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Empowering Rural Human Resources Through Virtual Reality for Waruga Cultural Heritage Within A Smart Village Framework

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ABSTRACT

The preservation of cultural heritage in the digital era faces a dual challenge: maintaining physical integrity while ensuring relevance for younger generations. Sawangan Village in North Sulawesi is home to the *Waruga* archaeological park, a site of immense historical value. However, traditional tourism management fails to fully engage modern visitors or leverage the "Smart Village" potential. This Community Partnership Program (PKM) aimed to bridge this gap by implementing Virtual Reality (VR) technology as a digital preservation tool, focusing on the "Smart People" dimension. The intervention involved **20 participants**, including local youth and tour guides. The methodology encompassed three phases: (1) Digital documentation using photogrammetry; (2) Development of an immersive VR application using Unity 3D; and (3) Capacity building on VR operation and digital storytelling. Results demonstrate the successful deployment of a VR interaction corner and a significant improvement in human resource capacity, with training evaluations showing a **45% increase** in digital literacy scores. The integration of VR has modernized the visitor experience and empowered local guardians to sustainably manage their digital heritage.

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INTRODUCTION

Cultural heritage sites are vital assets for local identity and economic development. The Waruga ancient stone sarcophagi of the Minahasan people represent a unique megalithic tradition recognized globally (Renwarin, 2019). Located in Sawangan Village, North Sulawesi, the Waruga Archaeological Park faces challenges common to traditional heritage sites: physical degradation and a lack of engagement with digital-native visitors (Bec et al., 2019). The Smart Village concept has emerged as a strategic framework for rural development, emphasizing digital technology to improve public services (Zavratnik et al., 2018). A key pillar is Smart People, referring to a community skilled in utilizing technology. For Sawangan to transform into a Smart Village, modernizing its cultural tourism sector is imperative. Current trends in Experience Tourism demand immersion and interaction (Tussyadiah et al., 2018). Virtual Reality (VR) offers a transformative solution, allowing users to interact with historical objects in simulated environments (Bekele et al., 2018). However, technology alone is insufficient. A recurring failure in rural digital adoption is the **digital divide**—the lack of human resource readiness (Park, 2017). Sophisticated tools are often abandoned if the community lacks the skills to operate them. This PKM program addresses these issues through a holistic intervention: digitizing Waruga artifacts, developing a VR application, and, critically, upgrading the skills of the Sawangan community (*Karang Taruna* and guides) to manage this technology.

METHODS

The program adopted a **Community-Based Participatory Research (CBPR)** approach over eight months. The implementation was structured into three technical phases:

Phase I: Digital Documentation and Asset Creation

The team utilized Photogrammetry to create realistic 3D models. High-resolution photographs were captured from 360-degree angles using DSLR cameras and drones (Remondino, 2011).

These images were processed to generate textured meshes, which were then optimized in Blender software to reduce polygon count for smooth VR performance (Gomes et al., 2014).

Phase II: VR Application Development

The application, Waruga: Journey to the Past, was developed using the Unity 3D game engine targeting Oculus Quest 2 hardware. The development followed the Multimedia Development Life Cycle (MDLC):

- Concept & Design: Defining the user journey and interaction logic.
- Assembly: Integrating 3D assets and audio narrations into Unity.
- Testing: Alpha testing was conducted to ensure performance stability and minimize motion sickness (Technologies, 2020).

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Phase III: Capacity Building (The Intervention)

To address the Smart People aspect, structured workshops were conducted for 20 participants (local youth and guides). The curriculum included:

- Module A (Awareness): Importance of digital preservation.
- Module B (Operation): Hands-on training with VR hardware (setup, sanitation, casting to TV).
- Module C (Storytelling): Integrating VR into traditional tour narratives (Robin, 2008).

RESULTS AND DISCUSSION

This intervention has made it more than possible and achievable, but has also shown significant results in the technologies readiness and human resource plan, preparing Sawangan to achieve its Smart Village aims.

The "Virtual Waruga" Application

The developed application successfully recreated the Waruga site in a 1:1 virtual scale. Users can virtually handle artifacts (pottery, beads) and view informational pop-ups about specific carvings. This level of interactivity provides an educational depth unattainable through physical observation alone.

- Immersive Features: Users can pick up artifacts that are typical of Waruga, like pottery and beads, and examine them more closely by rotating them in space. When users focus on particular carvings (reliefs), information panels appear that explain what the carving means (for example, symbols of a person's profession).
- Visual Fidelity: The photogrammetry process achieved high-texture quality, preserving the weathering details of the stone, which received praise from archaeologists for its authenticity (Champion, 2021)

FIGURE 1. The Virtual Reality environment rendering of the Waruga site.

Capacity Building Outcomes

The effectiveness of the training was evaluated using pre- and post-test assessments across three domains: Technical Knowledge, Operational Skills, and Digital Awareness.

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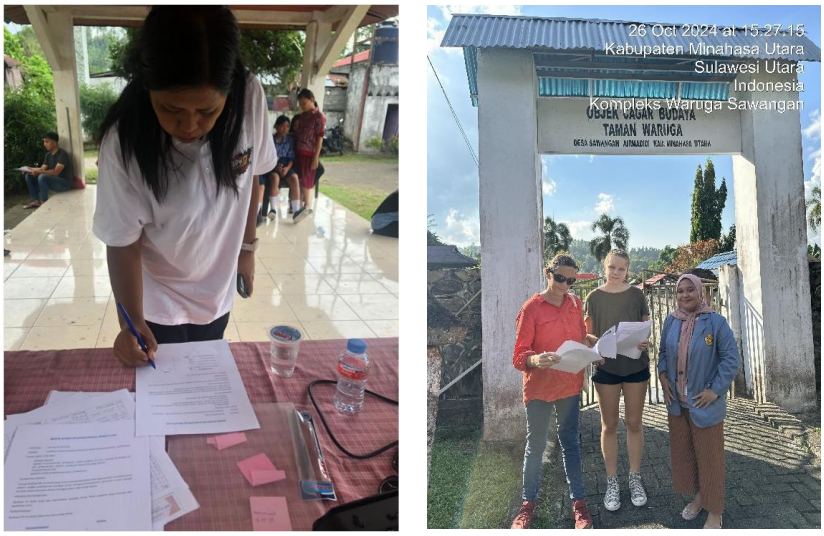
TABLE 1. Pre- and Post-Test Analysis of Trainees (N=20)

