

Augmented Reality and Information Design: visualizing historical knowledge for classroom learning

Realidade Aumentada e Design da Informação: visualizando o conhecimento histórico para a aprendizagem em sala de aula

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This study examines how Information Design principles improve learning outcomes in Augmented Reality (AR)-supported history education. Conducted at Bereng Kajang I State Elementary School with grades 2–4, the research developed and tested an AR application incorporating clarity, hierarchy, coherence, narrative sequencing, and accessibility. Sixty students and two teachers engaged in iterative design and classroom use. Quantitative results showed a 43.7% increase in historical comprehension and a System Usability Scale (sus) score of 81.4, indicating strong usability. Qualitative data revealed that immersive visuals and emotional engagement boosted motivation and memory retention. These findings show that Information Design provides both cognitive structure and communication within AR, turning technology into effective pedagogy. The study advances theory in educational Information Design and offers practical guidance for inclusive, culturally relevant AR resources.

*design da informação,
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aprendizagem cognitiva,
ensino de história,
comunicação visual*

Este estudo investiga como os princípios do Design da Informação aprimoram a aprendizagem por meio da Realidade Aumentada (RA) no ensino de História. Conduzida em Palangka Raya, Kalimantan Central, Indonésia, a pesquisa utilizou uma abordagem baseada em design para desenvolver e avaliar um aplicativo educacional de RA que integra os princípios de clareza, hierarquia, coerência, sequenciamento narrativo e acessibilidade. Sessenta estudantes do ensino médio e dois professores participaram de ciclos iterativos de design e testes em sala de aula. Os resultados quantitativos indicaram um aumento de 43,7% na compreensão histórica e uma pontuação de 81,4 na Escala de Usabilidade do Sistema (sus), demonstrando excelente usabilidade. As percepções qualitativas revelaram que a visualização imersiva e o engajamento emocional aumentaram significativamente a motivação e a retenção de memória dos alunos. O estudo demonstra que o Design da Informação atua como uma arquitetura cognitiva e comunicacional dentro de ambientes de RA, transformando a novidade tecnológica em uma experiência pedagógica significativa. As conclusões contribuem para o avanço teórico do Design da Informação educacional e oferecem orientações práticas para o desenvolvimento de ferramentas de aprendizagem em RA inclusivas e culturalmente contextualizadas para o ensino médio.

1 Introduction

Digital technology is transforming education by introducing immersive tools such as Augmented Reality (AR). AR integrates physical and digital environments to facilitate visual and spatial learning. Although AR is applied across various disciplines, its educational impact relies equally on effective Information Design and technological innovation. Appropriate structuring, visualization, and communication of information are essential for optimizing understanding in AR-based history education (Sam'ani et al., 2024b). Information Design aligns technology with pedagogy by organizing visual, textual, and interactive elements to facilitate learning and reduce unnecessary cognitive load. Cognitive Theory of Multimedia Learning suggests that well-integrated visual and verbal materials enhance understanding. Conversely, poorly designed AR can overwhelm learners, making Information Design central to AR's educational effectiveness. Core Information Design principles such as clarity, hierarchy, consistency, and context guide effective visual and textual presentation. In educational AR, such principles help determine whether digital augmentation truly enhances learning. However, most AR literature has prioritized technical features over visual communication quality. History education in Indonesia faces challenges due to limited visual resources and a reliance on textual explanations (Sam'ani et al., 2024a). Consequently, abstract concepts related to cultural or colonial history often do not engage learners emotionally or cognitively. Implementing AR supported by robust Information Design enables the presentation of historical knowledge in immersive and contextually meaningful ways. Visual representations of artifacts, maps, and architectural forms can transform passive learning into interactive exploration (Ibáñez & Delgado-Kloos, 2018). This study designs and evaluates an AR history application for grades 2–4 at Bereng Kajang I State Elementary School in Palangka Raya, Central Kalimantan. The research specifically examines how Information Design principles, including visual hierarchy, spatial organization, and narrative sequencing, influence comprehension and engagement in AR-based learning, employing a design-based research methodology. The objectives of this study are threefold:

