Developing Augmented Reality Lontar Prasi Bali as an E-learning Material to Preserve Balinese Culture

I Gede Iwan Sudipa[1*], Putu Wirayudi Aditama[2] and Christina Purnama Yanti[3]

[1*]Lecturer and Researcher, Informatics Engineering Study Program, Faculty of Information and Technology Institute of Business and Technology Indonesia (INSTIKI), Bali, Indonesia.
iwansudipa@instiki.ac.id, gedeiwansudipa@gmail.com,
ORCID: https://orcid.org/0000-0002-4278-9068

[2]Lecturer and Researcher, Informatics Engineering Study Program, Faculty of Information and Technology Institute of Business and Technology Indonesia (INSTIKI), Bali, Indonesia.
wirayudi.aditama@instiki.ac.id, ORCID: https://orcid.org/0000-0003-4618-176X

[3]Lecturer and Researcher, Informatics Engineering Study Program, Faculty of Information and Technology Institute of Business and Technology Indonesia (INSTIKI), Bali, Indonesia.
christinapy@instiki.ac.id, ORCID: https://orcid.org/0000-0003-4952-633X

Received: September 22, 2022; Accepted: December 10, 2022; Published: December 31, 2022

Abstract

Preservation of cultural heritage is one of the efforts that can be made to maintain and pass it on to the next generation, one of which is Lontar Prasi Bali. Thousands of prasi lontars are recorded in poorly maintained and damaged conditions in terms of form and physical appearance. This article aims to implement Augmented Reality in digitizing the Balinese lontar prasi so that it can preserve, promote, and develop the arts and ancestral heritage so that they have appeal and understanding in the present and even into the future. The application development method uses research and development with the stages of making 3D objects and the process of character animation with Blender, building applications with Unity software and making markers consisting of 3D objects and marker configurations on the Prasi Lontar Sheet. Application testing using a loading response time technique with higher smartphone specification results can provide a faster response time needed to run the application, as well as a User Experience Questionnaire (UEQ) test with 86 respondents who showed pragmatic quality, herdonic quality, and overall results above the average (Excellent), so that it shows that this AR application is good and as expected.

Keywords: Digitalization, Augmented Reality, Virtual Application, User Experience.

1 Introduction

Lontar is a medium used to write literature, starting from the royal era to the present. Writing on Lontar leaves is a Balinese tradition from ancient times that has been passed down from generation to generation as a cultural heritage. In general, lontar consists of lontar in the form of Balinese script text and pictures [1]. Prasi is a type of lontar which contains "Rerajahan", or a painting drawn on palm leaves. Lontar Prasi is called traditional Balinese comic) which tells the stories of Balinese epics such as the Ramayana and Bharathayuda which illustrates wayang characters (wayang kulit plays) and

Journal of Wireless Mobile Networks, Ubiquitous Computing, and Dependable Applications (JoWUA), volume: 13, number: 4 (December), pp. 169-181. DOI: *10.58346/JOWUA.2022.I4.011*

*Corresponding author: Lecturer and Researcher, Informatics Engineering Study Program, Faculty of Information and Technology Institute of Business and Technology Indonesia (INSTIKI), Bali, Indonesia.

contains instructions and insights into life lessons and Balinese local wisdom from the stories on each lontar sheet [2]. Lontar prasi has an important role as a medium in documenting historical Balinese stories and is full of meaning and advice in life. Based on data from the Balinese Language Extension Team, there are 8,239 Lontars that need to be rescued scattered throughout Bali. The total number recorded is 8,370 lontars. The details are 5,804, which are categorized as well-maintained with the condition that the lontars can still be read but require further conservation. The other 2,562 lontars are thought to be in bad shape, both in terms of how they look and how their contents are put together (July to the middle of September 2016). Currently, the physical condition of the prasi lontar that can still be seen and assessed is the typical lontar prasi tenganan. The urgency of the physical condition of the prasi lontar, which is not durable and prone to damage because it has been stored for decades, is one of the concerns about the importance of caring for and preserving cultural heritage and the need to digitize cultural heritage in order to survive in the future [3] [4]. Protection of cultural heritage is also strengthened by the Bali Governor Regulation No. 80 of 2018 concerning the Protection and Use of Balinese Language, Script, and Literature and the Implementation of Balinese Language Month [5]. The process of digitizing the lontar prasi requires a combination of technology [6] in digitizing the characters or figures told in the lontar prasi, visualizing [7] each story on a palm leaf sheet, and narrating the storyline from the Balinese text.

One technology that is very popular in visualizing objects is Augmented Reality (AR) [8]–[10]. Augmented Reality technology can combine the real world and the virtual world in real time by displaying 3-dimensional or 2-dimensional objects and modeling even intangible objects [11]. This AR capability is in line with the need for visualization of characters or story characters in lontar prasi. The development of AR technology in the era of industrial technology disruption 4.0 has become a necessity in terms of digitalization and visualization in various fields [12], [13]. AR is the choice in visualizing learning media as digital literacy support [14] in the field of education and learning both offline and online [15], interactive media really supports learning [16] [17] so that AR technology can be used to model objects to be studied.

