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Development of MDLC-Based WebAR and WebVR Platforms as Digital Educational Media for Batik Motifs

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ABSTRACT

Background: The low interest of the younger generation in Malay hand-drawn batik and the limitations of interactive learning media pose challenges in efforts to preserve local culture. This study aims to develop more attractive and accessible digital educational media through the integration of Web Augmented Reality (WebAR) and Web Virtual Reality (WebVR).
Contribution: This activity contributes to providing an immersive web-based cultural education platform that does not require the installation of any applications, so that it can be used by the general public, especially the younger generation and batik SME players, to improve cultural literacy and promotional effectiveness.
Method: The approach used was the Multimedia Development Life Cycle (MDLC), which includes the stages of concept, design, material collection, assembly, and testing. The testing phase consisted of alpha testing by experts and usability testing involving 60 young users aged 15–30 years.
Results: The usability testing results showed a very good acceptance rate, namely 92% for ease of use, 88% for increased interest in batik, 84% for attractiveness compared to conventional media, and 92% for the usefulness of the application as a promotional medium.
Conclusion: The development of the WebAR and WebVR platforms successfully fulfilled the research objectives, namely to provide more attractive, interactive, and accessible digital educational media to increase the younger generation's understanding and interest in Malay hand-drawn batik motifs.

1. Introduction

Hand drawing batik as one of Indonesia's cultural heritages has historical, aesthetical, and economic values. But even with new digital tools, like AR-based marketing options, there are real barriers in preserving these traditions, including varying levels of tech adoption by artisans and local groups. Whilst there is evidence of the potential for AR to increase engagement and interest from past research, many of the small to medium sized batik operators are ill-prepared and uptake has been limited [1]–[3]. Dependence on static advertisements even further limits the public's exposure to information regarding pattern, production methods and ideologies [4]. In this context, interactive tools such as WebAR offer an accessible and engaging framework for displaying cultural content [5], [6], innovative ways are thus required to preserve batik and increase the level of cultural understanding among the younger generation.

The recent development of AR and VR has expanded the potential for richer and more effective information conveyance in educational and cultural environments [7]. Marker-based WebAR for instance allows users to interact with the 3D model directly in the browser – a convenience that bypasses friction from app installations and renders the experience just a click away across many devices [8]. Various computational techniques and optimization methods have been used to enhance immersion, however, most of the research is focused on engineering and technical education [9], [10]. Still, a number of studies show for well-designed immersive environments a lowering of cognitive load with lessening forms of user discomfort promoting learning and retention [11], [12].

In the preservation of digital culture field, AR storytelling has proven effective in interpreting layered cultural narratives [1]. More precisely, AR for batik has managed to enhance users' interest, engagement, and purchase intention [2], [3]. The results of this study indicate that people in such an environment will respond to the modern, authentic promotion of culture using new media. The development of AR/VR applications typically is based on the Multimedia Development Life Cycle (MDLC) that include a process flow from concept and design, to material preparation, development and usability testing [13]–[19]. Usability testing in particular is essential to ensure applications are intuitive and effective in cultural and educational contexts [20]–[24]. Emerging trends, such as machine learning–augmented AR and immersive VR memory palaces, point to new directions for supporting cultural learning and long-term retention [25].

To our knowledge, few studies combine WebAR and WebVR within a single, installation-free web platform, and none have simultaneously offered interactive 3D visualization, AR-based real-world projection, and browser-based VR exploration specifically for batik content. This gap motivated the present study, which proposes an integrated WebAR–WebVR platform for visualizing Malay hand-drawn batik motifs and enabling users to explore a 3D virtual gallery through a standard browser. The main contribution is an accessible, cross-platform immersive solution that supports cultural engagement and MSME promotion, alongside an MDLC-based workflow that other cultural-heritage projects can adapt.

