Terbit *online* pada laman web jurnal : www.journal.unbara.ac.id/index.php/INTECH
INFORMATIKA DAN TEKNOLOGI (INTECH)
ISSN (Online) : 2722-7367

Developing an Augmented Reality Learning Application for the 10 Plagues Bible Story Using the MDLC Method

Pranatania Putri Karista Rembet[1], Chriestie Ellyane Juliet Clara Montolalu[2], Mahardika Inra Takaendengan[3*], Christian Alderi Jeffta Soewoeh[4], Stephano Caesar Wenston Ngangi[5], Dodisutarma Lapihu[6]

[1,2,3*,4,5,6]Universitas Sam Ratulangi, Manado, Indonesia

[*]mahardika@unsrat.ac.id

ABSTRACT

Sunday School learning needs interactive media that can help children understand Bible stories through concrete visual experiences. This study developed an Android-based Augmented Reality learning application for the 10 Plagues Bible story using the Multimedia Development Life Cycle method. The application was built with Unity and Vuforia and used marker-based AR to display 3D objects and animations related to each plague. Data were collected through observation, questionnaires, functional testing, technical testing, and usability evaluation. The evaluation included Black Box Testing, marker-distance testing, lighting testing, device testing, and System Usability Scale testing. The results showed that all 10 Black Box Testing scenarios were successful, indicating that the main application functions worked as designed. Marker detection worked at 15 cm and 20 cm under normal lighting. The application also ran smoothly on the tested Android devices. However, marker detection failed under dim lighting. The SUS test produced an average score of 69.79, categorized as grade D with an Ok rating. These findings show that the application is functional and usable, although improvements are still needed in user guidance, interface clarity, and low-light marker detection. The application can support Sunday School teachers in presenting Bible stories through more visual and interactive learning media.

Keywords: Augmented Reality, Marker-Based AR, Sunday School, Bible Story Learning, Multimedia Development Life Cycle

ABSTRAK

Pembelajaran Sekolah Minggu membutuhkan media interaktif yang dapat membantu anak memahami cerita Alkitab melalui pengalaman visual yang konkret. Penelitian ini mengembangkan aplikasi pembelajaran berbasis Augmented Reality pada cerita Alkitab 10 Tulah menggunakan metode Multimedia Development Life Cycle. Aplikasi dikembangkan menggunakan Unity dan Vuforia dengan teknologi marker-based AR untuk menampilkan objek 3D dan animasi yang berkaitan dengan setiap tulah. Data dikumpulkan melalui observasi, kuesioner, pengujian fungsional, pengujian teknis, dan evaluasi kegunaan. Evaluasi meliputi Black Box Testing, pengujian jarak marker, pengujian pencahayaan, pengujian perangkat, dan pengujian System Usability Scale. Hasil penelitian menunjukkan bahwa seluruh 10 skenario Black Box Testing berhasil, sehingga fungsi utama aplikasi berjalan sesuai rancangan. Deteksi marker berjalan baik pada jarak 15 cm dan 20 cm dalam kondisi pencahayaan normal. Aplikasi juga berjalan stabil pada perangkat Android yang diuji. Namun, marker tidak terdeteksi dalam kondisi pencahayaan redup. Hasil SUS memperoleh skor rata-rata 69,79, berada pada grade D dengan kategori Ok. Temuan ini menunjukkan bahwa aplikasi bersifat fungsional dan dapat digunakan, tetapi masih memerlukan peningkatan pada panduan pengguna, kejelasan antarmuka, dan deteksi marker pada cahaya rendah. Aplikasi ini dapat mendukung guru Sekolah Minggu dalam menyampaikan cerita Alkitab melalui media pembelajaran yang lebih visual dan interaktif.

