**Indonesian Journal of Social Science Education (IJSSE)**

Indonesian Journal of Social Science Education

https://ejournal.uinfasbengkulu.ac.id/index.php/ijsse

**E-ISSN: 2655-6278 P-ISSN: 2655-6588**

# UI/UX Design Development for The SiCamar Application: A VR-Based Interactive Learning Media

BAYU KURNIAWAN[1], WAHYU DJOKO SULISTYO[2], LISTYO YUDHA IRAWAN[3]
[1,3]PPG Sekolah Pascasarjana, Universitas Negeri Malang, Indonesia.
[2]Departemen Sejarah, Universitas Negeri Malang, Indonesia.
Email: bayu.kurniawan.fis@um.ac.id

**ABSTRACT:**
The rapid advancement of technology significantly affects various life aspects, notably education. Virtual reality (VR) is a key technology that enables the creation of educational media for historical sites. However, previous research indicates limitations in features and accessibility. This study aims to develop a prototype application called SiCamar (Malang Raya Temple Site) based on VR. Using a research and development (R&D) approach, we applied the ADDIE model, focusing only on the Analysis, Design, and Development stages since the goal was to create a prototype and test its initial feasibility. The needs analysis revealed that users desired to experience the historical site via a VR platform. Essential features identified include 360-degree panoramas, videos, teaching materials, and maps, while necessary learning activities involve virtual tours, video observation, reading materials, and answering questions. In the design phase, the use of AI facilitated the creation of an attractive user interface. User testing results indicate that the SiCamar application effectively enhances user satisfaction, particularly in supporting the learning process.
**Keywords:** SiCamar, Virtual Reality, Historical Site, Temple, Learning Media

**ABSTRAK:**
Pesatnya perkembangan teknologi berdampak signifikan pada berbagai aspek kehidupan, termasuk pendidikan. Salah satu teknologi yang menonjol dalam bidang ini adalah virtual reality (VR) yang mempermudah pembuatan media pembelajaran situs sejarah. Namun, penelitian sebelumnya menunjukkan keterbatasan fitur dan aksesibilitas. Penelitian ini bertujuan untuk mengembangkan prototipe aplikasi SiCamar (Situs Candi Malang Raya) berbasis Virtual Reality (VR). Dengan menggunakan pendekatan penelitian dan pengembangan (R&D), kami menggunakan model pengembangan ADDIE, namun karena hanya mengembangkan produk prototipe aplikasi dan menguji kelayakan awal, maka peneliti hanya menerapkan tahap Analysis, Design, dan Development saja pada penelitian ini. Hasil pada tahap analisis kebutuhan menunjukkan bahwa, pengguna menginginkan virtualisasi situs Sejarah menggunakan platform virtual reality (VR). Selain itu, fitur-fitur yang dibutuhkan yakni: 1) panorama 360, video, bahan ajar, dan maps. Aktivitas pembelajaran yang dibutuhkan yakni: 1) eksplorasi virtual tour, mengamati video, membaca bahan ajar, dan menjawab soal. Pada tahap desain, pemanfaatan AI memberikan kemudahan untuk mendapatkan desain interface yang menarik bagi pengguna. Hasil uji coba kepada pengguna menunjukkan aplikasi SiCamar memberikan kepuasan bagi pengguna terutama dalam membantu pada proses belajar.
**Kata Kunci:** SiCamar, Virtual Reality, Situs Sejarah, Candi, Media Pembelajaran

**Article History:** Received: 02-09-2024, Accepted: 18-01-2025, Published: 31-01-2025.
**PLEASE CITE AS:** Kurniawan, B., Sulistyo, W.D., & Irawan, L.D. (2025). UI/UX Design Development for The SICAMAR Application: A VR-Based Interactive Learning Media. *Indonesian Journal of Social Science Education (IJSSE), 7* (1), 34-45. DOI: http://dx.doi.org/10.29300/ijsse.v7i1.6902