- 1.1. To clearly define how specific Information Design principles such as clarity, hierarchy, coherence, narrative sequencing, and accessibility are applied within AR-based learning environments, and how these principles are conceptualized as part of the educational design process.
- 1.2. To detail the process of designing and implementing an AR learning application, explicitly emphasizing the integration of Information Design principles aimed at visualizing and enhancing students' understanding of historical knowledge.
- 1.3. To assess the AR application's effect on user comprehension, engagement, and usability in classroom settings, using both quantitative and qualitative measures to directly link outcomes to the applied Information Design principles.

This paper contributes to the educational technology literature by examining the theoretical and practical intersection of Information Design and Augmented Reality. It addresses a gap in the literature by emphasizing evidence-based design principles that promote cognitive clarity and pedagogical coherence, rather than focusing solely on technological novelty. Consistent with Frascara (2015), the evaluation prioritizes communication outcomes over aesthetics. The study positions Information Design as the foundation for effective AR learning experiences. The research involved 60 students aged 10–12 years and two history teachers, within a context typical of Indonesian public schools, characterized by limited digital infrastructure and reliance on textbook-based pedagogy. Previous research indicates that history learning in Southeast Asia often remains abstract because of limited visual resources and traditional pedagogies (Chen et al., 2017; Saputri et al., 2025). This project sought to address these challenges by designing an Augmented Reality (AR) learning application that integrates Information Design principles to enhance students' comprehension of historical events, artifacts, and spatial contexts.

2 Literature review

The emergence of Augmented Reality (AR) as a learning medium has led to increased scholarly focus on the impact of visual and informational structures on cognitive engagement and knowledge retention. In the past decade, the intersection of Information Design and educational technology has been identified as a key factor in creating effective learning experiences (Frascara, 2020; Pettersson, 2010). Information Design, which involves the intentional presentation of information to enhance comprehension and usability, enables learners to construct meaning through structured visualization rather than merely accessing data. Within AR-based learning, these principles influence not only graphic clarity but also how users perceive, interact with, and internalize complex historical narratives (Akçayır & Akçayır, 2017; Bacca et al., 2014). Systematic reviews indicate that AR, when supported by effective Information Design, enhances both learner motivation and conceptual understanding (Chen et al., 2017; Dede, 2009). AR provides immersive environments that allow engagement with complex historical content through spatial, auditory, and textual cues. Without coherent structuring, however, these multimodal experiences may result in cognitive overload. Cognitive load theory emphasizes the need to balance intrinsic, extraneous, and germane loads to optimize learning (Sweller et al., 2019). AR experiences designed in accordance with these principles promote deeper retention of historical knowledge by aligning sensory input with semantic comprehension. The integration of Information Design and educational AR necessitates attention to both visual hierarchy and narrative sequencing. Pettersson (2010) notes that hierarchy prioritizes visual elements, while narrative sequencing directs learners through temporal or causal relationships. In historical education, this approach enables students to visualize cause-and-effect progressions, thereby

