E-ISSN: xxxx-xxxx
DOI: https://doi.org/10.64803/cessmuds.v1.78
Hermansyah, Wirda Fitriani, Mai Sarah

Development of Augmented Reality–Based Learning Media for Historical Object Recognition at Deli Serdang Museum

Hermansyah[1,*], Wirda Fitriani[2], Mai Sarah[3]

[1] Faculty of Computational Science and Digital Intelligence, Information Technology, Universitas Pembangunan Panca Budi,Indonesia
[2] Faculty of Data Science and Digital Intelligence, Computer Engineering, Universitas Pembangunan Panca Budi, Medan, Indonesia
[3]Faculty of Computer Science and Digital Intelligence,Computer Systems,Universitas Pembangunan Panca Budi, Medan, Indonesia
E-mail: [1],*hermansyah@pancabudi.ac.id, [2]wirdafitriani@pancabudi.ac.id, [3]maisarah@student.pancabudi.ac.id
*E-mail Corresponding Author: hermansyah@pancabudi.ac.id

Abstract

History learning in museums is generally still dominated by conventional information delivery through text labels and verbal explanations, which tends to be less engaging for the digital generation. This study aims to develop and evaluate the feasibility of an Augmented Reality (AR)–based learning media application for introducing historical objects at the Deli Serdang Museum on Android devices. A research and development (R&D) approach was employed using the Waterfall software development model, consisting of requirements analysis, design, implementation, and testing. Data were collected through literature review, observation and documentation of museum collections, and interviews with museum staff. The system was designed using UML and implemented with Unity, Vuforia, and 3D object modelling. Functional testing was carried out using black box testing, while an initial feasibility test involved 10 respondents who completed a questionnaire on system performance and user experience. The results show that all core features (marker detection, 3D object display, rotation and zoom functions, and menu navigation) operated according to specification without critical errors. Most respondents stated that the application is easy to use, visually attractive, and helpful in understanding the museum's historical collections. Therefore, the developed AR application is considered feasible as a supplementary learning medium at the Deli Serdang Museum and has the potential to be extended to other museum contexts.

Keywords: *Augmented Reality, learning media, museum, historical objects, Android*

I. INTRODUCTION

The development of information technology has shifted the learning paradigm from teacher-centered to learner-centered, with an emphasis on interactive, contextual, and meaningful learning experiences. Learning media function as channels that help reduce noise in educational communication so that learning material can be received more clearly and comprehensively by students (Arsyad, 2014). Learning media are not merely visual aids, but an integral part of the instructional system that can enhance motivation, attention, and the quality of understanding of abstract concepts. In the context of 21st-century education, the use of ICT-based media, especially those that are interactive and multimodal, has become a necessity so that learning remains relevant to the characteristics of today's digital generation (Arsyad, 2014).

One of the technologies that has rapidly developed and is widely applied in education is Augmented Reality (AR). (Azuma, 1997) defines AR as a technology that integrates three-dimensional virtual objects into the real environment in real time, enabling users to see the real world enriched with additional digital information (Azuma, 1997). Later surveys further emphasize three key characteristics of AR, namely the combination of real and virtual worlds, real-time interactivity, and registration within three-dimensional space (Billinghurst et al., 2015).In the learning context, AR helps bridge the gap between abstract representations and real objects, allowing students to visualize objects that are difficult to bring directly into the classroom, enrich learning experiences, and increase engagement and learning motivation (Lando, 2017).

In the field of history and cultural education, museums are highly potential sources of authentic learning. Collections of artifacts, documents, and historical objects enable students to study past events in a contextual manner. However, in practice, learning activities in museums are often still dominated by static forms of information, such as text labels or one-way explanations from guides, which may be less attractive for young visitors who are accustomed to interactive digital media. Recent studies show that the integration of AR in museums

can enrich how visitors interact with collections by adding layers of digital information, narratives, 3D animations, and simulations that encourage self-exploration and improve visitors' historical understanding (Ghouaiel, Cieutat, et al., 2017).