AR can be used on smartphones, user-friendly [18] and mobile-based [19] so that it can support efforts to attract the interest of the younger generation in reading lontar prasi. AR is very potential when used in cultural digitization because many objects are very interesting [20] [21] but cannot be seen because the visual media is outdated. So that AR technology can be used to make each character or character asset, visualize movement based on the story, and add sound based on the story's narration.

This article aims to implement AR in digitizing the Balinese lontar prasi, which aims to preserve, promote, and develop arts and ancestral heritage so that they have appeal and understanding in the present and even into the future. The digitization of lontar is focused not only on making lontar prasi characters so that they can be seen augmented and making animations so that each character object can move when scanning each lontar prasi sheet, but can also be implemented on smartphone devices [22], which can attract the attention of the younger generation. to see and help preserve the cultural heritage of Lontar Prasi Bali [23].

2 Literature Review

Based on some literature, it is stated that the role of AR in making interactive and interesting learning media is very significant. AR as a technology that supports the field of education [24] and a pioneer of technology-based education [25] [26], for example, in visual simulation into E-Learning through smart devices [22] [16], AR research to improve students' abilities in learning with AR [15] [27], the use of

AR in learning media to make learning classes more interactive and informative [28] [29]. AR is also able to model MSME business processes [30], even in creating unique assets on social media to support the metaverse era [31] [32]. AR is very compatible with mobile devices, allowing it to reach users from all walks of life, particularly the younger generation [33] [34].

Utilization of AR technology in the process of digitizing cultural and historical objects around the world, for example, the preservation of traditional masks [35]. AR technology can be used to support the visualization of objects in museums to make it easier for visitors to see each object [36] [37]. There is also a visualization of historical places or buildings [38] [39].

From the existing study literature, the authors can study and evaluate the technology developed to support the digitization of lontar prasi as an effort to preserve Balinese cultural heritage in particular [40]. This article work digitalizes culture by applying augmented reality to mobile phone applications, which have been proven to provide convenience for users, attract the attention of the younger generation to participate in preserving culture, and shows that AR has made and continues to make a major contribution to the digitization of culture around the world, especially Balinese culture.

3 Methodology

3.1. Concept of Augmented Reality

The user must first launch the installed AR application on a smartphone in order to use an augmented reality application [41]. The user then points the camera to scan the marked object when the application has finished executing. A 3D object will display on the smartphone's screen if the marker is recognized [42].

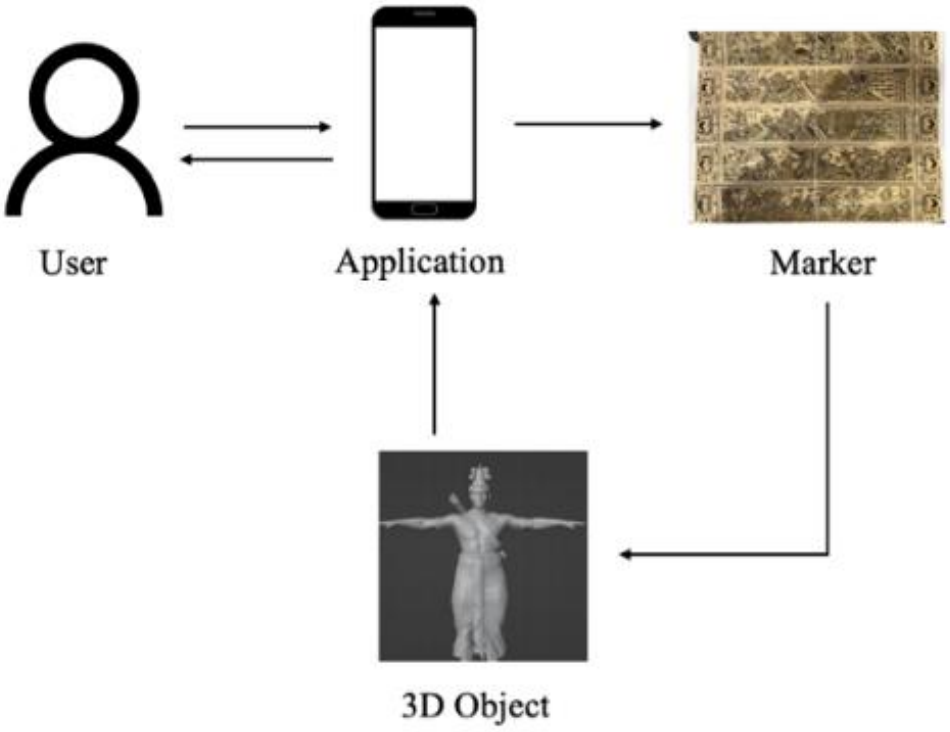

Figure 1: Augmented Reality Concepts

3.2. Research Methodology

The implementation of augmented reality in lontar prasi bali uses the Research and Development (R&D) method [43]. R&D can be used to produce relevant and quality products based on needs analysis and test the effectiveness of products in order to contribute to society [44] [24].