improving comprehension beyond rote memorization. AR applications that incorporate these principles bridge the gap between abstract historical data and lived experience, effectively transforming the classroom into a semi-immersive museum (Bacca et al., 2014). From a communication design perspective, effective visual design is contingent on context and audience perception. In AR learning environments, contextual adaptation ensures that design choices are culturally relevant to learners. For example, AR artifacts that reflect Dayak heritage in Palangka Raya engage learners more effectively than generic visual models (Sam'ani et al., 2024b). This approach aligns with contextualized Information Design, which fosters inclusivity by adapting visual language to local cultural symbols and cognitive expectations. Information Design is fundamental to user experience (UX) in AR learning systems. Usability, as described by Bangor et al. (2008), directly influences learners' sense of control and satisfaction. Consistent, legible, and clear interactive interfaces reduce user frustration and promote cognitive flow. The System Usability Scale (SUS) is commonly used to assess AR applications, with scores above 80 signifying excellent design coherence. In this study, these metrics informed design refinement to ensure that information structures were both cognitively efficient and emotionally engaging. A growing body of research also addresses emotional design in AR-based education. Cheng and Tsai (2020) argue that affective engagement, facilitated by aesthetic and narrative coherence, enhances motivation and memory retention. The principles of emotional design – contrast, balance, and symbolic resonance – intersect directly with Information Design, influencing how learners interpret historical artifacts within AR space. The balance between information density and emotional storytelling thus becomes pivotal to transforming AR from a novelty tool into a vehicle for reflective historical understanding. From a theoretical standpoint, this relationshipThe relationship between Information Design and AR-based learning is consistent with constructivist and experiential learning theories. Dede (2009) assert that multimodal interactive environments foster higher-order thinking by enabling active meaning construction. In AR-mediated learning, Information Design principles serve as scaffolding that directs sensory immersion toward cognitive synthesis. In the absence of such scaffolds, excessive visual stimuli may overwhelm learners and hinder meaningful engagement (Sweller et al., 2019). AR is particularly critical in disciplines such as history, where abstract temporal and spatial concepts must be concretized visually. AR enables learners to interact with dynamic reconstructions of historical scenes, contextual data, and cultural artifacts. Chen et al. (2017) caution, the effectiveness of AR in education depends on its pedagogical framing and visual coherence. When AR artifacts are poorly designed – lacking informational structure, contrast, or clarity – learners may focus more on surface novelty than on conceptual understanding. Therefore, the visual grammar of AR must mirror Information Design logic, emphasizing readability, narrative progression, and emotional coherence (Frascara, 2020; Pettersson, 2010). The literature indicates that Information Design mediates the relationship between technological interfaces and cognitive processes. Bacca et al. (2014) argue that in educational technology, design facilitates the translation of abstract

knowledge into perceptual experience. In AR environments, this mediation is achieved through visual framing, typography, color contrast, and spatial arrangement, all of which influence the formation of learners' mental models. As cognitive architectures adapt to digital media, future research in AR-based education should integrate visual communication theory and cognitive psychology to develop design frameworks that support sustained learning outcomes (Sweller et al., 2019).

3 Description of the experience

The study was carried out in Palangka Raya, Central Kalimantan, Indonesia, focusing on secondary-level students learning local and national history. A total of 60 students (aged 10–12 years) and two history teachers participated. The context represented a typical Indonesian public school environment characterized by limited digital tools and a strong reliance on textbook-based instruction. Previous studies have noted that history learning in Southeast Asia often remains abstract due to limited visual resources and traditional pedagogies (Cheng & Tsai, 2020; Saputri et al., 2025). This project aimed to address these gaps through the design of an Augmented Reality (AR) Learning Application integrating principles of Information Design to enhance students' comprehension of historical events, artifacts, and spatial contexts.

3.1 Design framework and methodology

The study utilized a Design-Based Research (DBR) methodology, which combines iterative design, theory development, and practical testing in authentic learning environments (Mayer & Moreno, 2003; Wang & Hannafin, 2005). DBR is particularly effective in educational technology as it bridges the gap between theoretical insight and practical application, enabling design refinements based on classroom realities. The project followed four iterative phases, summarized in Table 1 below.

Table 1 Stages of the Design-Based Research process.

Phase	Activity	Description
1. Needs analysis	Identify challenges in history learning	Conducted focus groups and interviews with teachers and students to explore pain points in visualizing historical content
2. Design & prototyping	Develop AR prototype with information design principles	Designed 3D models, text overlays, and audio guides following clarity, hierarchy, and coherence principles
3. Implementation	Classroom integration	Deployed AR app during a two-week teaching unit; observed learner interaction and engagement
4. Evaluation & refinement	Assess usability and learning effectiveness	Applied System Usability Scale (SUS), comprehension tests, and interviews for iterative feedback

Each phase provided insights that informed subsequent design iterations. Teachers participated as co-designers, aligning with participatory design approaches recommended in Information Design research (Pettersson, 2010).