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2. Method

2.1. Development Procedure (MDLC)

At this stage, the system objectives, user characteristics (ages 15–30), and technical requirements, such as devices compatible with WebXR, were determined. This stage was significant because it determined the direction of the prototype development that was subsequently tested. This stage produced the application architecture design, WebAR and WebVR navigation flows, and interface plans. Material Collection, this stage yielded the application architecture design, WebAR and WebVR navigation flow, and interface design: 1). High-resolution batik images, 2). Low-poly 3D models, 3). Narrative audio, 4). Cultural metadata about batik motifs.

Assembly, all collected assets are integrated into, 1). WebAR (marker-based 3D visualization), 2). WebVR (360° environment containing the batik-making process and philosophy). Testing, the testing phase includes two methods, the results of which appear in the results section, First, Alpha testing by AR/VR, UI/UX, and cultural experts to evaluate functionality and visual quality. Second, Usability testing with 60 users to assess ease of use, increased interest, engagement, and system usability.

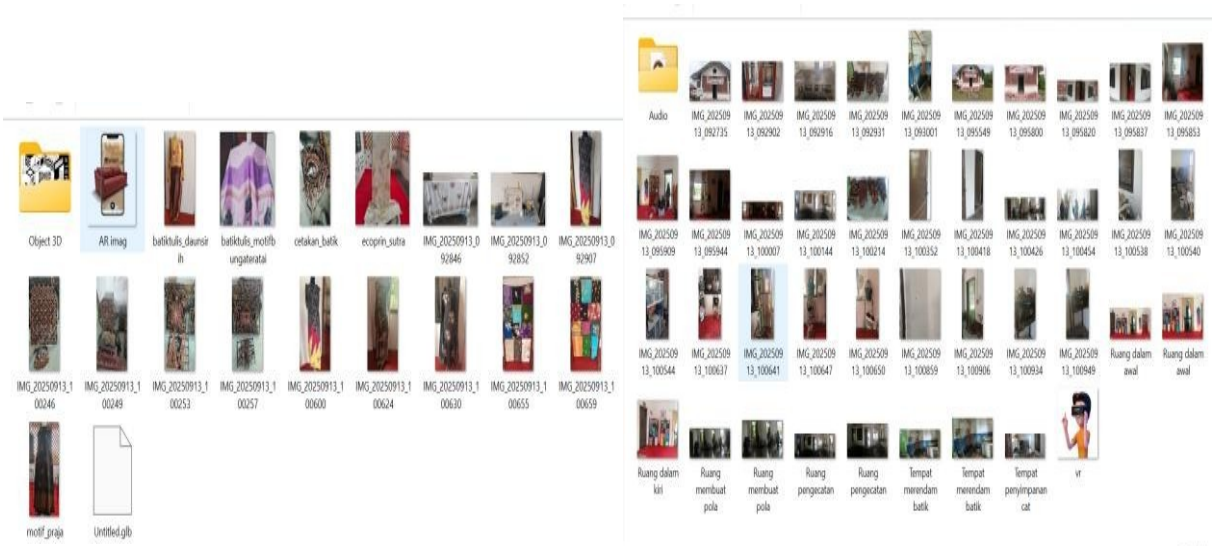
2.2. Location and Time

The study was conducted at Batik Prima Jaya in Tanjung Kasau Village, Batu Bara Regency, from July to November 2025. The research involved collecting data, creating multimedia assets, developing the system, and conducting user trials. The research population consists of users aged 15–30 years. A total of 60 respondents were selected using proportionate stratified random sampling, in accordance with the usability test requirements and the research results presented.

2.3. Instruments and Data Collection

The instruments used are only those that generate data in the research results section. First, interviews with MSME parties to validate cultural content (see Figure 1). Second, structured observations during trials to record obstacles such as texture sharpness and marker stability (see Figure 2). Usability questionnaire with a 5-point Likert scale. Secondary Data, Literature related to AR/VR and cultural preservation used in the discussion.