A growing body of research has specifically developed AR applications as learning media in the museum context. Ghouaiel et al. (2017) designed a mobile AR touring system and reported that it contributed to a more worthwhile learning experience during museum visits (Ghouaiel, Cieutat, et al., 2017) developed interactive learning media for museum introduction based on AR and found that AR-based visualization made museum objects more attractive and intuitive to explore for visitors, especially students (Haryani & Triyono, 2020). Other empirical studies in various museums show that AR can enhance visitors' historical knowledge, learning attraction, and overall satisfaction with the museum visit. Meta-analytic and review studies also indicate that AR and VR have been widely used in science, art, and history museums to support learning and provide immersive experiences (Zhou et al., 2022) Overall, these findings confirm that AR is effective as a medium for learning history and culture because it combines the real context of museums and their collections with rich, interactive virtual information.

Deli Serdang Museum is a history and culture museum located in the government complex of Deli Serdang Regency, North Sumatra. This museum houses various collections that represent the history of Deli Serdang, from prehistoric times and the Sultanate of Serdang to the post-independence period. Its collections include artifacts such as *meriam lela* and *tapak bendera*, traditional musical instruments (e.g., *penganak* and *gendang Melayu*), traditional household tools, and colonial-era equipment such as *brandweer* and *kereta angin*. This rich collection has great potential to be used as a learning resource for local history for elementary and secondary school students who conduct educational visits to the museum.

However, the use of interactive digital technology in Deli Serdang Museum is still very limited. Information about the collections is generally presented in the form of descriptive text and verbal explanation from guides, so visitors who are less interested in reading or listening to lengthy explanations may not gain optimal understanding of the artifacts they see. On the other hand, students as the main visitor group tend to be more attracted to dynamic visual media, 3D animation, and interaction via mobile devices such as smartphones. This condition creates a gap between the potential of the museum's collections as learning resources and the way information is currently presented, which remains conventional. Similar gaps have been reported in other museum contexts, encouraging the adoption of AR-based media to support more engaging and student-centered learning (Ghouaiel, Garbaya, et al., 2017).

Based on this needs analysis, the development of AR-based learning media specifically designed to introduce historical objects in Deli Serdang Museum becomes relevant and important. An Android-based AR application enables visitors, especially students, to point their smartphone camera at markers associated with specific collections and see 3D representations along with supporting information displayed in real time. This approach is expected to increase the attractiveness of museum visits, enrich learning experiences, and help students better understand the historical context and function of each artifact (Ghouaiel, Garbaya, et al., 2017).

Previous work underlying this study has designed and implemented an AR application for introducing historical objects in Deli Serdang Museum using Unity and Vuforia, following the waterfall software development model, and conducting initial feasibility testing through user questionnaires. However, there is still a need for scientific publication in the form of a proceedings article that summarizes the development process, user interface design, and evaluation results of the application's feasibility as learning media in a museum environment.

Therefore, this article aims to: (1) describe in detail the development process of Augmented Reality–based learning media for introducing historical objects at Deli Serdang Museum; and (2) present the results of feasibility testing of the application in terms of system performance and user experience as a basis for utilizing this application as local history learning media in the museum.

II. RESEARCH METHODOLOGY

This study employed a research and development (R&D) approach focusing on the development of an instructional media application based on Augmented Reality (AR) for introducing historical objects at the Deli Serdang Museum. The software development process followed the waterfall model, which consists of the stages of requirements analysis, design,

implementation, and testing (Sommerville, 2011). This model was chosen because the system requirements were relatively clear from the outset and because it supports structured documentation throughout the development of educational applications.