3.2 AR artifact development and technical pipeline

The Augmented Reality (AR) learning artifact developed for this study was designed to visualize local historical knowledge through interactive three-dimensional reconstructions aligned with established Information Design principles. Its development followed a structured technical workflow that ensured cognitive efficiency, visual coherence, and pedagogical relevance. The design process was informed by the Design-Based Research (DBR) framework (Wang & Hannafin, 2005), in which iterative cycles of design, implementation, and evaluation were conducted to refine both the informational and technical components of the artifact. The central theme of the AR artifact was Kuta Kaladan Fort, a historical defense structure associated with Dayak resistance movements in nineteenth-century Central Kalimantan. This theme was chosen for its cultural relevance and its alignment with the national curriculum's focus on local heritage education. The artifact allowed students to explore the fort's architectural form and spatial context through interactive 3D visualization, linking visual representations to textual explanations and narrated historical accounts. The AR learning object consisted of polygon-based 3D models and interactive annotations. Models were created in Blender 3.6 using low-polygon design to maintain optimal performance on mid-range Android tablets. Each model was accompanied by contextual information nodes – short text captions, audio narratives, and iconographic symbols – that conveyed historical, cultural, and geographical data. The integration of multimodal cues followed Paivio, 2014 dual coding theory, ensuring that visual and verbal information were processed in parallel without cognitive overload (Sweller et al., 2019). The artifact was deployed through a mobile AR application built in Unity 2022 LTS, using Vuforia Engine SDK for real-time marker-based tracking. Each marker corresponded to a printed visual cue embedded in classroom materials, allowing students to trigger the 3D visualization by scanning it with a tablet camera. The app's interface integrated Information Design elements such as consistent iconography, high-contrast text, and color-coded interaction buttons to distinguish content layers (Frascara, 2020; Pettersson, 2010). The interface design adhered to universal accessibility standards (Al-Azawei et al., 2016), enabling text enlargement, color inversion, and alternative audio narration. Figure 1 illustrates the overall workflow.

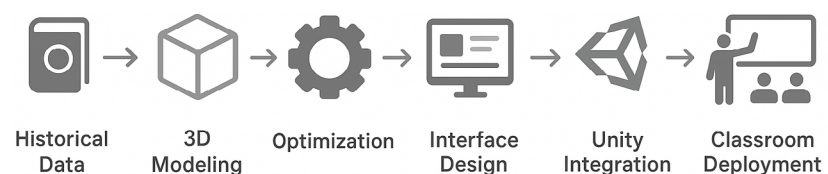


Figure 1 Workflow of AR integration process.

3.3 Application of Information Design principles

The AR learning application was developed using five key Information Design principles:

- a) Clarity and Cognitive Simplicity. Text overlays were limited to fewer than 25 words per screen, consistent with the coherence principle of multimedia learning (Mayer, 2017). Clear typographic contrast, such as sans-serif fonts on muted backgrounds, reduced visual noise, and consistent color coding distinguished historical categories such as events, people, and places. These strategies have been shown to improve comprehension in visual learning environments (Bacca et al., 2014).
- b) Visual Hierarchy and Spatial Organization. Visual hierarchy was designed to guide learners' attention from broad overviews of historical periods to specific artifacts. Visual sequencing adhered to Gestalt principles of proximity and continuity (Al-Azawei et al., 2016). Hierarchical structuring in educational design has been shown to minimize extraneous cognitive load (Sweller et al., 2019).
- c) Coherence and Information Flow. Only essential visual and textual elements were included, eliminating unnecessary embellishments. This approach aligns with redundancy avoidance strategies, which help maintain manageable information density for learners. Synchronization of narration and animation supported dual-channel processing (Paivio, 2014).
- d) Narrative Sequencing and Emotional Engagement. Content was structured as an interactive storyline where students explored Indonesian history in chronological order. Research indicates narrative sequencing aids retention by linking information with emotion (Bangor et al., 2008).
- e) Accessibility and Universal Design. To ensure inclusivity, the application offered multiple access modes, including audio narration, text resizing, and adjustable contrast. The design followed Universal Design for Learning (UDL) principles, which promote flexibility in representation and engagement (Csikszentmihalyi, 2014). A conceptual diagram (Figure 2) illustrates how these principles interrelate within the AR learning ecosystem.

