratives into AI-based learning environments. The findings imply that technology acceptance in elementary education is strongly influenced not only by interface usability but also by narrative relevance and cultural resonance. The innovation of this study lies in combining AI-assisted storytelling, user-centered interaction, and local cultural immersion within a single instructional platform. Students also responded positively, perceiving the media as engaging, interactive, accessible, and supportive of their understanding of historical content and cultural values through concrete and enjoyable visual-narrative experiences (see Figure 5).

Figure 5. Media Practicality Process

3.4 Field Implementation Results

The field implementation results reveal significant improvements in students' cultural literacy, character development, and multidimensional engagement following the use of the Ethno-Digital Comic (see Tables 7). The high N-Gain scores and large effect sizes indicate that AI-assisted ethno-digital narrative learning effectively strengthened students' interpretation, reflection, and contextual understanding of local cultural values. These findings support constructivist learning theory and culturally responsive pedagogy, emphasizing that meaningful learning occurs when students actively connect instructional content with their sociocultural experiences.

Table 7. Results of Cultural Literacy, Character Development, and Student Engagement

Domain	Indicator	Pretest Mean ± SD (%)	Posttest Mean ± SD (%)	Δ Mean / Gain / N-Gain / t-value	Cohen's d (Category)
Cultural Literacy	Cultural Interpretation	52.4 ± 9.18	84.6 ± 7.02	Δ = 32.2; N-Gain = 0.68; t = 14.82	1.91 (Moderate)
	Narrative Inference	49.8 ± 10.04	82.3 ± 7.45	Δ = 32.5; N-Gain = 0.65; t = 13.94	1.78 (Moderate)
	Moral Value Reflection	50.1 ± 8.73	86.2 ± 6.11	Δ = 36.1; N-Gain = 0.72; t = 16.37	2.12 (High)
	Contextual Meaning-Making	48.7 ± 10.21	83.9 ± 6.84	Δ = 35.2; N-Gain = 0.69; t = 15.76	2.03 (Moderate)
	Local Cultural Awareness	53.2 ± 8.56	88.1 ± 5.92	Δ = 34.9; N-Gain = 0.75; t = 17.14	2.24 (High)
	Average	50.8 ± 9.34	85.0 ± 6.67	Δ = 34.2; N-Gain = 0.70; t = 15.61	2.02 (High)
Character Development	Religiosity	67.2 ± 7.84	88.5 ± 5.62	Δ = +21.3	1.72 (Very High)
	Nationalism	69.4 ± 8.11	91.2 ± 4.97	Δ = +21.8	1.85 (Very High)
	Integrity	65.8 ± 8.43	87.4 ± 5.88	Δ = +21.6	1.69 (Very High)
	Mutual Cooperation	70.1 ± 7.25	93.1 ± 4.42	Δ = +23.0	1.94 (Very High)
	Independence	64.7 ± 8.96	85.9 ± 6.31	Δ = +21.2	1.63 (Very High)
	Average	67.4 ± 8.12	89.2 ± 5.44	Δ = +21.8	1.77 (Very High)
Student and Emotional Engagement	Attention and Focus During Learning Activities	68.5	92.4	Gain = +23.9 (Very High)	—
	Active Participation in Discussions	65.7	89.7	Gain = +24.0 (Very High)	—
	Enthusiasm and Emotional Responsiveness	63.8	91.2	Gain = +27.4 (Very High)	—
	Emotional Connection with Characters	60.9	88.6	Gain = +27.7 (Very High)	—
	Ability to Reflect on Cultural Values	61.4	87.9	Gain = +26.5 (Very High)	—
	Interpretation of Cultural Narrative Meanings	64.2	89.1	Gain = +24.9 (Very High)	—
	Collaboration and Group Interaction	67.1	90.5	Gain = +23.4 (Very High)	—
	Average	64.5	89.9	Gain = +25.4 (Very High)	—

Previous studies have shown the effectiveness of digital storytelling for literacy learning; however, this study extends prior work by integrating AI-generated cultural visualization, reflective character education, and immersive narrative interaction simultaneously. The findings imply that AI-assisted storytelling can serve as an effective medium for strengthening cultural identity and character internalization in elementary education. The

pedagogical novelty of this study lies in transforming local historical narratives into immersive AI-driven learning experiences that combine literacy, emotional engagement, and character formation.

3.5. Qualitative Findings and Pedagogical Reflections

The qualitative findings further strengthen the quantitative results by showing that students experienced emotional immersion, cultural connectedness, and reflective participation during the implementation of the AI-assisted Ethno-Digital Comic (see Tables 8). Students were not only cognitively engaged with the historical narratives but also emotionally connected to the cultural values represented within the stories.