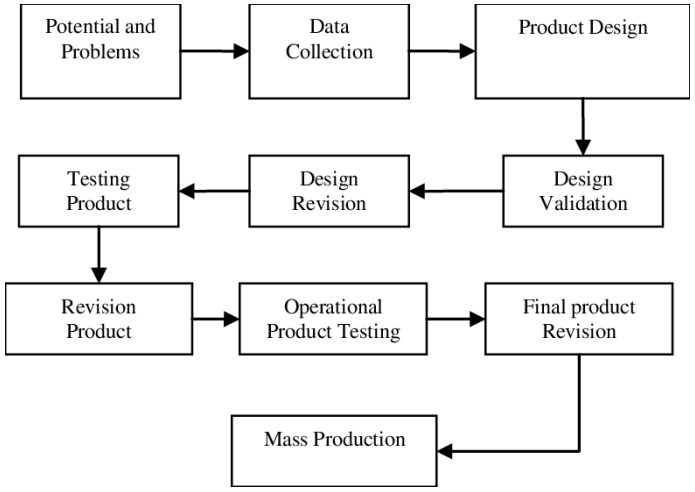

Figure 2: Research and Development Flow Search[45]

The first step in this research is to analyze the problem of the old Balinese prasi papyrus, which is prone to damage so that it requires digitalization efforts with technology. The second stage is to conduct a survey using a random sampling technique [46] and provide questionnaires to 189 respondents. The results of collecting data showed that 82.5% of respondents did not know about Lontar Prasi. 83.9% of respondents are also interested in understanding London. Data collection is also done through interviews, observations, and questionnaires. One of the datasets needed is Lontar Prasi, which is used as a marker. The third stage is product design, which consists of 3 stages: (1) the process of making 3D objects, which consists of modeling and making 3-dimensional characters according to the characters from the Prasi Lontar story; adding texture to 3-dimensional objects. The process of animation on the Prasi Lontar story characters and exporting (exporting object data for reprocessing to support applications). (2) Use the Unity software to code AR applications. (3) Make a marker out of 3D objects and marker configurations (a mapping process between 3D objects and markers to detect them). The fourth stage is validating the product in the form of an AR application and its components before testing it. The fifth stage is to revise the 3D assets, sound and text. The sixth stage is testing AR application products in a small environment. The seventh stage is to revise the product that has been tested, so that the product can be developed. In the eighth stage, the product is tested to ensure its functionality prior to mass production. This is accomplished by evaluating the smartphone loading response time and the User Experience Questionnaire (UEQ). The ninth stage is the final product revision stage as a whole for the Augmented Reality-based Lontar Prasi Bali application. The last stage is to produce products on a large scale so that the products can be marketed widely.

4 Results and Discussions

The researcher implemented augmented reality Lontar Prasi Bali using three steps: (1) The process of making 3D objects, which includes modeling, in order to produce three-dimensional characters based on the stories of Prasi Lontar. Texturing three-dimensional things. The exporting and animation of the characters from the Lontar Prasi narrative (exporting object data for reprocessing to support

applications). (2) Develop AR applications using the Unity software. (3) Construct a marker from 3D objects and marker setups (the process of mapping 3D objects and markers to detect them). Image-recognition techniques were utilized to estimate the placement and rotation of markers. Then, it places a 3D Object in the specified location. This program's 3D objects include Kumbakarna, Rama, Hanuman and other Lontar Prasi characters. The 3D objects were built using the application Blender.

4.1. Markers

The technique of constructing markers is performed using the Vuforia software development kit. The marked-object (Lontar Prasi) will be employed to transform static augmented photos into movies or moving images. The images of lontar prasi that have been uploaded into Vuforia will become a database. Then the database file is imported into Unity so that it automatically takes from the Vuforia database when building the target image. Then so that the camera can read the marker from Vuforia and display objects at the time of application development in Unity must also enter the License Key obtained from Vuforia.

Figure 3: Lontar Prasi Marker

4.2. 3D Modelling Object

Designing 3D models using the Blender program. To ensure the quality and realism between the 3D model and the character objects on the lontar [11], there is a process of adding textures to the lontar prasi characters as well as an animation process. Unity software was utilized in the development of the application. Unity is a program for creating designs for interactive objects. In order to create an Augmented Reality application, the result of designing 3D objects will be processed by the Unity application.