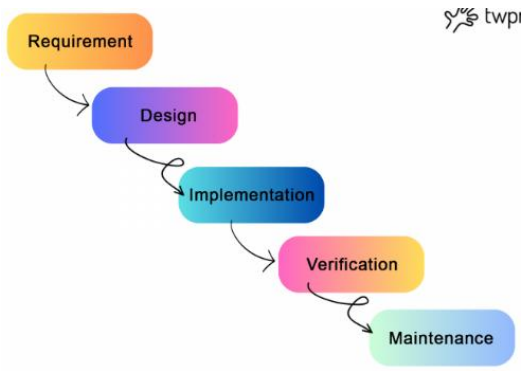

Figure 1. Research Methodology
Source: Twproject.com

The data required for media development were obtained through literature review and field data collection. The literature review was conducted to examine theories of instructional media, AR technology, Android application development, and the role of museums as learning resources for history. Field data were collected at the Deli Serdang Museum through observation of the collections and visitor flow, interviews with museum staff regarding information on historical objects, and photographic documentation of the objects to be modeled in 3D. Descriptions of each historical object were then synthesized into concise informational texts to be displayed in the application.

The system design stage utilized the Unified Modeling Language (UML) to model system requirements and workflows, including *use case diagrams* and *activity diagrams* that describe user interactions with the application (Hermansyah et al., 2023). User interface (UI) design covered the structure of menus (main menu, AR menu, history menu, help, and profile) and the layout to ensure the application is easy to use for students and general visitors.

During the implementation stage, 3D models and markers were integrated within the AR development environment on Android devices so that, when the camera is directed at a marker, the system displays a 3D object and its historical information in real time.

The final stage involved application testing, which comprised functional testing using a *black box testing* approach to ensure that all main features (marker scanning, 3D object display, menu access, and navigation) operated according to specifications (Pressman, 2012), as well as limited user trials to obtain preliminary feedback on usability, visual appeal, and perceived usefulness of the application as a learning medium. Data from the user trials were analyzed descriptively as a basis for the initial feasibility assessment of the application and for recommendations for further development.

III. RESULTS AND DISCUSSION

3.1 Implementation of the Waterfall Model in Media Development

The development of the augmented reality–based learning media for introducing historical objects at the Deli Serdang Museum was carried out by following the structured and sequential stages of the Waterfall model, namely requirements, design, implementation, testing, and maintenance(Pressman, 2012). This model was selected because of its systematic flow, in which each stage produces clear artefacts that can be traced back to the initial user requirements.

3.1.1 Requirements Phase

In the requirements phase, the researchers identified user needs through field visits to the Deli Serdang Museum, collection of information about historical objects, and analysis of the existing history learning process, which is still dominated by conventional media. Data were obtained through observation, discussions with museum staff, and review of museum profile documents. The functional requirements formulated include:

1. The application can display 3D objects of historical artefacts when the camera is directed at specific markers.
2. The application provides short textual information about the history and description of each object.
3. The application offers a simple main menu with access to AR features, historical information, help, and developer profile.
4. The application runs on Android devices in offline mode to accommodate possible limitations of internet access in the museum area.

Non-functional requirements considered include ease of use (user friendly), attractive visual design, and

E-ISSN: xxxx-xxxx
DOI: https://doi.org/10.64803/cessmuds.v1.78

stable performance on mid-range Android smartphones.

3.1.2 Design Phase

The design phase involved modelling the system using UML diagrams, including use case diagrams, activity diagrams, and sequence diagrams, as well as flowcharts of the application workflow. These diagrams describe user interactions with the system, navigation flow from the main menu to AR features, history, help, and profile, and the sequence of processes from camera detection of markers to the display of 3D objects.