## A. INTRODUCTION

The Cyber-Physical Systems (CPS) era is characterized by the integration of systems combining cyber (computational and network) and physical (mechanical, electromechanical, and biological) components. This era is marked by the adoption of technologies such as the Internet of Things (IoT) (Atzori et al., 2017; Dorsemaine et al., 2015; Mouha, 2021), big data analytics (Bi & Cochran, 2014; Kambatla et al., 2014), robotics (Rubio et al., 2019; Simoens et al., 2018), autonomous vehicles, (Faisal et al., 2019; Brummelen et al., 2018) and other intelligent systems. These remarkable advancements have significantly impacted various aspects of life. In the field of education, a paradigm shift from traditional learning methods toward technology integration is evident. One tangible implementation is the utilization of ICT-based learning media. Among the technologies extensively applied in education is virtual reality (VR), which seemingly removes the boundaries between the physical and digital worlds.

To date, research on the use of virtual reality (VR) in education has grown considerably. In health education, VR has been employed in medical training, particularly for surgeons (Frankiewicz et al., 2023; Gendia, 2023; Long et al., 2023), and nurses (Le Duff et al., 2023; Mäkinen et al., 2022). In the field of sports, VR has been used for karate training (Pastel et al., 2022), Similarly, in language learning, VR has facilitated vocabulary acquisition in English (Chen et al., 2022; Tai et al., 2022), Moreover, VR has also been utilized to enhance the learning experiences of students with disabilities (Drigas et al., 2022). Field-based learning has increasingly adopted VR (Cheng, 2022; Zhao et al., 2022). Historical education has become a prominent user, aiming to engage students and the public in exploring the grandeur of the past. In Spain, the Neolithic site of La Draga was digitized using VR technology and showcased through traveling exhibitions (Puig et al., 2020). Similarly, in Italy, an underwater prehistoric site was developed using VR as an educational tool, successfully providing an immersive experience for its users (Bruno et al., 2018).

VR technology should be utilized effectively, particularly for valuable historical sites. Malang Regency, rich in Hindu-Buddhist relics, features numerous significant temples, including Singosari, Jago, Kidal, and Badut, among others throughout the region.

The implementation of VR technology remains insufficient due to significant challenges, such as the need for specialized skills and high development costs. This poses difficulties for history teachers and educators, as it lies outside their area of expertise. Furthermore, research on VR technology in temple-based learning is limited, with most VR applications focused on tourism rather than educational purposes (Fitriastuti et al., 2022; Purwanto et al., 2022; Rahman, 2022; Wati, 2022). Currently, learning media emphasizes audio-visual (Agustina, 2022), visual (Alim, 2022), multimedia (Anggraini & Jati, 2023), comics (Al Ashar, 2022), and relief reading applications (Setyawan, 2022). Thus, developing a user-friendly VR-based learning platform for educators and students is essential. This platform should offer comprehensive, independent, engaging, and interactive features, particularly about the temple sites in Malang Raya. This study aims to address this gap and contribute to knowledge development by creating SiCamar (Malang Raya Temple Site) application VR-based.

## B. METHOD

This study use Research and Development (R&D) aimed at producing a prototype product in the form of the SiCamar (Situs Candi Malang Raya) application based on Virtual Reality(Gall et al., 1996). The researchers employed the ADDIE development model (Analysis, Design, Development, Implementation, and Evaluation) to develop the application (Branch, 2009). However, since the study focuses solely on developing the SiCamar application prototype and conducting initial feasibility testing, the ADDIE stages were only carried out up to the Analysis, Design, and Development phases.

### 1. The analysis phase

The analysis phase aimed to gather data on the learning application needed by university students. The findings will shape the application's initial design, including its interface, features, and content. The indicators for the needs analysis (NA) include: 1) alternative solutions (NA-1), 2) required platform (NA-2), 3) necessary features (NA-3), and 4) preferred learning activities (NA-4). A questionnaire was distributed to 130 students across various academic programs.

### 2. The design phase

In this phase, the research team developed the initial design concept for the SiCamar application based on the needs analysis results. This design process encompasses the application's interface, specifications, and features.

### 3. The development phase

This phase focuses on evaluating the technical aspects of the SiCamar application prototype. Researchers conducted validation testing with instructional media experts and small-scale user testing. Nielsen (1994) suggests that involving 5 users is adequate, though 10–20 can provide richer data. For the small-scale trials, 18 university students were engaged as users of the SiCamar application.