Kata Kunci : Augmented Reality, Marker-Based AR, Sekolah Minggu, Pembelajaran Cerita Alkitab, Multimedia Development Life Cycle

INFORMASI ARTIKEL

Submit	Diterima	Publish Online
25, April, 2026	25, Mei, 2026	31, Mei, 2026

INTRODUCTION

Sunday School plays an important role in children's spiritual education. It introduces Bible stories, Christian values, worship practices, and moral reflection from an early age. At GPdI Bukit Zaitun Kleak Kampus Manado, Sunday School learning is carried out through Pelayanan Anak Pantekosta and involves children from different age groups. Children aged 9 to 12 years require learning materials that are concrete, visual, and easy to relate to their daily experience. This need is consistent with the concrete operational stage [1], in which children begin to think logically but still depend on visible objects and direct experiences to understand concepts.

The learning process in Sunday School still faces a practical challenge. Teachers often deliver Bible stories through storytelling, reading, or simple visual aids. This approach does not always maintain children's attention. Some children lose focus because the story lacks concrete examples, visual objects, or interactive support [2]. At the same time, children are increasingly familiar with digital devices. This condition creates a need for learning media that can connect Bible storytelling with children's digital habits without reducing the spiritual purpose of the learning process.

Learning media can help teachers present abstract or narrative material in a more concrete form. Learning media as an intermediary between teachers and learners that stimulates motivation and supports meaningful learning [3]. Visual media can clarify information, attract attention, and increase learner involvement. In Bible story learning, visual media is especially useful because many stories contain events, places, and characters that children cannot observe directly.

Augmented Reality offers a relevant solution for this context. AR combines virtual objects with the real environment in real time. Through AR, digital objects can appear on a mobile device screen and be observed as part of the user's surrounding space [4]. Marker-based AR uses a printed marker as a trigger to display digital objects. This method is suitable for classroom use [5] because it provides a simple interaction pattern: the user scans a marker and the system displays the related 3D object.

Previous studies have shown the potential of AR in learning media. [6] developed an Android-based AR application for Sunday School learning. [7] designed AR media for Sunday School children using 3D objects. [8] applied the MDLC method to develop AR-based learning media for children. These studies show that AR can support visual learning, but further work is still needed for Bible story learning that focuses on specific narratives, structured multimedia development, and usability evaluation [9].

This study develops an Android-based marker-based AR application for the Bible story of the 10 Plagues. The story was selected because it contains strong visual elements that can be represented through 3D objects and animation. The application is designed to help Sunday School teachers present the story in a more concrete and interactive way. The study addresses two questions: how can an interactive AR learning application be developed for Sunday School learning, and how can the MDLC method guide the development process. Therefore, the objective of this study is to develop and evaluate a marker-based AR learning application for the 10 Plagues Bible story using the Multimedia Development Life Cycle method [10].

LITERATURE STUDY

Augmented Reality and Marker-Based AR

Augmented Reality is a technology that integrates virtual objects into the real environment in real time [11]. It allows users to see digital content through a device screen while still interacting with their physical surroundings. In education, AR supports learning by presenting material in a more concrete and visual form [5]. This feature is useful for children because it helps them observe objects or events that are difficult to present directly.

Marker-based AR uses a specific image marker as a recognition target [12]. When the camera detects the marker, the system displays a digital object on the device screen. This approach provides a stable reference point for placing virtual objects. In this study, each marker represents one event from the 10 Plagues story, allowing children to view related 3D objects through an Android device [13].

Digital Learning Media

Learning media supports communication between teachers and learners. It helps teachers explain material more clearly and helps learners receive information in a more meaningful way. Digital learning media can combine text, images, sound, animation, and interaction. This combination can increase attention and reduce boredom during learning activities [3].

For Sunday School learning, digital media should not only display information. It should also help children engage with the story. AR-based media can support this goal because it allows children to observe Bible story objects through direct interaction [10].

Sunday School and Bible Story Learning

Sunday School is a Christian education space for children. It introduces children to Bible stories, worship, prayer, and Christian values. Bible stories help children understand moral and spiritual messages through narrative [6]. However, children often need visual support to understand stories that involve historical settings, symbolic events, or unfamiliar objects.