1. Use Case Diagrams Application

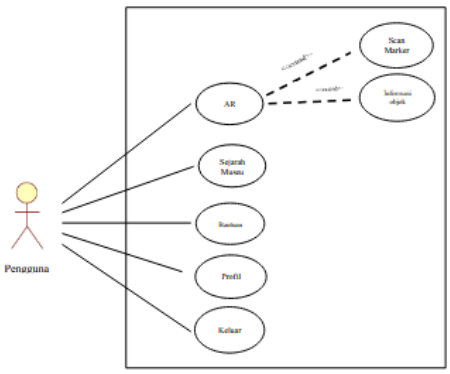

Figure 2. Use Case Diagrams Application

2. Activity Diagrams Application

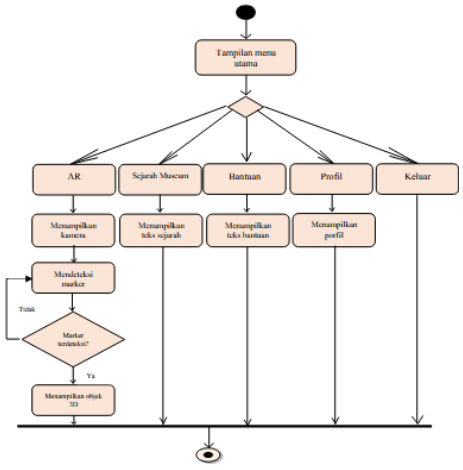

Figure 3. Activity Diagrams Application

3. Sequence Diagrams Application

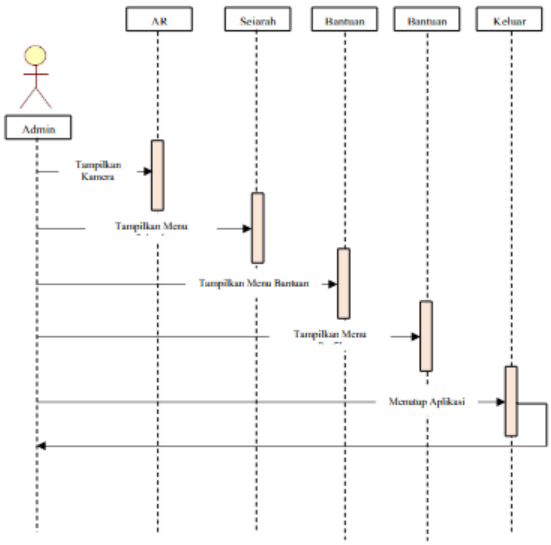

Figure 4. Sequence Diagrams Application

4. Flowcharts Application

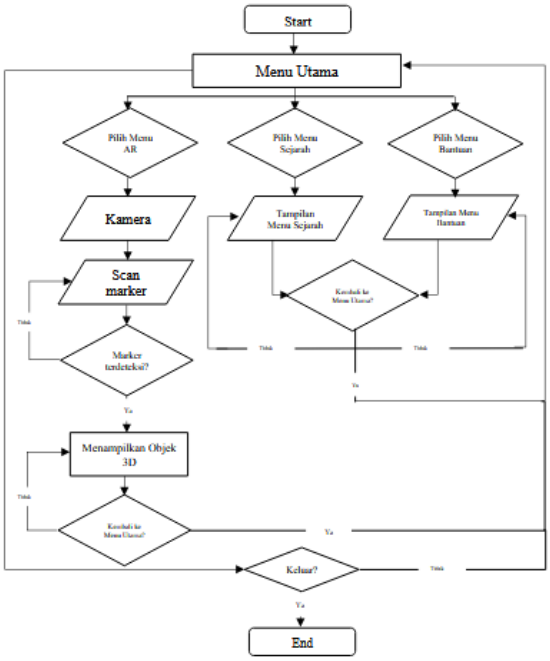

Figure 5. Flowcharts Application

In addition to workflow modelling, the design process also covered user interface (UI) design**.** The interface was designed to be minimalistic, featuring five main buttons on the home screen—AR, History, Help, Profile, and Exit—to make it easier for museum visitors who may be unfamiliar with AR applications.

Figure 6. User interface (UI) design

At this stage, the markers were also determined. These markers are images representing specific collections, such as *Meriam Lela* and *Tapak Bendera*, *Penganak* (small gong), and *Gendang Melayu*; each marker triggers the display of a corresponding 3D model when scanned.

3.1.3 Implementation Phase

The implementation phase realised the design into a working application. The application was developed using Unity 3D as the game engine, Vuforia SDK as the AR marker detection library, and Blender for creating and processing 3D objects. The programming language used was C#/JavaScript as supported by Unity.