## C. RESULT AND DISCCUSSION

### 1. The needs analysis results

Researchers distributed a needs analysis questionnaire to 130 university students to guide the development of the SiCamar application, allowing them to choose desired menus and features. According to the data in Figure 1, students identified the virtualization of historical sites as a key requirement, selecting it 103 times (NA-1). They preferred virtual tours/virtual reality as the platform, with 62 selections (NA-2). Essential features for the application included 360-degree panoramas (106 selections), videos (93), learning materials (84), and maps (73) (NA-3). Desired learning activities consisted of virtual tour exploration (122 selections), video observation (100), reading materials (75), and answering quiz questions (40) (NA-4).

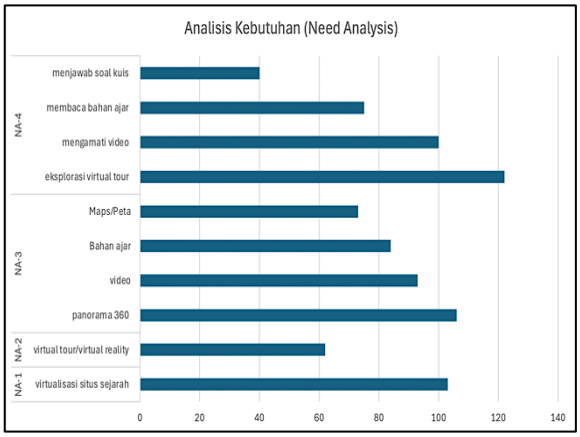


**Figure 1. The needs analysis results of SiCamar apps**

### 2. The design results

During the design phase, the researchers undertook several processes, including creating moodboards, wireframes, and high-fidelity designs (Figures 2, 3, and 4). AI was

used to develop an engaging user interface, and the Keypano application facilitated the 360-degree panorama display. The outcome of the high-fidelity design resulted in a prototype or model that closely resembles the final product.


**Figure 2. SiCamar initial interface**


**Figure 3. Homepage interface**


**Figure 4. The temple virtual tour interface**

**a. Features/components: application interface**

The design results: The front display includes a "Start" button to access the application without a login process, enabling easy entry. It features a full AI-generated illustration of a temple alongside the text, "Welcome to SiCamar."

**b. Features/components: homepage interface**

The design results: The homepage features options for virtual temple tours and an "Exit" button. There are four buttons for selecting virtual temples, each with an icon of its respective temple. Users can easily tap a button to start a virtual tour. The "Exit" button returns users to the application's main page. The design also includes

an Oculus illustration, symbolizing the Virtual Reality (VR) character, along with the text "SiCaMar" and "Situs Candi Malang Raya".

**c. Features/components: The Virtual Tour of temple interface**

The design results: The SiCamar application offers a virtual tour of a temple with 360-degree panoramas, along with a location map, educational videos, and a Google Forms-based quiz, all accessible within the app.

## 3. The development resuts

Expert validation of the SiCamar application yielded scores of 93 for visual communication, 91 for ease of use, and 92 for app appearance (Figure 5). Consequently, the application is classified as "very good".

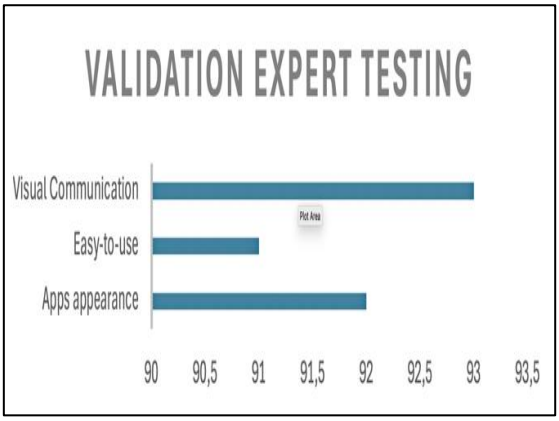


**Figure 5. The validation expert testing results**

The small-scale user testing results were evaluated based on indicators such as interface, ease of use, interactivity, support for learning, and user satisfaction. The scores from the trial were 89 for user satisfaction, 88 for support for learning, 87 for ease of use and interactivity, and 85.5 for the interface (Figure 6). The overall average score was 87.37, which, according to the System Usability Scale method by Brooke (2013), indicates that the application has good feasibility.