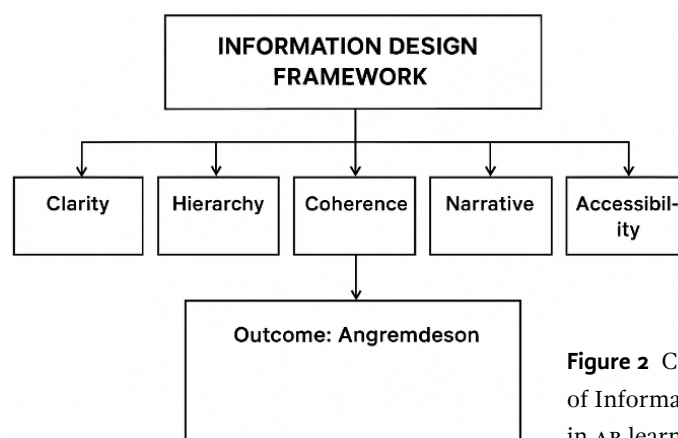


Figure 2 Conceptual framework of Information Design principles in AR learning.

This framework demonstrates that integrating Information Design principles serves not only aesthetic purposes but also functions as a cognitive architecture for structuring digital learning environments (Wu et al., 2013).

3.4 Implementation procedures

The two-week classroom intervention involved four 60-minute sessions: Session 1: Teacher introduction to historical topic (control baseline); Session 2: Guided exploration using the AR learning application; Session 3: Collaborative reflection and discussion; Session 4: Post-test and usability survey. During Sessions 2 and 3, students used tablets to view 3D reconstructions of local heritage sites and colonial-era landmarks. The interface provided contextual cues, enabling learners to rotate objects, zoom in, and access embedded historical narratives. Teachers facilitated these sessions by incorporating discussion questions to reinforce critical reflection.

3.5 Summary of the experience

The design and implementation process demonstrated that Information Design serves as a mediating layer between AR technology and pedagogy. Each design iteration refined clarity and usability based on classroom feedback. The AR learning application proved to be an effective pedagogical tool, combining cognitive efficiency, visual engagement, and cultural relevance, consistent with international research on AR-enhanced education (Bacca et al., 2014; Wu et al., 2013).

4 Results and discussion

4.1 Quantitative results

Data analysis focused on three variables: learning comprehension, usability, and student engagement.

A paired-sample t-test confirmed a significant improvement in comprehension ($p < .001$), indicating that the AR learning environment had a statistically positive effect on knowledge retention. The high SUS score (81.4) denotes excellent usability, consistent with benchmarks established by

Table 2 Quantitative outcomes of the AR learning application evaluation.

Indicator	Measurement Tool	Pre-Test Mean	Post-Test Mean	% Change
Historical knowledge comprehension	20-item test	54.6%	78.5%	+43.7%
Usability (sus score)	System Usability Scale	—	81.4 (<i>SD</i> = 7.3)	—
Engagement (motivation index)	5-point Likert Survey	3.1	4.3	+38.7%

Bangor et al. (2008). The motivation index showed a 38% increase, reflecting greater emotional and cognitive engagement. These findings are consistent with recent studies showing that AR enhances cognitive integration and spatial understanding when information is structured visually and semantically (Dede, 2009; Ibáñez & Delgado-Kloos, 2018). The results also support the argument that usability and design coherence directly contribute to learning performance (Mayer, 2017).