The 3D objects representing the historical artefacts were modelled to resemble the actual collections at the Deli Serdang Museum, while still considering the resource constraints of mobile devices. Each 3D object was then linked to a specific marker through Vuforia so that when the smartphone camera recognises the marker, the corresponding 3D object appears on the screen in real time.

The implementation of the interface produced several main views, including:

- An application icon as the visual identity displayed when the app is installed on the device.

Figure 7. Visual Identity Displayed

- A main menu with five functional buttons (AR, History, Help, Profile, Exit).

Figure 8. Visual Main Menu

- An AR menu that shows the camera view and displays 3D objects when markers are detected.

Figure 9. View And Displays 3D Objects

- History, Help, and Profile menus, each containing supporting information about the objects, guidance on how to use the application, and developer information.

Figure 10. View History, Help, and Profile Menus

3.1.4 Testing Phase

Testing was conducted in two forms: functional system testing **and** user-based feasibility testing.

For functional testing, the application was run on a laptop and smartphone with predefined specifications. The hardware used included a laptop with an Intel Core i7 2.8 GHz processor and 8 GB RAM, and an Android smartphone with 2 GB RAM, while the software environment comprised Windows 10 Pro 64-bit and development tools such as Unity, Vuforia, Blender, and Microsoft Visual Studio.

The testing results show that all main features—including marker detection, 3D object rendering, drag, rotation, zoom in–zoom out functions, and access to history, help, and profile menus—worked as designed without disruptive errors.

Feasibility testing was conducted by distributing a questionnaire to 10 respondents representing potential users of the application. The questionnaire consisted of 11 items assessing **system smoothness** and **user experience**, with response categories of *strongly agree, agree,* and *disagree*.

3.1.5 Maintenance Phase

In the context of this study, the maintenance phase was limited to minor revisions during the trial process, such as adjustments to textures on 3D objects, fine-tuning marker detection sensitivity, and improving text layout on certain screens. Long-term maintenance—such as adding new collections or updating content—is recommended as a follow-up when the application begins to be used more widely in the museum environment.

3.2 System Specifications and Feature Realisation

The hardware and software specifications indicate that the application can be developed and tested in a relatively common environment for AR-based Android applications. A laptop with a mid-range processor and 8 GB RAM was sufficient for handling 3D modelling and Unity project compilation, while a smartphone with 2 GB RAM and Android 8.1 could still run the application smoothly without significant lag.

In terms of feature realisation, the application has fulfilled the functional requirements formulated in the requirements phase. The AR menu functions as the core of the application, displaying 3D objects when markers are detected, while the History menu provides short narratives to deepen users' understanding of the historical context of the objects. The Help menu serves as a practical guide so that first-time users can operate the application independently.

3.3 Functional Testing Results

The functional testing results indicate that:

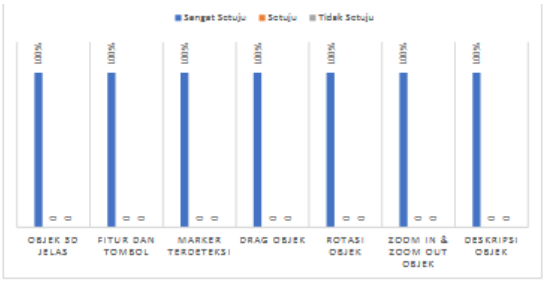

Figure 11. Graph of System Smoothness Evaluation

- Marker detection runs stably; all markers used (*Meriam Lela* and *Tapak Bendera*, *Penganak*, *Gendang Melayu*) can be recognised by the camera under adequate lighting conditions.
- 3D objects appear correctly positioned on top of the markers, without significant drift when the device is moved within reasonable limits.
- The drag, rotation, and zoom features work properly, allowing users to observe the objects from various angles and distances, thereby supporting richer visual exploration.
- Navigation between menus operates without crashes, and the Exit function behaves as intended.