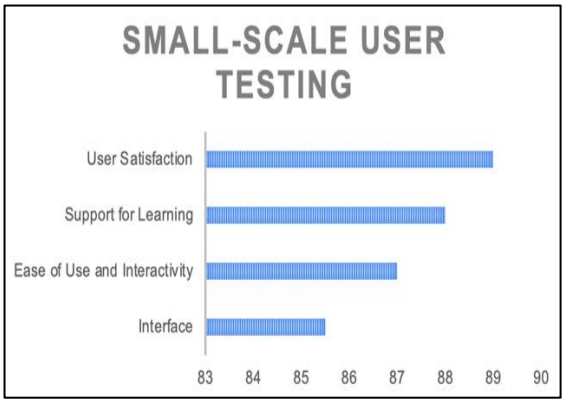


**Figure 6. The small-scale user testing results**

Innovation in Indonesia's historical sites is essential due to rapid technological advancements. Researchers must prioritize needs analysis in this innovation process. Current findings suggest that the virtualization of historical sites using Virtual Reality (VR) technology is necessary. Studies indicate that VR can provide meaningful experiences for students without requiring physical visits to these sites (Kurniawan et al., 2022, 2023; Naiborhu & Kurniawan, 2024; Ningsih & Kurniawan, 2024). Beyond education, VR technology is applicable in housing marketing (Sulaiman et al., 2020), tourism (Lu et al., 2022; Moraes et al., 2022; X. Wu & Lai, 2022), and museum collections (Lee et al., 2022; Li & Huang, 2022). It has been shown to enhance student engagement (Barry & Kanematsu, 2022). and supports computational thinking (Agbo et al., 2022), aids metacognitive training for individuals with disabilities (Drigas et al., 2022), and fosters empathy and understanding (Riches et al., 2022).

AI technology plays a significant role in helping individuals create personalized applications. It has been effectively applied across various fields, including instructional material design (Haerani & Sallu, 2024; Lubis et al., 2022), healthcare (Rawas et al., 2024; Vasdev et al., 2024), transportation

innovation (Abduljabbar et al., 2019; Nikitas et al., 2020; J. Wu et al., 2022), and industrial production (Chryssolouris et al., 2023).

Other findings shows that VR in learning increases user satisfaction and aids students in their studies. Recent findings indicate that virtual reality can enhance learning outcomes and comprehension (Haryana et al., 2022). However, achieving self-regulated learning remains challenging, necessitating innovations in this area. Notably, virtual reality has been shown to improve students' self-regulation skills (Wu et al., 2021).

## D. CONCLUTION

Needs analysis is essential in developing an educational media product to ensure it meets its objectives. Based on this analysis, students, potential users of the SiCamar application, expressed a desire for virtual tours. Key features for the application include 360-degree panoramas, educational videos, learning materials, and maps to locate historical sites. Required learning activities involve virtually exploring sites, accessing audio-visual materials for comprehension, and self-assessing understanding. The application's interface design, enhanced by AI, has effectively engaged users. User testing results showed high satisfaction and notable support for their learning process.

## E. ACKNOWLEDGEMENT

We sincerely thank to the Graduate School of Universitas Negeri Malang for funding this activity through Rector's Decree No. 27.5.226/UN32/KP/2024.

## F. REFERENCES

Abduljabbar, R., Dia, H., Liyanage, S., & Bagloee, S. A. (2019). Applications of Artificial Intelligence in Transport: An Overview. *Sustainability*, *11*(1), Article 1. https://doi.org/10.3390/su11010189

Agbo, F. J., Oyelere, S. S., Suhonen, J., & Tukiainen, M. (2022). Design, development, and evaluation of a virtual reality game-based application to support computational thinking. *Educational Technology Research and Development*. https://doi.org/10.1007/s11423-022-10161-5

Agustina, F. I. (2022). Pengembangan Media Audio Visual Candi Prambanan Bermuatan Pendidikan Karakter Dalam Pembelajaran Sejarah SMA. *Historia Vitae*, *2*(1), Article 1. https://doi.org/10.24071/hv.v2i1.4560