Table 8. Qualitative and Quantitative Results of Student Engagement During the Implementation

Engagement Dimension	Coding Segments (%)	Quantitative Indicator	Observation Results (Mean ± SD; n; Category)	Key Findings
Emotional Engagement	48 (80.0%)	Positive emotional response	4.17 ± 0.64; 50 students; High	Students showed enthusiasm, curiosity, enjoyment, and empathy toward the story.
Narrative Immersion	45 (75.0%)	Attention focus toward the media	4.41 ± 0.52; 53 students; Very High	Students consistently focused on the storyline, visual narratives, and historical characters.
Cultural Connectedness	43 (71.7%)	Reflection on cultural values	4.25 ± 0.55; 51 students; High	Students connected Banten Sultanate narratives with daily life and local identity.
Reflective Learning	39 (65.0%)	Participation in discussion	4.33 ± 0.61; 52 students; Very High	Students actively discussed and reflected on moral and cultural values.
Collaborative Interaction	37 (61.7%)	Collaborative interaction	4.23 ± 0.58; 51 students; High	Students collaborated actively and exchanged ideas during group activities.
Learning Enthusiasm		Learning enthusiasm	4.58 ± 0.47; 55 students; Very High	Students demonstrated strong motivation and active engagement throughout learning.
Overall Average		Overall student engagement	3.46 (1–4 scale) / 4.33 (1–5 scale); Very High	AI-assisted storytelling and local cultural narratives created immersive and meaningful learning experiences.

These findings are consistent with narrative engagement theory, which explains that emotionally meaningful stories increase empathy, reflection, and contextual understanding. In comparison with previous studies on digital comics and storytelling, the present study demonstrates a stronger integration between AI-generated visualization, local cultural identity, and character-based reflection activities. The findings imply that culturally grounded AI-assisted storytelling can create more participatory and meaningful learning experiences in elementary education. The novelty of this study lies in integrating emotional engagement, local cultural narratives, and AI-driven visual storytelling into a contextualized cultural literacy learning model.

The findings from the analysis and exploration phase revealed that cultural literacy learning in elementary schools remains predominantly teacher-centered, text-based, and insufficiently connected to students' sociocultural contexts (Table 4). Limited use of interactive digital media, weak reflective cultural discussion, and low student participation indicate that conventional instructional practices have not yet aligned with the needs of digital-native learners. Contemporary studies emphasize that educational digital transformation requires participatory, adaptive, and contextually meaningful learning experiences rather than passive content transmission [3], [27], [28]. Moreover, culturally disconnected learning environments may hinder students' contextual understanding and cultural identity development [29], [30]. These findings are consistent with constructivist learning theory, which highlights the importance of contextual interaction and reflective experiences in supporting meaningful learning and character internalization [31], [32].

Students' strong preference for visual–interactive storytelling media (81.0%–88.4%) supports Dual Coding Theory and Multimedia Learning Theory, which suggest that the integration of verbal and visual information enhances comprehension, retention, and cognitive engagement [16], [17]. Previous studies have shown that interactive storytelling, digital comics, and multimedia narratives improve engagement, participation, and conceptual understanding among elementary learners [34], [35], [37]. Unlike prior research that primarily focused on generic multimedia instruction, this study integrates AI-assisted storytelling with Banten Sultanate

narratives, positioning local culture as the central pedagogical foundation rather than supplementary content [39], [40].

The pedagogical novelty of this study lies in the development of an AI-assisted ethno-digital narrative learning model that integrates contextual storytelling, reflective learning, character education, and local cultural heritage within immersive digital environments. This approach transforms learning from passive content delivery into participatory and culturally meaningful experiences while strengthening cultural identity and contextual understanding [21], [29], [41]. Consistent with culturally responsive digital storytelling research, the model also promotes identity awareness, reflective engagement, and socio-cultural understanding [42]-[44].

The iterative DBR process demonstrated that integrating AI Comic Factory significantly improved visual quality, cultural accuracy, emotional expression, and narrative readability across development cycles (Table 5). Increasing expert evaluation scores indicate that iterative prompt engineering and expert-guided refinement effectively enhanced both pedagogical and cultural quality, consistent with AI-driven instructional design and DBR principles emphasizing adaptive optimization and continuous refinement [9], [27], [45].

The improvements in visual engagement and emotional immersion align with Narrative Transportation Theory and multimedia learning principles, which emphasize that immersive storytelling enhances empathy, emotional involvement, and reflective cognition [16], [17]. AI-generated visual narratives enabled students to perceive historical events and cultural figures more concretely, which is particularly beneficial for learners at the concrete operational stage [5]. Unlike previous digital comic studies that focused mainly on engagement or cognitive outcomes, this study extends AI-assisted storytelling toward reflective cultural literacy and character internalization [42], [46]. The findings further support the view that AI can function not only as a content generator but also as a pedagogical mediator that facilitates contextual visualization, emotional expression, and historical representation within culturally responsive learning environments [47]-[49]. This is consistent with evidence showing that AI-based learning systems are most effective when embedded within instructional design frameworks [50].