Figure 4: 3D Modelling

4.3. AR Application Results

The augmented reality application has three primary menus: Play, Info, and Close App. When users press the Play button, a camera display appears with instructions to point the camera at the marked object (Lontar Prasi). Then, a smartphone will display a 3D object on its screen. On each lontar prasi sheet, users can download information about the characters who appeared, view the story-appropriate shapes of the characters, and observe the movement animations of the characters with voice narration.

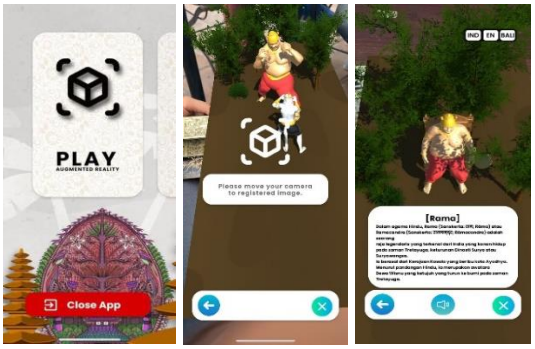

Figure 5: Displaying Augmented Reality Application

4.4. Application Testing Results

During the testing phase of the AR application, two tests were conducted: testing based on application loading times on multiple smartphones and testing user experience using the User Experience Questionnaire (UEQ) [47].

Response Time Loading testing uses Performance Testing techniques where the testing process is carried out to determine the durability and stability of application waiting times in responding to user requests. The response time starts when the user sends a request and ends when the application time states the request has been completed.

As for testing User Experience Questionnaire using the technique of giving questionnaires to application users, this technique measures comfort in the user experience in using the application. UEQ can be processed using UEQ tool analysis.

a) Response Time Loading Result

The response time loading test is performed when the application is run on smartphones with varying specifications. The researcher tested the response time required when activating the AR application until the 3D objects appeared using three different types of smartphones.

Table 1: Response Time Loading on Various Smartphone

Test Scenario	Samsung A03 (second)	OPPO A83 (second)	Xiaomi Poco F1 (second)
Loading time to open the application	4	3	3
Loading time displays the main menu	1	1	1
Loading time to open augmented reality camera	10	8	8
Loading time to detect marker	12	20	16

The **Table 1** loading test results demonstrate that each smartphone has a unique response time. It was observed that the "Samsung A03" ran the program four seconds slower than comparable

cellphones. However, while presenting the main menu, they all responded simultaneously. The "Samsung A03" required more time to open the AR camera. However, it was able to detect the marker faster than others, allowing the depicted object to appear on the screen. In brief, the shorter the response time required to launch an application on a smartphone, the higher its specifications. Inadequate specifications will impact the application's performance. The effect of smartphone specifications on application performance can be seen from the test results on the Samsung A03 smartphone, where most of the results of the response time loading are longer than the OPPO A83 and Xiaomi Poco F1 smartphones. It can be seen from the loading response time of opening the application Samsung A03 is 1 second slower than the two smartphones. In terms of loading response time displaying the main menu, Samsung A03 is 2 seconds slower than the two smartphones because Samsung A03 has lower specifications than the other two smartphones. However, in terms of marker detection, Samsung A03 has a faster loading response time which can be caused by camera pixels that are easier to detect objects compared to the other two smartphones.

b) User Experience Questionnaire (UEQ) Result

The objective of user satisfaction testing or usability testing with the User Experience Questionnaire (UEQ) is to ensure that the system being developed meets user requirements and is simple to use [48]. Testing is done by distributing questionnaires. There are eight questions. Of all the distributed questionnaires, 56 responses were obtained for the data. After the data has been entered into the UEQ table for analysis with the UEQ data analysis tool, this tool will automatically transform the data[49].

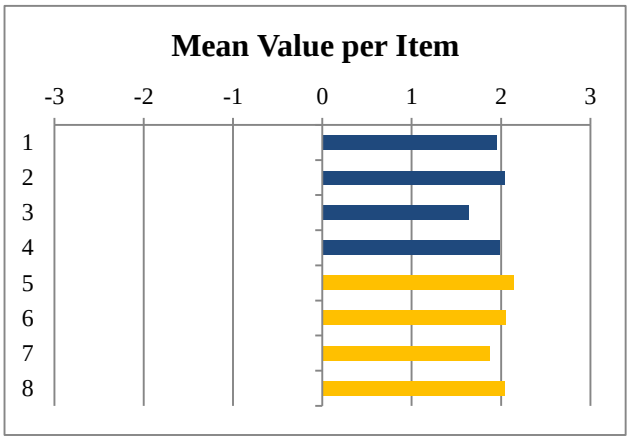

Figure 6: Average Assessment Results of UEQ Question Items

Based on the user experience assessment results of 8 related question items related to pragmatic quality, practical aspects, efficiency, access speed, and ease of use of the application. Four question items related to hedonic quality, namely useful aspects, understandable applications, clear displays, and user-friendly, the average result of each item is obtained at +1.5 positive value, which means good. These results are obtained from the respondent's assessment of each question item with a value scale of -3 to +3. The next process calculates the total value of pragmatic quality and hedonic quality.