Figure 1. Interview with the Village Head



(a) (b)

Figure 2. Assets (a) WebAR, (b) WebVR

3. Results and Discussion

3.1. System Development Results

The development of the system followed the Multimedia Development Life Cycle (MDLC) phase, from conceptualization, design, material gathering, assembly construction to testing and distribution in order to create an effective WebAR–WebVR prototype for interactive displaying Malay hand-drawn batik motifs. The WebAR module makes use of marker-based tracking and touch gestures to position and manipulate 3D motifs in the physical environment, while the WebVR module offers a 360° view of a scene showing users art making instructions and cultural values behind each motif. Primarily targeting young people between the ages of 15 and 30, as well as the Batik Prima Jaya MSME community, the platform is compatible with WebXR browsers, eliminating the requirement to download apps and thus reducing any barriers to adoption while also allowing for one-click browser access to diverse cultural content.

The WebAR design includes the workflows for marker activation, three-dimensional object rendering, and interaction controls such as tap, pinch, and rotate. As illustrated in Figure 3, (a) accessing the WebAR page through a web browser, (b) scanning the marker, (c) visualizing the three-dimensional batik motif, and interacting with the object (zoom/rotate) or playing the accompanying narrative or process animations. The navigation structure and interface layout are presented to provide an overview of the system's operational flow and user interaction pathways.

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(a) (b) (c)

Figure 3. WebAR Batik output

The WebVR design combines structured navigation, 360° scene layout, and gaze- or cursor-based control mechanisms. Users can navigate non-linearly through the following sequence: starting from the Main Menu, entering the Motif Gallery, selecting "Batik Making Process Scene." As illustrated in Figure 4, the navigation structure.

(a) (b)

Figure 4. WebVR Batik Output: (a) accessing the WebVR page via a smartphone using a VR headset, and (b) displaying the 360° scene layout

The storyboard, 3D models, narrative text, audios and videos were amalgamated into two application modes (WebAR and WebVR) during the assembly phase. WebAR mode is a marker-based system that serves three-dimensional batik motif objects with additional information on overlays. At the same time, the WebVR version was developed as a 360° WebXR/A-Frame experience that allowed participants to explore the batik-making process in an interactive way.

The testing phase consisted of two stages. First, alpha testing was carried out to evaluate system functionality and visual quality. This process was conducted by experts in graphic design, mobile development, and virtual reality (VR), ensuring that the system's technical performance and visual output were properly validated. Second, usability testing was conducted using a stratified random sample of young users aged 15–30. The usability questionnaire comprised four primary items, Q1: Ease of use. Q2: Increased interest in hand-drawn batik. Q3: Perceived attractiveness compared to conventional media. Q4: The potential of the WebAR/WebVR interface to support future batik promotion. Overall, the system's performance was deemed satisfactory, with minor observations related to texture sharpness and marker-tracking stability (see Table 1).

Table 1. Usability testing results of WebAR/WebVR (N = 60)

Code	Question	Score (%)	Interpretation
Q1	Is the WebAR/WebVR easy to use?	92%	Very easy to use
Q2	Does WebAR/WebVR increase your interest in hand-drawn batik?	88%	Strongly increases interest
Q3	Is WebAR/WebVR more engaging than conventional promotional media?	84%	Very engaging
Q4	Is WebAR/WebVR useful for supporting future batik promotion?	92%	Very useful

3.2. Effectiveness of Combining WebAR and WebVR

The main results obtained through system development and testing are outlined in this section and interpreted in recent research framework, discussing their achievements, technological limits, and wider implications. The discussion is structured into a few notable areas, including the system's contribution in user experience (UX), user perception and performance, technical performance of the mobile application and prospects for MSMEs/Cultural Preservation.