The 10 Plagues story is suitable for AR-based visualization because it contains several observable events, such as water turning into blood, frogs, livestock disease, darkness, and other plagues. Presenting these events through 3D objects and animation can make the story easier to observe and discuss in class [7].

Multimedia Development Life Cycle

The Multimedia Development Life Cycle is a development method for multimedia applications. It consists of six stages: concept, design, material collecting, assembly, testing, and distribution [14], [15]. This method is suitable for applications that combine visual assets, animation, interaction, and user interface design [2], [16].

In this study, MDLC guides the development of the AR learning application. The concept stage defines the users, topic, and learning goal. The design stage prepares the application structure and interface. The material collecting stage gathers markers, 3D models, animation assets, and interface elements. The assembly stage builds the application using Unity and Vuforia [16]. The testing stage evaluates function, detection, compatibility, and usability. The distribution stage produces the Android APK.

System Usability Scale

The System Usability Scale is a usability evaluation method based on 10 statements with a five-point Likert scale. SUS produces a score from 0 to 100. A higher score indicates better perceived usability [17]. In this study, SUS is used to evaluate whether users can operate the AR learning application with sufficient ease. This evaluation is important because the application targets children and Sunday School learning activities.

RESEARCH METHOD

RESEARCH DESIGN

This study used a development research design with descriptive quantitative evaluation [14]. The main output was an Android-based marker-based AR learning application named Aplikasi Cerita Alkitab: 10 Tulah. The application was developed to support Sunday School teachers in presenting the 10 Plagues Bible story through 3D visualization and animation. The study did not use experimental testing or inferential statistics. The evaluation focused on product development, application functionality, marker detection, lighting condition, device compatibility, usability, and learning participation observation.

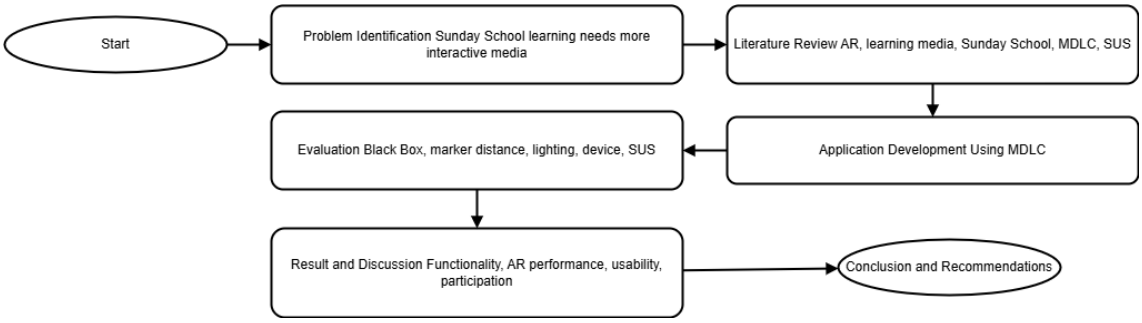

Figure 1. Research flow of the marker-based AR Learning application development

Research Location and Participants

The study was conducted at GPdI Bukit Zaitun Kleak Kampus Manado. The initial needs analysis involved 10 Sunday School teachers and 10 Sunday School children. The usability evaluation involved 12 respondents. The target child users were children aged 9 to 12 years.

Table 1. Application Features

Participant group	Number of participants	Purpose
Sunday School teachers	10	To identify learning problems and media needs
Sunday School children	10	To identify interest in Bible story learning and visual media
SUS respondents	12	To evaluate application usability

Research Objects

The research object was an Android-based AR learning application named **Aplikasi Cerita Alkitab: 10 Tulah**. The application presents the Bible story of the 10 Plagues using marker-based AR [4]. Each marker represents one plague. When users scan the marker, the application displays related 3D objects and animations. The application includes the following main features:

Table 2. Application Features

Feature	Function
Main menu	Provides access to the main application features
Plague selection menu	Allows users to choose one of the 10 Plagues
Marker scanning page	Activates the camera to detect AR markers
3D object display	Shows Bible story objects in AR form
Animation	Displays object movement and story changes
Instruction page	Explains how to use the application
About page	Shows information about the application and developer
Exit button	Closes the application

Development Procedure

The application was developed using MDLC. This method was selected because the application combines interface design, markers, 3D objects, animation, interaction, and Android deployment [15].