The cultural innovation of this study is reflected in the systematic integration of Banten Sultanate narratives, character values, and reflective activities into measurable instructional components [25], [51]. By connecting historical content with students' social realities, the learning design strengthened cultural connectedness and contextual understanding, consistent with culturally responsive pedagogy [29], [52]. Previous studies similarly demonstrate that local history integration promotes historical consciousness and cultural identity formation in primary education [23], [53]. Unlike earlier approaches that treated local culture as supplementary content, this study structurally embedded cultural narratives into the learning process, thereby supporting meaning-making and identity development through reflective interaction [42].

The findings further demonstrated substantial improvements in behavioral, emotional, cognitive, and reflective engagement (Tables 5–6). Emotional engagement and reflective participation showed the strongest gains, indicating that AI-assisted ethno-digital storytelling fosters immersive and emotionally meaningful learning experiences [16], [42]. These results support Student Engagement Theory and Narrative Immersion Theory, which highlight the role of emotional attachment and contextual storytelling in enhancing participation, motivation, and reflective thinking [14], [31], [54]. The visual–interactive narrative design effectively sustained attention and encouraged active participation, while reflective activities enabled students to interpret moral values, relate cultural narratives to everyday experiences, and engage in contextual reasoning [54]-[56]. Consequently, AI-assisted storytelling extends beyond surface-level engagement by promoting deeper cognitive and reflective learning processes.

These findings are consistent with prior research showing that digital storytelling enhances emotional engagement, collaboration, and comprehension [55], [56]. However, this study extends existing work by integrating AI-generated visualization with culturally grounded Banten Sultanate narratives, positioning local cultural heritage as the core pedagogical framework [23], [39]. This culturally responsive AI-assisted narrative model enables students to construct meaning through immersive storytelling, reflection, and dialogue-based interpretation while addressing the cultural disconnection often found in conventional digital learning environments [54], [57]. The approach also reflects a shift toward participatory, inquiry-based, and culturally meaningful learning environments aligned with twenty-first-century educational frameworks [58], [59].

Implementation results demonstrated significant improvements across all dimensions of cultural literacy and character development, with high N-Gain values and very large effect sizes (Table 7). The strongest gains occurred in local cultural awareness and moral reflection, suggesting that AI-assisted ethno-digital narrative learning effectively strengthens both interpretive and reflective dimensions of cultural literacy. These findings are consistent with culturally responsive pedagogy and situated learning theory, which emphasize that meaningful learning occurs when knowledge is embedded within authentic cultural and social contexts [29], [60], [61]. Through the integration of historical narratives, visual storytelling, and reflective dialogue, students were able to internalize values such as nationalism, integrity, religiosity, and cooperation more meaningfully. This result aligns with digital storytelling research demonstrating that multimodal narrative environments support identity formation, empathy, and value internalization [42], [43]. Compared with previous studies, this research offers

stronger integration between cultural literacy, AI-assisted visualization, and measurable character outcomes [22], [62].

The pedagogical novelty of this study lies in integrating AI-assisted visual narratives with reflective character-based learning activities. This approach supports a transition from teacher-centered instruction toward immersive, student-centered learning environments, consistent with emerging AI-in-education frameworks [27], [48], [49]. The technological innovation is reflected in the use of AI Comic Factory to generate adaptive, emotionally engaging, and culturally accurate historical representations [13], [63]. Furthermore, AI-assisted design enables continuous refinement of cultural accuracy and emotional expression, representing a significant advancement over static digital learning media [64]. From a cultural perspective, transforming local heritage narratives into interactive learning experiences strengthens students' cultural identity while supporting intercultural awareness and participatory meaning-making [65], [66].

Overall, the findings indicate that AI-assisted ethno-digital narrative learning is an effective pedagogical alternative for strengthening cultural literacy, character education, and student engagement in elementary schools [1], [67], [68]. The integration of AI Comic Factory, culturally responsive pedagogy, and narrative immersion demonstrates that artificial intelligence can function as a transformative educational mediator rather than merely a technological tool [2], [69], [70]. The study highlights the importance of contextual, reflective, and participatory learning environments while showing that AI-assisted storytelling can support adaptive visualization, emotional immersion, and interactive learning experiences that strengthen cultural identity in the era of digital globalization [47], [63], [71].