Al Ashar, H. (2022). *Pengembangan Media Pembelajaran Berbasis Komik Cerita Rakyat Sidoarjo "Asal Mula Candi Pari" Untuk Meningkatkan Hasil Belajar Tema 8 Subtema 1 Pembelajaran 3 Pada Siswa Kelas IV A SDN Medaeng 1 Sidoarjo*. https://repository.unej.ac.id/xmlui/handle/123456789/107257

Alim, M. R. (2022). Pengembangan Media Galeri Visual Sejarah (GVS) berbasis Website pada Materi Candi-Candi di Malang Raya. *Historia: Jurnal Pendidik dan Peneliti Sejarah*, *5*(2), Article 2. https://doi.org/10.17509/historia.v5i2.35323

Anggraini, E. N., & Jati, S. S. P. (2023). Pengembangan media historiografis interaktif berbasis Adobe Flash tentang Candi Surawana untuk kelas X SMK Diponegoro Tumpang Kabupaten Malang. *Historiography:*

*Journal of Indonesian History and Education*, *3*(1), Article 1.

Atzori, L., Iera, A., & Morabito, G. (2017). Understanding the Internet of Things: Definition, potentials, and societal role of a fast-evolving paradigm. *Ad Hoc Networks*, *56*, 122–140. https://doi.org/10.1016/j.adhoc.2016.12.004

Barry, D. M., & Kanematsu, H. (2022). Virtual reality enhances active student learning. *Procedia Computer Science*, *207*, 408–415. https://doi.org/10.1016/j.procs.2022.09.075

Bi, Z., & Cochran, D. (2014). Big data analytics with applications. *Journal of Management Analytics*, *1*(4), 249–265. https://doi.org/10.1080/23270012.2014.992985

Branch, R. M. (2009). *Instructional design: The ADDIE approach*. Springer.

Brooke, J. (2013). SUS: A retrospective. *Journal of Usability Studies*, *8*(2). http://uxpajournal.org/wp-content/uploads/sites/7/pdf/JUS_Brooke_February_2013.pdf

Bruno, F., Barbieri, L., Lagudi, A., Cozza, M., Cozza, A., Peluso, R., & Muzzupappa, M. (2018). Virtual dives into the underwater archaeological treasures of South Italy. *Virtual Reality*, *22*(2), 91–102. https://doi.org/10.1007/s10055-017-0318-z

Chen, B., Wang, Y., & Wang, L. (2022). The Effects of Virtual Reality-Assisted Language Learning: A Meta-Analysis. *Sustainability*, *14*(6), Article 6. https://doi.org/10.3390/su14063147

Cheng, K.-H. (2022). Teachers' perceptions of exploiting immersive virtual field trips for learning in primary education. *Journal of Research on Technology in Education*, *54*(3), 438–455. https://doi.org/10.1080/15391523.2021.1876576

Chryssolouris, G., Alexopoulos, K., & Arkouli, Z. (2023). Artificial Intelligence in Manufacturing Systems. In G. Chryssolouris, K. Alexopoulos, & Z. Arkouli, *A Perspective on Artificial Intelligence in Manufacturing* (Vol. 436, pp. 79–135). Springer International Publishing. https://doi.org/10.1007/978-3-031-21828-6_4

Dorsemaine, B., Gaulier, J.-P., Wary, J.-P., Kheir, N., & Urien, P. (2015). Internet of Things: A Definition & Taxonomy. *2015 9th International Conference on Next Generation Mobile Applications, Services and Technologies*, 72–77. https://doi.org/10.1109/NGMAST.2015.71

Drigas, A., Mitsea, E., & Skianis, C. (2022). Virtual Reality and Metacognition Training Techniques for Learning Disabilities. *Sustainability*, *14*(16), Article 16. https://doi.org/10.3390/su141610170

Faisal, A., Kamruzzaman, M., Yigitcanlar, T., & Currie, G. (2019). Understanding autonomous vehicles: A systematic literature review on capability, impact, planning and policy. *Journal*

*of Transport and Land Use*, *12*(1), 45–72.