The system proves that, as well in usability testing, with 92% of the participants stating that it is easy to use (Q1), 88% who said they have an improved interest (Q2), 84% mentioned that the interface is attractive visual (Q3), and 92% realized its usefulness (Q4). These results indicate that the combination of WebAR with WebVR forms an immersive and instinctual experience for users. In line with Tuah [26], WebAR with a marker-based feature provides users with natural interaction by generating 3D response, which leads to a more substantive

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experience when comparing with cultural content [27]. Likewise, the result on animation of 3D object and its effect towards engagement and realism correlates with that by Yang [28], The immersive VR environment with 360-degree field of vision, gaze-based navigation also helps in augmenting these effects promoting better comprehension and interactivity as observed by Bhatt [9]. In general, the WebVR mode of this work facilitates users to explore the batik-making process and cultural philosophy involved also in a better way than using static media.

3.3. Technical Comparison with Previous Studies and Optimization Recommendations

In the process of development, we came across a few technical problems, including unstable AR marker tracking in varying light, large texture files that caused initial load times to be slow, and laggy WebVR rendering on mid-range devices. These difficulties are reminiscent of Boutsi [8], propose multi-resolution rendering and texture optimization for improving WebAR performance, and their work echoes Tallulembang [14] focus on illumination-correction methods to prevent tracking errors caused by markers; in practice, AI-supported adjustment of lighting may provide a helpful solution. Mid-level hardware tends to suffer from the rendering bottlenecks Meanwhile, we also observe that the red dots, corresponding to Liu et al.'s findings [10] of the necessity for efficient rendering pipelines in order to maintain WebVR accessibility and robustness. These technical lessons underscore the strength of a structured development process: using the MDLC framework, as Roedavan [27] suggest, helped keep the work systematic and ensured that performance improvements stayed aligned with user-experience goals.

The findings show that the WebAR/WebVR application is proven to have potential to bring benefits for batik MSMEs, especially Batik Prima Jaya: the platform obtained 92% in term of perceived profitability (Q4) demonstration that respondents believe the technology can support promotional activity and increasing cultural branding. These findings are in agreement with those of Hartoko [29], claiming that interactive marketing media help MSMEs to improve product attraction, which can be achieved through immersive visualization provided by WebAR/WebVR. Similarly, Triyanto [1] reported that AR can support a batik advertisement with colorful products display, proved that AR enhances the marketing promotion of batik by showing the product representation is vivid, and Maryani [2] found that AR enhances interest and empathy of younger people. And from its strategy aspect, Rahmawati [30] they mentioned that digital media can enhance MSME resilience by reducing printing costs and enabling updating content anytime. Overall, the application that we have developed is not just innovation in technology, but this application is also a practical tool for cultural preservation, batik education and digital transformation of MSMEs.

4. Conclusion

This paper has designed and implemented an interactive WebAR–WebVR platform for the preservation and promotion of hand-drawn batik of Malay community generated by the Batik Prima Jaya MSME. Informed by the Multimedia Development Life Cycle (MDLC), development was continued through alpha and usability testing with 60 individuals.

Meanwhile, user feedback was overwhelmingly positive with 92% finding the system easy to use, 88% waking up more interest, 84% ranking the system as more engaging than traditional media and 92% considering it useful. Taken together, these results suggest that the inclusion of WebAR and WebVR into educational and promotional efforts can increase engagement, enhance understanding of batik making, serve as an immediately accessible avenue for cultural outreach. The contribution of the study is three-fold. Well, for one, it offers a cross-platform WebAR/WebVR solution right in your browser that doesn't require a separate app installation. Second, it offers empirical support for the enriching attractive and instructional value in batik content through immersive AR and VR. Third, it provides an MDLC-based blueprint that other cultural-heritage projects can follow and employ.

The study also demonstrates some obvious constraints: it is a case report from one SME, and not followed longitudinally; restricting the generalizability of the study. It can be further generalized in future to test the platform over broader, more diverse sample of MSMEs but also to introduce technical refinements like (LOD) level of details strategies or texture compression and downstream effects on consumer behavior and/or MSME economic outcome. In conclusion, the platform has reached its aims and demonstrates a promising potential as an effective and sustainable tool for cultural preservation, education and digital transformation of small heritage businesses.

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