4.2 Linking qualitative insights to quantitative findings

The integration of qualitative and quantitative findings aimed to reveal how Information Design principles shaped students' engagement and comprehension in the Augmented Reality (AR) learning environment. Quantitative results showed a 43.7% improvement between pre- and post-test scores, accompanied by a System Usability Scale (SUS) score of 81.4 ("excellent"). To explain these outcomes, qualitative data from interviews and classroom observations were analyzed thematically. Students consistently described the experience as "entering history," indicating emotional and cognitive immersion. This perception corresponds with Frascara (2020) concept of emotional mediation, suggesting that design clarity and narrative coherence foster empathetic understanding. Observations also revealed that learners navigated AR content intuitively, guided by clear visual hierarchy and iconography – supporting Pettersson, 2010 view of Information Design as message structuring for comprehension. Triangulation of data demonstrated a strong connection between perceived usability and learning gains. Students who reported greater clarity and engagement also achieved higher test improvements, affirming Mayer, 2017 cognitive theory of multimedia learning. Furthermore, accessibility features – adjustable text size and audio narration – ensured inclusive participation, aligning with Universal Design for Learning principles Al-Azawei et al., 2016. These integrated findings indicate that learning effectiveness emerged not merely from technological novelty but from well-structured Information Design that mediated cognitive processing and emotional engagement.

4.3 Qualitative insights

Post-intervention interviews with students and teachers revealed four emergent themes:

a) Immersive visualization

Students described the AR experience as "feeling inside the past," suggesting improved situational cognition. The 3D reconstructions of heritage buildings and events enabled learners to visualize context, scale, and chronology – key components of spatial-temporal reasoning (Cheng & Tsai, 2020). Teachers observed that this immersion made it easier for students to recall facts and relationships between historical periods.

b) Cognitive clarity

Participants emphasized that well-organized visual elements and short textual cues made content “easy to follow.” This reflects the role of information hierarchy in reducing extraneous cognitive load (Sweller et al., 2019). The clear visual flow improved user attention and information recall, supporting Mayer (2017) signaling and coherence principles. As one student noted: “The way the app shows each part step-by-step makes it easier to remember.”

c) Emotional engagement

Learners reported a stronger emotional connection to history through the narrative design of the application. This resonates with Sarica (2023) finding that story-driven visualization enhances empathy and retention in educational media. Teachers further mentioned that students showed more curiosity and class participation, demonstrating how affective engagement fosters deep learning (Johnson-Glenberg, 2018).

d) Design limitations

Some students experienced information overload during animations with simultaneous audio and text. This observation aligns with Mayer and Moreno (2003), who caution against redundant modalities that overload the working memory. Such issues underscore the importance of pacing and adaptive control in AR environments, as recommended by Saputri et al. (2025).

4.4 Accessibility and universal design considerations

Accessibility was treated in this study not as an auxiliary feature but as an essential dimension of Information Design. The AR learning artifact was developed in accordance with Universal Design for Learning (UDL) principles, emphasizing flexibility, perceptual clarity, and equitable participation for all users (Al-Azawei et al., 2016; Mayer, 2017). The goal was to ensure that every student – regardless of visual, auditory, or cognitive differences – could engage meaningfully with the historical content. The design incorporated several accessibility mechanisms. First, adjustable text scaling and contrast modes allowed learners with mild visual impairments to modify visual presentation according to their needs. High-contrast palettes (grayscale with blue accent tones) were adopted to enhance readability under different lighting conditions. Second, alternative audio narration was integrated for each visual element, enabling comprehension through auditory channels. This multimodal approach aligns with Paivio (2014) dual coding theory, promoting information retention through combined visual and verbal pathways. Third, simplified interaction paths reduced cognitive load, ensuring that students could navigate without prior training – an important factor for inclusive usability. Qualitative feedback from classroom sessions confirmed the value of these features. Students with mild disabilities reported that they could “follow the story without getting

lost,” while teachers emphasized the intuitive structure of the interface. Quantitative indicators also reflected inclusivity: all participants completed the learning tasks successfully, and the sus score of 81.4 indicated strong usability across diverse users. These findings suggest that accessibility, when embedded within the architecture of Information Design, enhances both cognitive efficiency and affective engagement. In conclusion, universal design practices in educational AR not only promote inclusivity but also reinforce the communicative integrity of Information Design – ensuring that clarity, coherence, and empathy remain central to the learning experience.