Fitriastuti, F., Setyawan, R. A., & Correia, H. R. (2022). Prototype Pengenalan Candi Di Yogyakarta Berbasis Augmented Reality. *Informasi Interaktif*, *7*(1), Article 1.

Frankiewicz, M., Vetterlein, M. W., & Matuszewski, M. (2023). VR, reconstructive urology and the future of surgery education. *Nature Reviews Urology*, 1–2. https://doi.org/10.1038/s41585-022-00722-x

Gall, M. D., Borg, W. R., & Gall, J. P. (1996). *Educational research: An introduction*. Longman Publishing. https://psycnet.apa.org/record/1996-97171-000

Gendia, A. (2023). Bariatric Surgery May Benefit From New Advances in Virtual Reality as A Virtual Eco-System. *Surgical Innovation*, 15533506221150674. https://doi.org/10.1177/15533506221150674

Haerani, Y., & Sallu, S. (2024). Rancangan Aplikasi Pembelajaran Hukum Ekonomi Berbasis Artificial Intelligence (AI) di Perguruan Tinggi. *Information System For Educators And Professionals : Journal of Information System*, *9*(1), 87–96. https://doi.org/10.51211/isbi.v9i1.2888

Haryana, M. R. A., Warsono, S., Achjari, D., & Nahartyo, E. (2022). Virtual reality learning media with innovative learning materials to enhance individual learning outcomes based on cognitive load theory. *The International Journal of Management Education*, *20*(3), 100657. https://doi.org/10.1016/j.ijme.2022.100657

Kambatla, K., Kollias, G., Kumar, V., & Grama, A. (2014). Trends in big data analytics. *Journal of Parallel and Distributed Computing*, *74*(7), 2561–2573. https://doi.org/10.1016/j.jpdc.2014.01.003

Kurniawan, B., Shrestha, R. P., Astina, I. K., Hadi, N., Irawan, L. Y., Kurniawati, E., & Wiradimadja, A. (2022). Developing a Virtual Nature Laboratory of Faculty Social Science (LAV-FIS) to Assists Field-Based Learning during Pandemic: A Need Analysis Review. *International Journal of Interactive Mobile Technologies (iJIM)*, *16*(07), Article 07. https://doi.org/10.3991/ijim.v16i07.28481

Kurniawan, B., Shrestha, R. P., bin Haji Mat Lazim, M. J., Abd Hamid, A. bin, Sulistyo, W. D., Utami, N. W., & Wahyuni, F. (2023). Si-VirPraJa: Using an Immersive Technology to Learn Prehistoric Sites in Indonesia. *International Journal of Interactive Mobile Technologies*, *17*(23).

Le Duff, M., Michinov, E., Bracq, M.-S., Mukae, N., Eto, M., Descamps, J., Hashizume, M., & Jannin, P. (2023). Virtual reality environments to train soft skills in medical and nursing education: A technical feasibility study between France and Japan. *International Journal of Computer Assisted Radiology and Surgery*.

https://doi.org/10.1007/s11548-023-02834-0

Lee, H.-K., Park, S., & Lee, Y. (2022). A proposal of virtual museum metaverse content for the MZ generation. *Digital Creativity*, *33*(2), 79–95. https://doi.org/10.1080/14626268.2022.2063903

Li, W., & Huang, X. (2022). The Interactive Design and User Experience of Virtual Museums: Case Study of the Virtual Palace Museum. In P.-L. P. Rau (Ed.), *Cross-Cultural Design. Applications in Learning, Arts, Cultural Heritage, Creative Industries, and Virtual Reality* (pp. 400–409). Springer International Publishing. https://doi.org/10.1007/978-3-031-06047-2_29

Long, A. S., Almeida, M. N., Chong, L., & Prsic, A. (2023). Live Virtual Surgery and Virtual Reality in Surgery: Potential Applications in Hand Surgery Education. *The Journal of Hand Surgery*. https://doi.org/10.1016/j.jhsa.2023.01.004

Lu, J., Xiao, X., Xu, Z., Wang, C., Zhang, M., & Zhou, Y. (2022). The potential of virtual tourism in the recovery of tourism industry during the COVID-19 pandemic. *Current Issues in Tourism*, *25*(3), 441–457. https://doi.org/10.1080/13683500.2021.1959526