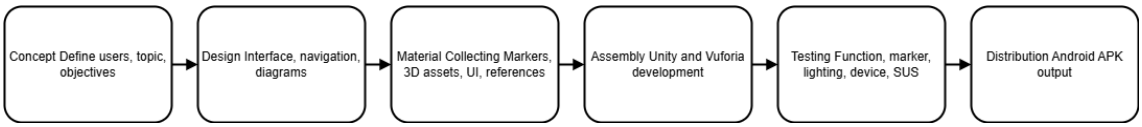

Figure 2. *MDLC procedure applied in the development of the AR learning application*

Table 3. MDLC Development Procedure

MDLC stage	Implementation
Concept	Defined the users, learning problem, Bible story topic, and AR interaction
Design	Prepared use case design, activity flow, navigation structure, and interface layout
Material collecting	Prepared markers, 3D objects, animation assets, Bible story references, and interface elements
Assembly	Built the application using Unity and Vuforia
Testing	Evaluated functionality, marker detection, lighting condition, device compatibility, and usability
Distribution	Built the final application as an Android APK

Figure 3. *Use case diagram of the 10 Plagues AR learning application*

Data Collection Techniques

Data were collected using observation, questionnaire, literature study, and application testing. Each technique supported a different part of the research.

Table 4. Data Collection Techniques

Technique	Data collected	Purpose
Observation	Sunday School learning conditions	To identify real learning problems
Questionnaire	Teacher and child responses	To identify user needs and learning media interest
Literature study	Theories and previous studies	To support the research basis
Application testing	Functional, technical, and usability data	To evaluate the developed application

Observation was used to understand how Bible stories were delivered in Sunday School [1]. Questionnaires were used to collect responses from teachers and children. Literature study was used to build the theoretical foundation. Application testing was used to evaluate whether the system worked and whether users could operate it properly.

Testing Procedure

The application was tested through five types of evaluation: Black Box Testing, marker-distance testing, lighting testing, device testing, and SUS testing [17].

Table 5. Testing Procedure

Test type	Purpose	Indicator
Black Box Testing	To test whether each feature works correctly	Feature success or failure
Marker-distance testing	To test AR marker detection at different distances	Marker detected or not detected
Lighting testing	To test marker detection under different lighting conditions	Object appears or does not appear
Device testing	To test Android device compatibility	Application runs smoothly or not
SUS testing	To measure application usability	SUS score

Black Box Testing focused on user-visible features. Marker testing focused on the ability of the system to recognize printed markers. Lighting testing checked whether the application could detect markers in dim and normal lighting. Device testing checked whether the application could run on Android devices. SUS testing measured user perception of usability.

Data Analysis Technique

The data were analyzed using descriptive quantitative analysis. Questionnaire responses were calculated using percentage. SUS data were calculated using the official SUS scoring procedure. The percentage formula is:

$$P = \left(\frac{f}{N}\right) x\ 100\% \quad (1)$$

Where:

P = Percentage

f = Frequency of response

N =

The SUS score was calculated using the standard SUS procedure. Odd-numbered items were calculated by subtracting 1 from the respondent score. Even-numbered items

were calculated by subtracting the respondent score from 5. The total converted score was multiplied by 2.5.

$$S_i = X_i - 1 \quad (1)$$

$$S_i = 5 - X_i \quad (2)$$

$$SUS = \left(\sum_{i=1}^{10} s_i \right) \times 2.5 \quad (3)$$

The average SUS score was calculated as:

$$\overline{SUS} = \frac{\sum SUS_j}{n} \quad (4)$$

Where:

X_i = Respondent score for item i

S_i = Converted score for item i

SUS_j = SUS score of respondent j

n = Number of respondents

The SUS result was interpreted using the score category. A higher score indicates better usability. In this study, the SUS score was used to assess whether the application was easy and practical for users [17].