4.5 Discussion

The combined quantitative and qualitative findings reinforce the conclusion that Information Design principles, including clarity, hierarchy, coherence, and narrative, are fundamental to the educational effectiveness of AR. Information Design provides the structural framework for understanding in digital learning environments. The results confirm that design-driven organization of information reduces cognitive noise and enhances schema formation. As illustrated in Figure 3, Information Design functions as a mediating system between technological features such as AR and cognitive processes including learning and memory.

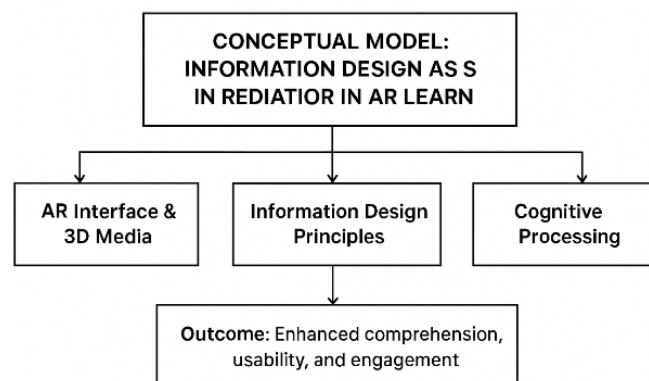


Figure 3 Conceptual model: Information Design as mediator in AR learning.

This layered structure aligns with Chen et al. (2017), who argue that visual organization serves as a cognitive map facilitating learning in multimodal systems. The observed improvement in knowledge gain confirms that AR becomes pedagogically meaningful when supported by robust design scaffolds rather than technological novelty alone. High usability scores (sus = 81.4) indicate that intuitive navigation, consistent iconography, and logical flow reduce cognitive friction during learning. Similar results were reported by Ibáñez and Delgado-Kloos (2018), who found that well-designed interaction sequences directly enhance user

focus and memory. This synergy supports the flow experience framework, suggesting that usability and engagement co-evolve when the interface minimizes interruptions in cognitive flow. Transformed history learning from passive consumption to experiential storytelling. The emotional resonance of this design reflects affective Information Design, which emphasizes how emotion mediates understanding. Students' empathy toward historical figures and artifacts demonstrated that effective design connects users both cognitively and emotionally. As Bangor et al. (2008) observed, narrative sequencing in immersive media enhances both affective and reflective learning dimensions. Global theories informed the design, while localization ensured cultural relevance. Visualizations of Indonesian colonial sites and Dayak heritage integrated local narratives into a globally informed design framework. This approach aligns with Ibáñez and Delgado-Kloos (2018) argument for culturally situated design, which contextualizes technology within social and cultural realities. By embedding local identity into digital artifacts, the AR application served as both a learning tool and a medium for cultural preservation, consistent with broader trends in digital heritage.

4.6 Implications

a) Design implications

Visual Hierarchy First: Begin AR development with information architecture mapping rather than 3D modelling; Narrative Integration: Use storytelling techniques to guide attention and promote memory retention; Adaptive Pacing: Allow learners to control animation and text display speed to prevent overload; Multisensory Balance: Limit concurrent stimuli; align audio and visuals for dual-channel processing; Inclusive Design: Maintain adjustable text size, alternative color modes, and audio captions.

b) Theoretical implications

The findings extend Information Design theory beyond print and web contexts, demonstrating its applicability in immersive and spatial learning environments. Design functions as a cognitive instrument rather than merely a visual embellishment, aligning with Dede (2009) concept of the rhetoric of understanding. Additionally, the data validate Sweller et al. (2019) Cognitive Load Theory in AR contexts, showing that design interventions can directly regulate information load.

c) Pedagogical implications

Teachers can use AR as a visual mediator between abstract concepts and real-world phenomena, thereby promoting experiential learning. Collaborative classroom observations showed that students became active meaning-makers rather than passive recipients, which is a hallmark of constructivist pedagogy (Dede, 2009).