This study introduces an AI-assisted ethno-digital narrative pedagogy that transforms learning from teacher-centered transmission into immersive, reflective, and culturally situated knowledge construction [9], [67]. Its novelty lies in positioning AI Comic Factory as a pedagogical generative system capable of producing culturally accurate, emotionally expressive, and cognitively scaffolded visual narratives [41], [63], [70]. By operationalizing Banten Sultanate heritage into structured learning narratives and integrating AI-assisted multimodal storytelling, the study transforms local culture into an active learning system rather than supplementary content [29], [71]. This finding is consistent with previous studies showing that digital narrative media, including comics, can enhance conceptual understanding, engagement, and contextual meaning-making in educational settings [73]-[75]. The integration of visual, textual, and emotional elements also supports dual-channel cognitive processing as proposed in multimedia learning theory [76]. Consequently, AI functions not only as a content-generation tool but also as a cognitive and pedagogical mediator that enhances engagement, comprehension, reflective learning, and academic development in culturally grounded educational contexts [76]-[72].

The implications of this study are threefold. Pedagogically, AI-assisted ethno-digital narrative learning offers an alternative instructional model for enhancing cultural literacy, engagement, and character education. Theoretically, it extends constructivist learning theory, multimedia learning theory, and culturally responsive pedagogy by demonstrating how AI-mediated narrative systems facilitate meaning-making, emotional engagement, and identity formation. Technologically, the findings suggest that generative AI tools such as AI Comic Factory can be systematically integrated into instructional design frameworks to support adaptive visualization, contextual storytelling, and reflective learning in primary education contexts.

Nevertheless, several limitations should be acknowledged. The study was conducted within a specific cultural context, which may limit generalizability to other regions. The relatively short intervention period did not allow examination of long-term impacts on cultural literacy retention and character development. In addition, the use of a single AI platform may introduce variations related to prompt design and system updates, while factors such as teacher digital competence and students' prior digital literacy were not fully controlled. Future studies should therefore involve more diverse cultural settings, longer intervention periods, and comparative evaluations of different AI-assisted instructional systems.

4. CONCLUSION

In the context of 21st-century educational transformation, elementary education continues to face a gap between the demands of digital literacy, cultural literacy, and character development and the persistence of conventional teacher-centered instruction. This gap highlights the need for learning models that integrate technology, local culture, and meaningful learning experiences. This study demonstrates that an AI-assisted Ethno-Digital Comic developed through a Design-Based Research (DBR) approach is an effective pedagogical innovation for enhancing cultural literacy, character development, and student engagement in elementary education. The developed model functions not only as a digital learning medium but also as a culturally grounded narrative system that supports meaningful and reflective learning experiences.The study contributes to three key areas: (1) pedagogical innovation through AI-assisted ethno-digital narrative learning; (2) technological innovation by positioning generative AI as a pedagogical and epistemic mediator; and (3) cultural integration innovation by embedding local historical narratives into immersive learning design. These contributions extend multimedia learning theory, culturally responsive pedagogy, and DBR by offering a unified framework for AI-based cultural

learning. Future research should examine the model across broader educational contexts, explore adaptive AI-driven personalization, and conduct longitudinal studies to assess long-term learning impacts. The integration of emerging immersive technologies such as augmented reality and virtual reality is also recommended to further enhance culturally based digital learning experiences. Overall, this study provides an empirically supported and theoretically grounded model for integrating artificial intelligence, pedagogy, and local cultural heritage in elementary education.

In conclusion, this study demonstrates that an AI-assisted Ethno-Digital Comic developed through a Design-Based Research (DBR) framework effectively enhances cultural literacy, character development, and student engagement in elementary education by integrating artificial intelligence, pedagogy, and local cultural heritage into a unified learning ecosystem. This study contributes to educational innovation by positioning generative AI as a pedagogical and epistemic mediator that enables culturally responsive and meaningfully contextualized digital learning experiences. Future research is recommended to investigate the scalability of the model across diverse educational contexts and to examine the long-term impact of adaptive AI-driven personalization in culturally based digital learning environments.

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AUTHOR CONTRIBUTIONS

Conceptualization, Teguh Ardianto and Nandang Kusmana; Methodology, Teguh Ardianto; Software, Teguh Ardianto; Validation, Teguh Ardianto, Nandang Kusmana, Sobri, Yusup Junaedi, and Andri Imam Subekhi; Formal Analysis, Teguh Ardianto; Investigation, Teguh Ardianto; Resources, Nandang Kusmana; Data Curation, Teguh Ardianto; Writing – Original Draft Preparation, Teguh Ardianto; Writing – Review & Editing, Nandang Kusmana and Andri Imam Subekhi; Visualization, Teguh Ardianto; Supervision, Nandang Kusmana; Project Administration, Nandang Kusmana; Funding Acquisition, Nandang Kusmana.

INFORMED CONSENT STATEMENT

Informed consent was obtained from all participants after they received clear information about the study objectives, procedures, risks, benefits, confidentiality, and their right to withdraw. Participation was voluntary, and all participants provided written consent prior to data collection.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest. The study was conducted without any commercial, financial, or personal relationships that could influence the results. The funders had no role in study design, data collection, analysis, interpretation, manuscript preparation, or publication decisions.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

Not applicable.

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