Table 2: UEQ Scale Results

Short UEQ Scales	
Pragmatic Quality	1,902
Hedonic Quality	2,027
Overall	1,964

The **Table 2** explains that the results of the UEQ scale have a pragmatic quality with a score of 1.902, indicating that this system is regarded as efficient, practical, quick, and simple to learn. Moreover, the value of hedonic quality is 2.027, indicating that, in terms of user pleasure and comfort, this system produces favorable results. From the results of pragmatic and hedonic quality, the average value is sought with the result of 1.964, indicating the results of the UEQ assessment of the average value for the pragmatic quality and hedonic quality are above the value of +1.5, which is categorized as Good. The next process compares the pragmatic quality and hedonic quality in the classification of benchmark values, which have the categories of Bad, Below Average (BA), Above Average (AA), Good, and Excellent.

Table 3: Benchmark Classification Value

Scale	Bad	B. A	A. A	Good	Excellent	Mean
Pragmatis	0,72	0,45	0,38	0,19	0,76	1,90
Hedonis	0,35	0,5	0,35	0,39	0,91	2,02
Overall	0,59	0,39	0,33	0,27	0,92	1,96

Each average value of the UEQ calculation results will be compared with the benchmark classification values shown in Table 3. The results of the comparison will be displayed in the graph shown in Figure 7.

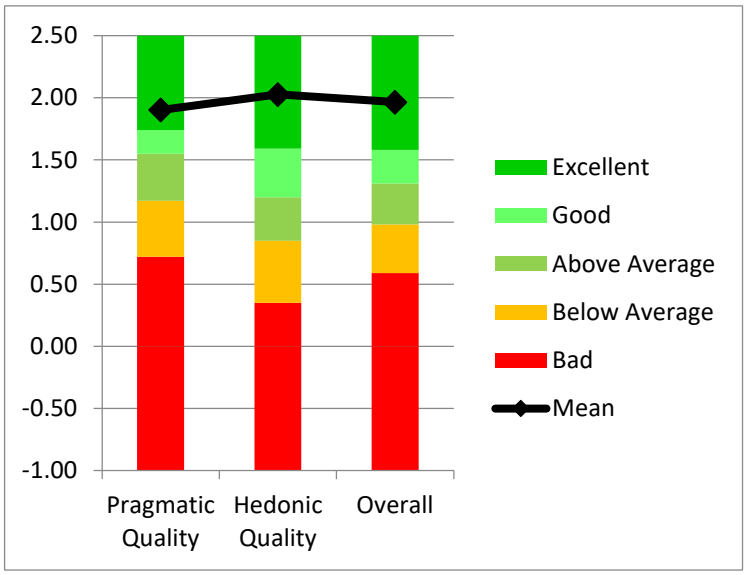

Figure 7: Benchmark Scale Results

Based on the results of the comparison with the benchmark scale in Figure 7, aspects of pragmatic quality, herdonic quality, and overall get results above the average (excellent). These results indicate that this AR application is good and as expected.

5 Conclusions

The main goal is to preserve Balinese cultural heritage, especially Lontar Prasi, by implementing Augmented Reality (AR) applications. Lontar Prasi becomes a marked object (marker) so that 3D characters, character animations, and voice narration of stories told in lontar will appear on the user's smartphone screen when running the AR application. This research methodology follows several steps in the R&D method with several main steps, namely (1) the process of making 3D objects consisting

of modeling to create 3-dimensional characters according to the characters from the Lontar Prasi story. Adding texture to 3-dimensional objects. The process of animation on the characters of the Lontar Prasi story, and exporting (exporting object data for reprocessing to support applications). (2) Use the Unity software to code AR applications. (3) Create a marker from 3D objects and marker configurations (a mapping process to detect 3D objects and markers). Application testing using loading response time and User Experience Questionnaire (UEQ) techniques.

Based on the objectives and discussion, several conclusions can be drawn. First, the loading response time test results show that higher smartphone specifications can provide a faster response time required to run applications. Whereas inadequate specifications will affect the performance of the application used. Second, the results of the UEQ test show pragmatic quality with a result of 1.902, which means this system is considered good at carrying out the function of using the system, both in terms of efficiency, practicality, speed, and ease of learning the system. Furthermore, the value of hedonic quality is 2.027, which means that in terms of pleasure and comfort, users get good results when running this system. From the results of pragmatic and hedonic quality, the average value is sought with the result of 1.96, referring to 8 related question items related to pragmatic quality, namely practical aspects, efficiency, access speed, and ease of use of the application. Four question items related to hedonic quality, namely aspects of usefulness, understandable applications, clear display, and user-friendly, the overall results of the UEQ test in terms of AR application performance and user experience are in a Good category. AR applications can be applied to preserve Balinese cultural heritage as indicated in the question item points to the user experience related to the application can be understood in content, clear and attractive appearance and user-friendly.