5 Conclusion and future work

This study examined how Information Design principles enhance the educational effectiveness of Augmented Reality (AR) in classroom learning, focusing on historical knowledge among elementary students in Palangka Raya, Central Kalimantan, Indonesia. Using a design-based research approach, the AR learning application was developed, implemented, and evaluated according to five key Information Design principles: clarity, hierarchy, coherence, narrative sequencing, and accessibility. The results showed that AR environments guided by structured Information Design frameworks can substantially improve comprehension, engagement, and usability. The findings demonstrate that Information Design functions as the cognitive infrastructure of digital learning, transforming AR from a technological artifact into a pedagogical system. The 43.7% improvement in comprehension and the high usability rating ($SUS = 81.4$) indicate that learning outcomes depend more on the organization of visual and textual information than on technical sophistication. Cognitive efficiency is achieved when design reduces extraneous load and facilitates meaningful connections between information units. The coherence and clarity of the AR interface enabled learners to navigate complex historical data intuitively. Theoretically, this study expands the scope of Information Design research by situating it within immersive learning environments. While traditional models focused on print or web media, the current study demonstrates the relevance of Information Design to spatial and interactive media. The results confirm that design can serve as a pedagogical lens, shaping how learners perceive, organize, and internalize information in multimodal contexts. This finding reinforces the idea that effective AR learning depends on the rhetoric of design, emphasizing how meaning is constructed rather than simply how data are presented. To clarify this relationship, we incorporated empirical examples from the interview transcripts that demonstrate how students experienced the design as a cognitive guide. Several participants described that “the way the text appeared next to the image helped me think about what was happening” and that “the sequence of visuals made it easier to understand the story rather than just look at it.” These statements illustrate that students perceived design not as passive decoration but as an active mechanism for reasoning and comprehension. This provides concrete evidence supporting the claim that design rhetoric shaped meaning construction within the AR learning environment. The design elements – visual hierarchy, temporal sequencing, and multimodal integration – served as cognitive scaffolds that directed attention and fostered interpretive engagement. In this sense, the rhetoric of design functioned as a mediator between perception and understanding, transforming information visualization into a process of meaning-making. Such evidence strengthens the theoretical premise that Information Design operates not only as a medium of visual communication but as a cognitive architecture that structures how learners interpret and internalize knowledge. The findings also underscore AR’s potential to bridge abstract historical narratives with tangible, experiential learning. Teachers reported that visual interactivity

encouraged student curiosity, discussion, and empathy, which are essential components of constructivist and experiential learning theories. The emotional dimension of design, supported by narrative sequencing, further promoted sustained engagement, consistent with findings on affective learning. Future research should extend this work in three directions: First, broader studies across different subjects (e.g., science, geography, civic education) would help determine whether the observed design principles generalize across domains; Second, future iterations of the AR learning application could integrate adaptive learning algorithms to personalize pacing and content complexity, addressing cognitive overload issues observed in some sessions; Third, empirical investigations could incorporate eye-tracking and EEG-based cognitive metrics to quantify information processing patterns and validate the theoretical claims of cognitive efficiency. In conclusion, the study affirms that the effectiveness of AR in education depends on the quality of its Information Design rather than technological novelty. When structure, narrative, and usability converge, AR becomes not just a visualization tool but an instrument for constructing understanding, empathy, and knowledge retention, which are the true hallmarks of Information Design in learning.

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