These findings indicate that, from a software engineering perspective, the implementation of the

Waterfall model has produced a stable product that meets the technical success criteria.

3.4 Feasibility and User Experience Testing Results

The feasibility test involved 10 respondents who used the application and then completed a questionnaire containing 11 statements. The recap of the results shows the following pattern:

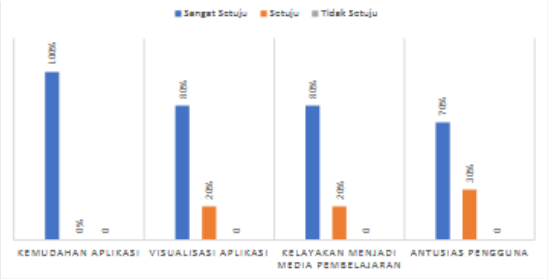

Figure 12. Graph of User Experience Evaluation

- All respondents **(**100%**)** *strongly agreed* that the 3D objects are displayed clearly and that the markers, drag, rotation, zoom in–zoom out features, and object descriptions function properly**.**
- All respondents (**100%**) *strongly agreed* that the application is easy to use and that the buttons/features work well.
- Most respondents (80%**)** *strongly agreed* and the remaining **(**20%**)** *agreed* that the visual appearance of the application is attractive and that it is suitable for use as AR-based learning media in a museum context.
- In terms of user experience, the majority of respondents *strongly agreed* and *agreed* that the application increases their enthusiasm for learning about historical objects using their mobile devices.

Overall, no *disagree* responses were recorded for items assessing object clarity, ease of use, and feasibility as a learning medium. This indicates that the prototype developed has met users' basic expectations in terms of usability and comfort.

3.5 Discussion

Compared with the initial objectives of the media development, the implementation results show that an Android-based augmented reality application can effectively bridge the need for history learning that is more concrete, engaging, and interactive**.** The 3D visualisation of historical artefacts allows users to examine objects that are typically viewed only from a distance inside glass displays, thereby aligning with the function of instructional media in clarifying messages and enhancing learning motivation (Arsyad, 2015).

From a software development perspective, the application of the Waterfall model proved adequate for a small–medium scale project with a relatively well-defined scope from the beginning. Each stage produced tangible outputs: requirements lists, UML models, interface designs, Unity–Vuforia–based implementation, and testing instruments. The linear flow made it easier to trace the consistency between requirements, design, and final application output.

The high level of agreement among respondents regarding the clarity of 3D objects, ease of use, and feasibility as learning media shows that the design principles adopted—simple interface and focus on core AR functionality—were appropriate. Nevertheless, the limited number of respondents and the fact that testing was carried out in a simulated usage context constitute limitations of this study. Future work may include testing the application in formal classroom settings or structured museum field trips, using instruments that measure learning achievement and learning motivation quantitatively.

Overall, the findings indicate that the development of augmented reality–based learning media for introducing historical objects at the Deli Serdang Museum using the Waterfall model has resulted in an application that performs well technically and is perceived as feasible and engaging by initial users. This opens up opportunities for broader application of AR as a learning medium in other museums with similar historical collections.

IV. CONCLUSION

This study developed an Android-based augmented reality learning application to introduce historical objects at the Deli Serdang Museum using an R&D approach and the Waterfall model. The development process—from requirements analysis, UML-based system design, implementation with Unity, Vuforia, and 3D modelling, to functional and user testing—resulted in an application that runs stably and meets the specified functional requirements. All core features (marker detection, 3D object display, interaction, and menu navigation) worked properly, and users reported that the application is easy to use, visually attractive, and helpful in understanding museum collections.

Pedagogically, the application helps make history learning more concrete and engaging by allowing users to explore 3D representations of artefacts that are normally viewed only behind glass. Although the study is limited by the small number of respondents and the focus on initial feasibility, the results indicate that AR-based media have strong potential as a complementary learning tool in museums. Future work can expand content, test with larger groups, and measure learning outcomes more systematically.