Lubis, B. S., Sari, S. P., Siregar, E. F. S., & Batubara, I. H. (2022). Pemanfaatan Adobe Illustrator (AI) Sebagai Aplikasi Desain Bahan Ajar Berbasis Komik. *Aksiologiya: Jurnal Pengabdian Kepada Masyarakat*, *6*(4), Article 4. https://doi.org/10.30651/aks.v6i4.9851

Mäkinen, H., Haavisto, E., Havola, S., & Koivisto, J.-M. (2022). User experiences of virtual reality technologies for healthcare in learning: An integrative review. *Behaviour & Information Technology*, *41*(1), 1–17. https://doi.org/10.1080/0144929X.2020.1788162

Moraes, C. M. dos S., Vega, B. D. L., Frenzel, F., Rega, I., & Mainard-Sardon, J. (2022). Favela virtual tour: Alternative mobilities in favela tourism during COVID-19 pandemic. In *Alternative (Im)Mobilities*. Routledge.

Mouha, R. A. (2021). Internet of Things (IoT). *Journal of Data Analysis and Information Processing*, *9*(2), Article 2. https://doi.org/10.4236/jdaip.2021.92006

Naiborhu, S., & Kurniawan, B. (2024). Pengembangan Aplikasi SIVIRCADO (Situs Virtual Candi-Candi di Sidoarjo) Berbasis Virtual Tour sebagai Media Pembelajaran IPS di SMP Bina Budi Mulia Malang. *Humanities Horizon*, *1*(1), Article 1.

Nielsen, J. (1994). *Usability engineering*. Morgan Kaufmann. https://books.google.com/books?hl=id&lr=&id=95As2OF67f0C&oi=fnd&pg=PR9&dq=Nielsen+(1994)+Usability+Engineering&ots=3dBEzrhw0p&sig=NVPKQhj8Uh1OgMF40ItJ_3F2_hY

Nikitas, A., Michalakopoulou, K., Njoya, E. T., & Karampatzakis, D. (2020). Artificial Intelligence, Transport and the Smart City: Definitions and Dimensions of a New Mobility Era. *Sustainability*, *12*(7), Article 7. https://doi.org/10.3390/su12072789

Ningsih, M., & Kurniawan, B. (2024). Pengembangan Aplikasi Si Calang (Situs Candi di Malang) Berbasis Virtual Reality Sebagai Media Pembelajaran IPS. *J-PIPS (Jurnal Pendidikan Ilmu Pengetahuan Sosial)*, *10*(2), Article 2. https://doi.org/10.18860/jpips.v10i2.23061

Pastel, S., Petri, K., Chen, C. H., Wiegand Cáceres, A. M., Stirnatis, M., Nübel, C., Schlotter, L., & Witte, K. (2022). Training in virtual reality enables learning of a complex sports movement. *Virtual Reality*. https://doi.org/10.1007/s10055-022-00679-7

Puig, A., Rodríguez, I., Arcos, J. Ll., Rodríguez-Aguilar, J. A., Cebrián, S., Bogdanovych, A., Morera, N., Palomo, A., & Piqué, R. (2020). Lessons learned from supplementing archaeological museum exhibitions with virtual reality. *Virtual Reality*, *24*(2), 343–358. https://doi.org/10.1007/s10055-019-00391-z

Purwanto, A., Cahyadi, H., Ramandha, D., Raharjo, W., & Wismadi, A. (2022). Pusat Informasi Konservasi dengan Fasilitas AR dan VR pada Candi Borobudur dengan Metode SWOT. *Aksen : Journal of Design and Creative Industry*, *6*(2), 1–15. https://doi.org/10.37715/aksen.v6i2.2225

Rahman, A. A. (2022). *Pengembangan Aplikasi Android Berbasiskan Building Information Modelling Virtual Reality (BIM-VR) Untuk Wisata Digital Pada Bangunan Bersejarah (Studi Kasus: Candi Kidal, Kecamatan Tumpang, Kabupaten Malang)* [Skripsi, Institut Teknologi Nasional Malang]. http://eprints.itn.ac.id/9470/