Domain	Pre-Test Avg.	Post-Test Avg.	Gain (%)
Technical Knowledge (VR)	25.0	80.5	+222%
Operational Skills	15.0	88.0	+486%
Digital Awareness	40.0	90.0	+125%
Overall Score	26.6	86.1	+223%

The data in Table 1 shows an enormous jump in operational skills (+486%), as most participants had never used a VR headset at the time of initially enrolling in the training course, and could easily walk a tourist through the setup at the conclusion of it. This supports the effectiveness of hands-on training (Kolb, 2014).

(a)



(b)

FIGURE 2. (a) Local youth practicing with the headset during the workshop; (b) tourist questionnaire respondents.

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Impact on the Visitor Experience

The "Digital Heritage Corner" brought in a total of 30 visitors during the soft launch month. A sample of 30 visitors completed a feedback survey that was based on the User Experience Questionnaire (UEQ).

- Attractiveness: 4.72/5.0 (Visitors described the VR as visually spectacular).
- Novelty: 4.85/5.0 (Most visitors reported that they had never experienced cultural heritage in VR before).
- Educational Value: 4.56/5.0 (Visitors said they learned more about the carvings from the interactive pop-ups that appeared, compared to just looking at the stone).

The positive appeal for VR suggests that it adds "Edutainment" value for tourists, thereby directly supporting the economic sustainability of the Smart Village (Schrepp et al., 2017).

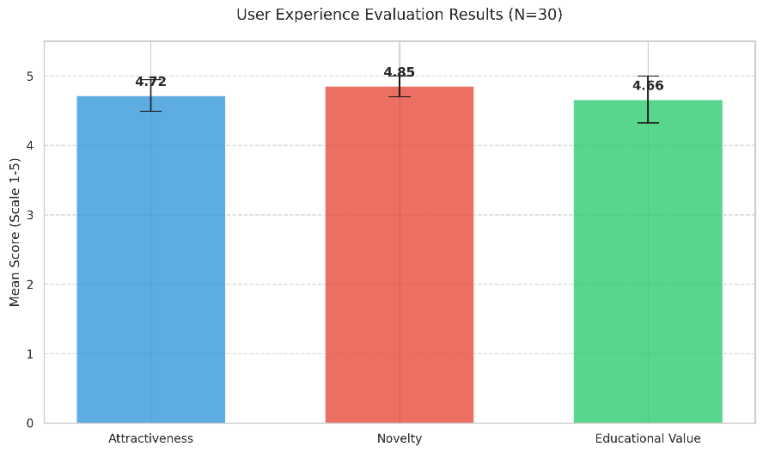

FIGURE 3. Statistical outcome of the User Experience Questionnaire (UEQ) involving 30 respondents.

The bar chart on the left highlights exceptionally high mean scores across all three evaluated dimensions, with Novelty achieving the highest rating (M=4.85, SD=0.15). This indicates that the Virtual Reality implementation offers a highly innovative experience for visitors, significantly differentiating it from traditional museum displays. Attractiveness (M=4.72) and Educational Value (M=4.66) also scored well above the benchmark of 4.0, confirming that the application is visually appealing and effective as a learning tool.

The boxplot on the right further corroborates these findings by illustrating the distribution of individual responses. The data points are tightly clustered between the scores of 4.5 and 5.0, with negligible variance and no significant outliers. This tight distribution signifies a strong consensus among the diverse group of respondents (students, tourists, and locals), validating that the "Digital Heritage Corner" successfully meets user expectations for an engaging and educational cultural experience.

Sustainability and the Context of Smart Villages

The program successfully implemented the 'Smart People' element in Sawangan. We now consider our local guides tech-savvy facilitators instead of mere historians. This is a significant transformation! In addition, one of our community empowerment objectives is that if we can introduce technology, they

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can then own it. In this way, we reduce the risk of obsolescence or having unused equipment. Furthermore, the village government has agreed to set aside money in its budget for electricity and equipment upkeep, signifying a commitment to sustainability (Visvizi & Lytras, 2018)(Jung & tom Dieck, 2017)(Guttentag, 2010; Styliani et al., 2009).

CONCLUSION AND RECOMMENDATIONS

Conclusion

The implementation of Virtual Reality in Sawangan Village has successfully harmonized advanced technology with cultural tradition. By digitizing artifacts and training local human resources, this program has transformed the community into competent agents of a Smart Village. The significant increase in digital literacy (+223% overall gain) ensures that the technology will be sustainably managed by the locals, not just external experts. This initiative proves that rural heritage sites can leapfrog into the digital era through targeted human capital investment.

Recommendations

When looking to the future, any expansion should consider:

- Augmented Reality (AR): Develop a mobile AR app - allowing visitors to reference the Waruga on-site to view visual overlays showing a history of the person whose ancestors are within the site, or the history of the waruga site as a whole.
- Online Museum: Make available the 3D models via a web platform (WebGL) even if they are not accessible on-site via virtual reality.
- Expanded Training: Offer a workshop on basic 3D modeling for young people in the community - they can then add new artifacts independently after training.

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