Research Instruments

The instruments used in this study included questionnaires, observation notes, test scenarios, and SUS statements.

Table 6. Research Instruments

Instrument	Used for	Data type
Observation sheet	Learning condition analysis	Qualitative description
Teacher questionnaire	Media needs analysis	Nominal and descriptive data
Child questionnaire	Learning interest analysis	Ordinal data
Black Box Testing scenario	Functional testing	Pass or fail data
Marker detection sheet	Marker-distance testing	Detection result
Lighting test sheet	Lighting-condition testing	Detection result
Device test sheet	Compatibility testing	Performance result
SUS questionnaire	Usability testing	Likert-scale data

These instruments were selected because the study evaluated both the development process and the application result. Functional and technical tests measured system performance. SUS measured user experience. Together, these instruments provided a stronger basis for assessing the feasibility of the AR learning application.

RESULT AND DISCUSSION

This section presents and interprets the development and evaluation results of the Android-based marker-based Augmented Reality learning application for the 10 Plagues Bible story. The results are organized based on the MDLC output, application functionality, AR marker performance, device compatibility, usability, and learning participation.

Application Development Result

The study produced an Android-based marker-based AR application for the 10 Plagues Bible story. The application was developed using Unity and Vuforia. Unity supported interface design, scene navigation, 3D objects placement, animation control, and Android build. Vuforia supported marker detection. The final output was an APK file that could be installed on Android devices.

Table 7. Application Development Output

Component	Result
Application name	Aplikasi Cerita Alkitab: 10 Tulah
Platform	Android
Development tools	Unity and Vuforia
AR method	Marker-based Augmented Reality
Main content	Bible story of the 10 Plagues
Main users	Sunday School children aged 9 to 12 years
Main interaction	Touch interaction and marker scanning
Final output	Android Package Kit file

The result shows that the MDLC method was applied successfully. The concept stage defined the users and learning problem. The design stage shaped the interface and navigation flow. The material collecting stage prepared markers, 3D objects, animation, and interface assets. The assembly stage produced the working application. The testing stage evaluated the system. The distribution stage produced the APK file

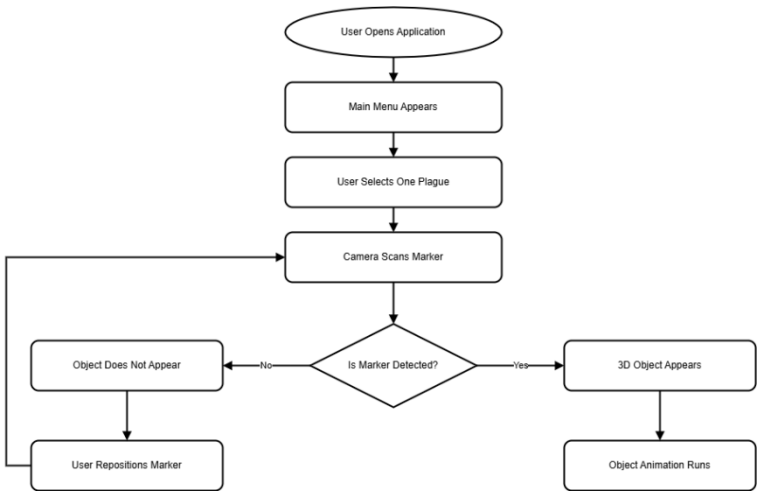

Figure 4.Marker-Based AR Interaction Flow

Interface, Navigation and AR Object Result

The application includes a main menu, plague selection menu, marker scanning page, 3D object display, animation, instruction page, about page, and exit function. These features show that the application was not limited to static learning content. It provided an interactive learning flow in which users selected a plague, scanned a marker, and viewed related 3D objects and animations. This design addresses the learning problem identified in the Introduction because it offers a visual alternative to conventional storytelling.