Acknowledgment

The authors would like to thank the Ministry of Education, Research, and Technology for the grant received to carry out this research as part of the Higher Education Leading Applied Research program scheme.

References

[1] Vickers, A. (1982). A Balinese illustrated manuscript of the Śiwarātrikalpa. *Bijdragen tot de Taal-, Land-en Volkenkunde*, (4de Afl), 443-469.

[2] Hinzler, H.I.R. (1993). Balinese palm-leaf manuscripts. *Bijdragen tot de taal-, land-en volkenkunde*, (3de Afl), 438-473.

[3] Aburamadan, R., Trillo, C., Udeaja, C., Moustaka, A., Awuah, K.G., & Makore, B.C. (2021). Heritage conservation and digital technologies in Jordan. *Digital Applications in Archaeology and Cultural Heritage*, *22*.

[4] Aditama, P.W., & Setiawan, I.N.A.F. (2020). Indigenous bali on augmented reality as a creative solution in industrial revolution 4.0. *In Journal of Physics: Conference Series*, *1471*(1), 1-8. IOP Publishing.

[5] Muliani, N.M., & Muniksu, I.M.S. (2020). Governor of Bali Regulation Number 80 of 2018 Concerning the Protection and Use of Balinese Language, Script and Literature and Implementation of the Balinese Language Month *Kalangwan Jurnal Pendidikan Agama, Bahasa dan Sastra*, *10*(1), 36-41.

[6] McGookin, D., Tahiroğlu, K., Vaittinen, T., Kytö, M., Monastero, B., & Vasquez, J.C. (2019). Investigating tangential access for location-based digital cultural heritage applications. *International Journal of Human-Computer Studies*, *122*, 196-210.

[7] Salinas, P., & Pulido, R. (2015). Visualization of conics through augmented reality. *Procedia Computer Science*, *75*, 147-150.
[8] Aslan, D., Çetin, B.B., & Özbilgin, İ.G. (2019). An innovative technology: Augmented Reality based Information systems. *Procedia Computer Science*, *158*, 407-414.
[9] Devagiri, J.S., Paheding, S., Niyaz, Q., Yang, X., & Smith, S. (2022). Augmented Reality and Artificial Intelligence in industry: Trends, tools, and future challenges. *Expert Systems with Applications*.
[10] Rahmawati, N.D., Buchori, A., & Ghoffar, M.H.A. (2022). Design of virtual reality-based mathematics learning media on trigonometry material in senior high school. *In AIP Conference Proceedings*, AIP Publishing LLC, *2577*(1).
[11] Xu, S. (2018). Intangible cultural heritage development based on augmented reality technology. *In IEEE International Conference on Robots & Intelligent System (ICRIS)*, 352-355.
[12] Joerss, T., Hoffmann, S., Mai, R., & Akbar, P. (2021). Digitalization as solution to environmental problems? When users rely on augmented reality-recommendation agents. *Journal of Business Research*, *128*, 510-523.
[13] Muhdi, M., Buchori, A., & Wibisono, A. (2019). Whiteboard Animation for Android Design Using Think Talk Write Model to Improve the Post Graduates Students' Concepts Understanding. *Jour of Adv Research in Dynamical & Control Systems*, *11*(7), 535-543.
[14] Blevins, B. (2018). Teaching digital literacy composing concepts: focusing on the layers of augmented reality in an era of changing technology. *Computers and Composition*, *50*, 21-38.
[15] Kao, G.Y.M., & Ruan, C.A. (2022). Designing and evaluating a high interactive augmented reality system for programming learning. *Computers in Human Behavior*, *132*.
[16] Baabdullah, A.M., Alsulaimani, A.A., Allamnakhrah, A., Alalwan, A.A., Dwivedi, Y.K., & Rana, N.P. (2022). Usage of augmented reality (AR) and development of e-learning outcomes: An empirical evaluation of students'e-learning experience. *Computers & Education*, *177*.
[17] Chang, R.C., & Yu, Z.S. (2017). Application of Augmented Reality technology to promote interactive learning. *In IEEE International Conference on applied system Innovation (ICASI)*, 1673-1674.
[18] Yavuz, M., Çorbacıoğlu, E., Başoğlu, A.N., Daim, T.U., & Shaygan, A. (2021). Augmented reality technology adoption: Case of a mobile application in Turkey. *Technology in Society*, *66*.
[19] Cabanillas-Carbonell, M., Cusi-Ruiz, P., Prudencio-Galvez, D., & Herrera Salazar, J.L. (2022). Mobile application with augmented reality to improve the process of learning sign language, *16*(11), 51–64.
[20] Tzima, S., Styliaras, G., & Bassounas, A. (2020). Augmented reality applications in cultural heritage: Technology or content? *In IEEE 11th International Conference on Information, Intelligence, Systems and Applications (IISA*), 1-8.
[21] Han, J.G., Park, K.W., Ban, K.J., & Kim, E.K. (2013). Cultural heritage sites visualization system based on outdoor augmented reality. *Aasri Procedia*, *4*, 64-71.
[22] Neffati, O.S., Setiawan, R., Jayanthi, P., Vanithamani, S., Sharma, D.K., Regin, R., & Sengan, S. (2021). An educational tool for enhanced mobile e-Learning for technical higher education using mobile devices for augmented reality. *Microprocessors and Microsystems*, *83*.
[23] Aditama, P.W., Aditya, I.N.A.F., Radhitya, M.L., & Ningsih, K.A.A. (2020). Melajah pupuh BALI application "anggita" as a medium of learning in multimedia. *In Journal of Physics: Conference Series*, *1516*(1). IOP Publishing.
[24] Fan, M., Antle, A.N., & Warren, J.L. (2020). Augmented reality for early language learning: A systematic review of augmented reality application design, instructional strategies, and evaluation outcomes. *Journal of Educational Computing Research*, *58*(6), 1059-1100.