V. RECOMMENDATIONS

Based on the development process and the findings of this study, several recommendations can be proposed for the future development and utilization of Augmented Reality–based learning media. First, the application should be further tested in authentic learning contexts, both through classroom-based activities and structured educational visits to the museum, so that its impact on students' learning outcomes, motivation, and engagement in history learning can be evaluated more objectively. Subsequent studies are also advised to involve a larger and more diverse number of respondents in terms of educational level and user background in order to obtain a more representative picture of usability, user experience, and the level of acceptance of AR-based learning media. In addition, feasibility testing should be complemented with learning outcome assessments such as pre–test and post–test, concept quizzes, or performance tasks, so that the contribution of the application to historical understanding can be measured quantitatively.

From a content development perspective, the current application still needs to be expanded by adding the number and variety of historical object collections, thematic narratives, and timelines, so that it can support a broader range of learning topics at the Deli Serdang Museum. The enrichment of interactive features—such as quizzes embedded in AR scenes, exploratory tasks, or achievement systems—is also recommended to strengthen the pedagogical value of the application and encourage deeper user interaction. Furthermore, providing language options (for example, Indonesian and English) and paying attention to accessibility aspects such as font size, visual contrast, and simple navigation will make the application more inclusive for various user groups, including visitors with special needs. Future development should also involve history teachers and museum educators more intensively in designing learning scenarios, worksheets, or lesson plans that integrate the AR application into the curriculum and museum-based learning activities. Finally, a clear plan for maintenance and periodic updates is needed to ensure that the application remains compatible with newer Android versions and that its content can be continuously adjusted to changes and additions in the museum's collections.

VI. REFERENCES

Arsyad, A. (2014). *Media pembelajaran*. RajaGrafindo Persada, .

Azuma, R. T. (1997). A Survey of Augmented Reality. *Presence: Teleoperators and Virtual Environments*, *6*(4), 355–385. https://doi.org/10.1162/pres.1997.6.4.355

Billinghurst, M., Clark, A., & Lee, G. (2015). A Survey of Augmented Reality. *Foundations and Trends® in Human–Computer Interaction*, *8*(2–3), 73–272. https://doi.org/10.1561/1100000049

Ghouaiel, N., Cieutat, J.-M., Jessel, J.-P., & Garbaya, S. (2017). Mobile Augmented Reality in Museums : Towards Enhancing Visitor's Learning Experience. *International Journal of Virtual Reality*, *17*. https://doi.org/10.20870/IJVR.2017.17.1.2885

Ghouaiel, N., Garbaya, S., Cieutat, J.-M., & Jessel, J.-P. (2017). Mobile Augmented Reality in Museums : Towards Enhancing Visitor's Learning Experience. *International Journal of Virtual Reality*, *17*(1), 21–31. https://doi.org/10.20870/ijvr.2017.17.1.2885

Haryani, P., & Triyono, J. (2020). The designing of interactive learning media at Yogyakarta's sandi museum based on augmented reality. *International Journal on Informatics Visualization*, *4*(1), 52–57. https://doi.org/10.30630/joiv.4.1.157

Hermansyah, H., Wijaya, R. F., & Utomo, R. B. (2023). Metode Waterfall Dalam Rancang Bangun Sistem Informasi Manajemen Kegiatan Masjid Berbasis Web. *KLIK: Kajian Ilmiah Informatika Dan Komputer*, *3*(5), 563–571. https://djournals.com/klik/article/view/756

Lando, E. (2017). How Augmented Reality Affects the Learning Experience in a Museum. *Degree Project Computer Science and Engineering*.

Pressman, A. (2012). *Designing architecture: The elements of process*. Routledge.

Sommerville, I. (2011). *Software Engineering*. Pearson. https://books.google.co.id/books?id=l0egcQAACAAJ

Zhou, Y., Chen, J., & Wang, M. (2022). A meta-analytic review on incorporating virtual and augmented reality in museum learning. *Educational Research Review*, *36*, 100454. https://doi.org/https://doi.org/10.1016/j.edurev.2022.100454