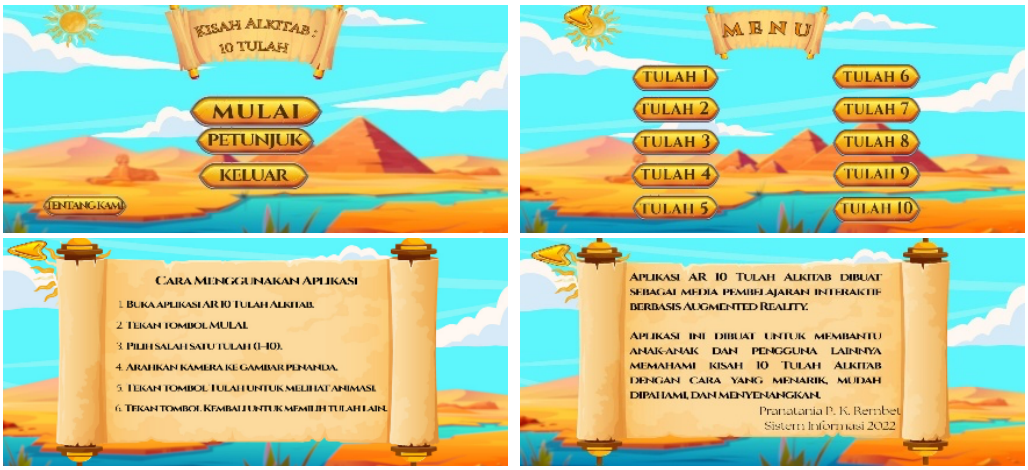

Figure 5. User Interface of the 10 Plagues AR Learning Application

Table 8. Interface and Navigation Result

Page or feature	Function	Result
Main menu	Displays main application navigation	Created successfully
Plague selection menu	Displays 10 Plagues options	Created successfully
Marker scanning page	Activates the camera for AR detection	Created successfully
3D object display	Shows Bible story objects on marker	Created successfully
Animation	Displays object movement and story transition	Created successfully
Instruction page	Explains application usage	Created successfully
About page	Shows application and developer information	Created successfully
Exit button	Closes the application	Created successfully

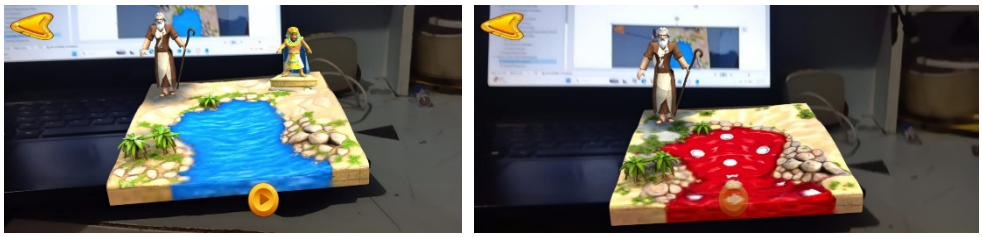

Figure 6. Marker-based AR display of 3D Bible Story objects

Black box Testing Result

Black Box Testing was used to test whether the application features worked according to the expected result. The testing focused on visible user functions, not internal code structure. Ten test scenarios were used, and all scenarios were successful.