[25] Roumba, E., & Nicolaidou, I. (2022). Augmented Reality Books: Motivation, Attitudes, and Behaviors of Young Readers. *International Journal of Interactive Mobile Technologies*, *16*(16), 59-73.
[26] Shirley, J.P., & Malathi, S. (2020). A Preview of Augmented Reality as Pioneering Method in Education. *In IEEE 9th International Conference System Modeling and Advancement in Research Trends (SMART)*, 474-479.
[27] Hajirasouli, A., & Banihashemi, S. (2022). Augmented reality in architecture and construction education: state of the feld and opportunities. *International Journal of Educational Technology in Higher Education*, (19), 30.
[28] Roopa, D., Prabha, R., & Senthil, G.A. (2021). Revolutionizing education system with interactive augmented reality for quality education. *Materials Today: Proceedings*, *46*, 3860-3863.
[29] Silva, A.C., Calderon, A.R., Retuerto, M.G., & Andrade-Arenas, L. (2022). Application of Augmented Reality in Teaching and Learning in Engineering Programs. *International Journal of Interactive Mobile Technologies*, *16*(15), 112-124.
[30] Cranmer, E.E., Urquhart, C., tom Dieck, M.C., & Jung, T. (2021). Developing augmented reality business models for SMEs in tourism. *Information & Management*, *58*(8).
[31] De la Fuente Prieto, J., Lacasa, P., & Martínez-Borda, R. (2022). Approaching metaverses: Mixed reality interfaces in youth media platforms. *New Techno Humanities*.
[32] Dwivedi, Y.K., Hughes, L., Baabdullah, A.M., Ribeiro-Navarrete, S., Giannakis, M., Al-Debei, M.M., & Wamba, S.F. (2022). Metaverse beyond the hype: Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management*, *66*.
[33] Oyman, M., Bal, D., & Ozer, S. (2022). Extending the technology acceptance model to explain how perceived augmented reality affects consumers' perceptions. *Computers in Human Behavior*, *128*.
[34] Faqih, K.M. (2022). Factors influencing the behavioral intention to adopt a technological innovation from a developing country context: The case of mobile augmented reality games. *Technology in Society*, *69*.
[35] Santoso, D.J., Angga, W.S., Silvano, F., Anjaya, H.E.S., Maulana, F.I., & Ramadhani, M. (2021). Traditional Mask Augmented Reality Application. *In IEEE International Conference on Information Management and Technology (ICIMTech)*, *1*, 595-598.
[36] Cranmer, E.E., tom Dieck, M.C., & Fountoulaki, P. (2020). Exploring the value of augmented reality for tourism. *Tourism Management Perspectives*, *35*.
[37] Hincapié, M., Díaz, C., Zapata-Cárdenas, M.I., Rios, H.D.J.T., Valencia, D., & Güemes-Castorena, D. (2021). Augmented reality mobile apps for cultural heritage reactivation. *Computers & Electrical Engineering*, *93*.
[38] Bozzelli, G., Raia, A., Ricciardi, S., De Nino, M., Barile, N., Perrella, M., & Palombini, A. (2019). An integrated VR/AR framework for user-centric interactive experience of cultural heritage: The Arkae Vision project. *Digital Applications in Archaeology and Cultural Heritage*, *15*, 1-19.
[39] He, Z., Wu, L., & Li, X.R. (2018). When art meets tech: The role of augmented reality in enhancing museum experiences and purchase intentions. *Tourism Management*, *68*, 127-139.
[40] Vital, R., & Sylaiou, S. (2022). Digital survey: How it can change the way we perceive and understand heritage sites. *Digital Applications in Archaeology and Cultural Heritage*, *24*, 129-131.
[41] Wölfel, M., Braun, M., & Beuck, S. (2019). How does Augmented Reality Improve the Play Experience in Current Augmented Reality Enhanced Smartphone Games?. *In IEEE International Conference on Cyberworlds (CW)*, 407-410.
[42] Pauls, A., & Karsakov, A. (2021). The concept of using augmented reality technology to present interactive calligraphic objects. *Procedia Computer Science*, *193*, 407-414.