Rawas, S., Tafran, C., AlSaeed, D., & Al-Ghreimil, N. (2024). Transforming Healthcare: AI-NLP Fusion Framework for Precision Decision-Making and Personalized Care Optimization in the Era of IoMT. *Computers, Materials and Continua*, *81*(3), 4575–4601. https://doi.org/10.32604/cmc.2024.055307

Riches, S., Iannelli, H., Reynolds, L., Fisher, H. L., Cross, S., & Attoe, C. (2022). Virtual reality-based training for mental health staff: A novel approach to increase empathy, compassion, and subjective understanding of service user experience. *Advances in Simulation*, *7*(1), 19. https://doi.org/10.1186/s41077-022-00217-0

Rubio, F., Valero, F., & Llopis-Albert, C. (2019). A review of mobile robots: Concepts, methods, theoretical framework, and applications. *International Journal of Advanced Robotic Systems*, *16*(2), 1729881419839596. https://doi.org/10.1177/1729881419839596

Setyawan, K. D. S. (2022). *Pengembangan media pembelajaran aplikasi baca relief (barel) berbasis android pada materi bubuksah gagang aking candi panataran untuk siswa kelas x sman 1 singosari / Khalfin Deby Setyawan* [Diploma, Universitas Negeri Malang]. http://repository.um.ac.id/201779/

Simoens, P., Dragone, M., & Saffiotti, A. (2018). The Internet of Robotic Things: A review of concept, added value and applications. *International Journal of Advanced Robotic Systems*, *15*(1), 1729881418759424. https://doi.org/10.1177/1729881418759424

Sulaiman, M. Z., Aziz, M. N. A., Bakar, M. H. A., Halili, N. A., & Azuddin, M. A. (2020). *Matterport: Virtual Tour as A New Marketing Approach in Real Estate Business During Pandemic COVID-19*. 221–226. https://doi.org/10.2991/assehr.k.201202.079

Tai, T.-Y., Chen, H. H.-J., & Todd, G. (2022). The impact of a virtual reality app on adolescent EFL learners' vocabulary learning. *Computer Assisted Language Learning*, *35*(4), 892–917. https://doi.org/10.1080/09588221.2020.1752735

Van Brummelen, J., O'Brien, M., Gruyer, D., & Najjaran, H. (2018). Autonomous vehicle perception: The technology of today and tomorrow. *Transportation Research Part C: Emerging Technologies*, *89*, 384–406. https://doi.org/10.1016/j.trc.2018.02.012

Vasdev, N., Gupta, T., Pawar, B., Bain, A., & Tekade, R. K. (2024). Navigating the future of health care with AI-driven digital therapeutics. *Drug Discovery Today*, *29*(9), 104110. https://doi.org/10.1016/j.drudis.2024.104110

Wati, L. (2022). Model Preservasi dan Pemanfaatan Candi Awang Maombiak Dharmasraya Provinsi Sumatera Barat. *Jurnal Hamsa*, *1*(1), Article 1.

Wu, J., Wang, X., Dang, Y., & Lv, Z. (2022). Digital twins and artificial intelligence in transportation infrastructure: Classification, application, and future research directions. *Computers and Electrical Engineering*, *101*, 107983. https://doi.org/10.1016/j.compeleceng.2022.107983

Wu, W.-L., Hsu, Y., Yang, Q.-F., Chen, J.-J., & Jong, M. S.-Y. (2021). Effects of the self-regulated strategy within the context of spherical video-based virtual reality on students' learning performances in an art history class. *Interactive Learning Environments*, *0*(0), 1–24. https://doi.org/10.1080/10494820.2021.1878231

Wu, X., & Lai, I. K. W. (2022). The use of 360-degree virtual tours to promote mountain walking tourism: Stimulus–organism–response model. *Information Technology & Tourism*, *24*(1), 85–107. https://doi.org/10.1007/s40558-021-00218-1

Zhao, J., Wallgrün, J. O., Sajjadi, P., LaFemina, P., Lim, K. Y. T., Springer, J. P., & Klippel, A. (2022).

Longitudinal Effects in the Effectiveness of Educational Virtual Field Trips. *Journal of Educational Computing Research*, *60*(4), 1008–1034. https://doi.org/10.1177/0735633121 1062925