Table 9. Black box Testing Result

No	Tested feature	Testing scenario	Expected result	Actual result	Status
1	Start button	User presses Start	Plague selection menu appears	Menu appeared	Successful
2	Plague selection menu	User selects one plague	Marker scanning page appears	Page appeared	Successful
3	Correct marker detection	User scans correct marker	Marker is detected	Marker detected	Successful
4	Incorrect marker detection	User scans incorrect marker	Marker is not detected	Marker not detected	Successful
5	3D object display	Marker is detected	3D object appears	Object appeared	Successful

No	Tested feature	Testing scenario	Expected result	Actual result	Status
6	Object animation	Object appears	Animation runs	Animation ran properly	Successful
7	Instruction button	User opens instruction page	Instruction page appears	Page appeared	Successful
8	About button	User opens about page	Application information appears	Information appeared	Successful
9	Back button	User presses Back	Previous page appears	Previous page appeared	Successful
10	Exit button	User presses Exit	Application closes	Application closed	Successful

$$Success\ Rate = \frac{10}{10} \times 100\% = 100\%$$

This result indicates that the main application functions worked according to the design. Therefore, the first research question is answered at the functional level. The application was successfully developed as an interactive AR learning medium with working navigation, marker scanning, 3D visualization, and animation.

Marker Detection and Lighting Result

Marker-distance testing was conducted at 15 cm and 20 cm. The marker was detected at both distances, and the 3D object appeared clearly or proportionally. This finding shows that marker-based detection can support common classroom scanning distances.

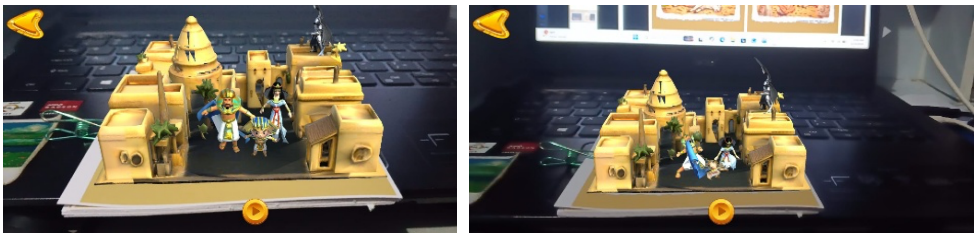

Figure 7. Marker Distance Test of 15cm and 20cm

Table 10. Marker-Distance Testing Result

Distance	Result	Interpretation
15 cm	Marker detected and 3D object appeared clearly	Effective at close distance
20 cm	Marker detected and 3D object appeared proportionally	Effective at normal scanning distance

Lighting testing showed a more limited result. The marker was not detected under dim lighting, but it was detected under normal lighting. This result shows that the application depends on sufficient lighting. The AR feature is suitable for normal classroom conditions, but it still needs improvement for low-light environments.

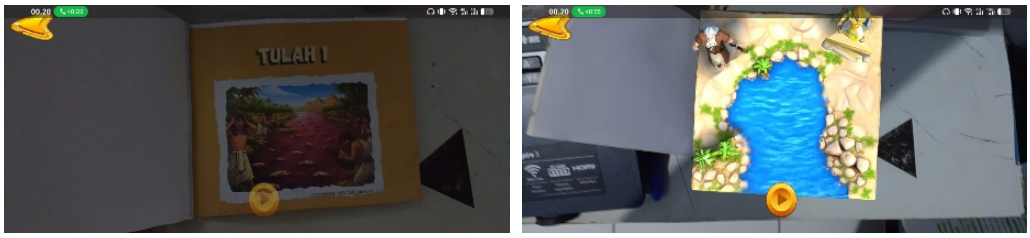

Figure 8. Lighting dimmed and normal scenario

Table 11. Lighting Testing Result

Lighting condition	Result	Interpretation
Dim lighting	Marker was not detected, and the object did not appear	AR detection failed
Normal lighting	Marker was detected, and the 3D object appeared stably	AR detection worked well

Device Testing Result

Device testing was conducted on two Android devices: Realme C85 with Android 15 and Infinix Note 30 with Android 14. The application ran smoothly on both devices, with stable performance, clear visual display, and smooth interface interaction. This result supports the feasibility of Android deployment