[43] Lee, K., Jeong, Y., & Yoon, B. (2017). Developing an research and development (R&D) process improvement system to simulate the performance of R&D activities. *Computers in Industry*, *92*, 178-193.
[44] Habib, K.N., Miller, E.J., Srikukenthrian, S., Lee-Gosselin, M., Morency, C., Roorda, M.J., & Shalaby, A. (2018). TTS2. 0: A research and development (R&D) project on passenger travel survey methods. *Transportation Research Procedia*, *32*, 659-665.
[45] Gall, M.D., Borg, W.R., & Gall, J.P. (1996). *Educational research: An introduction*. Longman Publishing.
[46] Shome, R., Triveni, K., Swati, S., Ranjitha, S., Krithiga, N., Shome, B.R., & Barbuddhe, S.B. (2019). Spatial seroprevalence of bovine brucellosis in India—A large random sampling survey. *Comparative Immunology, Microbiology and Infectious Diseases*, *65*, 124-127.
[47] Verhulst, I., Woods, A., Whittaker, L., Bennett, J., & Dalton, P. (2021). Do VR and AR versions of an immersive cultural experience engender different user experiences? *Computers in Human Behavior*, *125*.
[48] Hinderks, A., Schrepp, M., Mayo, F.J.D., Escalona, M.J., & Thomaschewski, J. (2019). Developing a UX KPI based on the user experience questionnaire. *Computer Standards & Interfaces*, *65*, 38-44.
[49] Wang, Y., Chardonnet, J.R., & Merienne, F. (2021). Development of a speed protector to optimize user experience in 3D virtual environments. *International Journal of Human-Computer Studies*, *147*, 1-24.
[50] Yang, J., Wang, L., & Shakya, S. (2022). Modelling Network Traffic and Exploiting Encrypted Packets to Detect Stepping-stone Intrusions. *Journal of Internet Services and Information Security (JISIS)*, *12*(1), 2-25.

Authors Biography

I Gede Iwan Sudipa

I Gede Iwan Sudipa, S. Kom., M.Cs. was born in Singaraja, Bali. The author completed his undergraduate education in the Informatics Engineering Study Program at STMIK AKAKOM Yogyakarta in 2010 and continued his Masters in Computer Science at Gadjah Mada University Yogyakarta in 2017. Currently the author is a lecturer and researcher at the informatics engineering study program, faculty of information and technology, at the Indonesian Institute of Business and Technology, Bali, Indonesia. In the field of science, namely Data science, Decision Support System, especially Multi-Criteria Decision Analysis, Information System, Data Mining, Data analytics, software testing, software engineering and Digital Culture.

E-mail: iwansudipa@instiki.ac.id; gedeiwansudipa@gmail.com
ORCID: https://orcid.org/0000-0002-4278-9068

Putu Wirayudi Aditama

Putu Wirayudi Aditama, S. Kom., M.Kom was born in Singaraja, Bali. The author completed his undergraduate education in the Informatics Engineering Study Program at STMIK STIKOM Indonesia and continued his Masters in Computer Science at the Postgraduate Faculty, Ganesha University of Education. Currently the author is a lecturer and researcher at the informatics engineering study program, faculty of information and technology, at the Indonesian Institute of Business and Technology, Bali, Indonesia. In the field of science, namely Data science, Multimedia, Augmented reality, Virtual reality application development in various fields and focus on the digitization of Balinese culture.

E-mail: wirayudi.aditama@instiki.ac.id
ORCID: https://orcid.org/0000-0003-4618-176X

Christina Purnama Yanti

Christina Purnama Yanti, S.Kom., M.Kom was born in Badung, Bali. The author completed her undergraduate education in the Informatics Engineering Study Program at Dhyana Pura University and continued her Masters in Computer Science at the Postgraduate Faculty, Ganesha University of Education. Currently the author is a lecturer and researcher at the informatics engineering study program, faculty of information and technology, at the Indonesian Institute of Business and Technology, Bali, Indonesia. In the field of science, namely software testing, Digital Image Processing, Augmented reality applications, Information System, Data science, and Machine Learning.

E-mail: christinapy@instiki.ac.id

ORCID: https://orcid.org/0000-0003-4952-633X