Table 12. Device Testing Result

Device	Android version	Screen size	RAM	Result
Realme C85	Android 15	6.8 inches	6 GB	Stable performance, clear visual display, smooth UI interaction
Infinix Note 30	Android 14	6.78 inches	8 GB	Stable performance, clear visual display, smooth UI interaction

System Usability Scale Result

The System Usability Scale test was used to measure user perception of application usability. The test involved 12 respondents. Each respondent answered 10 SUS items. The total SUS score was 837.5, and the average score was 69.79.

$$\overline{SUS} = \frac{837.5}{12} = 69.79$$

Indicator	Result
Number of respondents	12
Lowest SUS score	52.5
Highest SUS score	95
Total SUS score	837.5
Average SUS score	69.79
Grade scale	D
Adjective rating	Ok

The SUS result shows that the application is usable, but its user experience is not yet optimal. The score supports moderate usability rather than high usability. This interpretation is important because the target users include children. A learning application for children needs clear instructions, simple navigation, and minimal cognitive load. The

source data also shows that 33.3% of respondents agreed that users need to learn many things before using the application. This finding suggests that future revisions should focus on user guidance, interface clarity, and first-time use support.

Learning Participation Result

Observation results also showed that children appeared more enthusiastic when using the AR application than when listening to conventional storytelling. This result should be interpreted carefully. It indicates increased learning participation, but it does not prove improved learning outcomes because the study did not use a pre-test, post-test, or statistical comparison. Even so, the observation supports the practical value of the application as a visual learning aid for Sunday School.

Figure 9. Learning Condition before and after the use of the AR application

Table 13. Learning Participation Result

Learning condition	Result	Interpretation
Before using the application	Children were less interested in storytelling	Conventional delivery had limited engagement
During application use	Children looked more enthusiastic	AR increased attention and participation
Main learning impact	Bible story became more visual and interactive	Application supported Sunday School learning

This result supports the purpose of the study. The application helps teachers present Bible stories in a more concrete and interactive form. It also supports children's learning characteristics because children aged 9 to 12 years benefit from visual and concrete learning objects.

Overall, the results show that the MDLC method provided a systematic development structure. The application reached the distribution stage as an APK and passed all tested functional scenarios. Marker detection worked under normal distance and lighting conditions. Device testing showed stable Android performance. The usability score showed that the application can be used, but it still needs refinement. These findings support the use of marker-based AR as an interactive medium for Bible story learning, while also identifying lighting sensitivity and usability as the main areas for improvement

CONCLUSION AND SUGGESTIONS

This study developed an Android-based marker-based Augmented Reality learning application for the 10 Plagues Bible story using the Multimedia Development Life Cycle method. The MDLC stages supported a structured development process from concept

design, asset preparation, assembly, testing, to APK distribution. The application integrated menu navigation, plague selection, marker scanning, 3D object visualization, animation, instruction page, about page, and exit function. The Black Box Testing result showed that all 10 functional scenarios were successful, indicating that the application worked according to its design. Marker detection also worked at 15 cm and 20 cm under normal lighting, and the application ran smoothly on the tested Android devices. However, marker detection failed under dim lighting, showing that the AR feature still depends on sufficient lighting conditions. The SUS score of 69.79 placed the application in grade D with an Ok rating, which means the application is usable but still requires improvement in guidance, interface clarity, and ease of use. Observation results indicated that children showed higher enthusiasm during AR-based learning than during conventional storytelling. Therefore, the application can support Sunday School teachers in presenting Bible stories through more visual and interactive media, but future development should improve usability, low-light detection, 3D object quality, and content coverage.

DAFTAR PUSTAKA

[1] N. Hidayani, U. A. Rosyidah, and G. Abdurrahman, "Implementasi Augmented Reality Sebagai Media Interaktif Edukasi Anak Untuk Peningkatan Kognitif," *J. Digit. Lit. Volunt.*, vol. 2, no. 2, pp. 44–51, Mar. 2024, doi: 10.57119/litdig.v2i2.82.

[2] P. H. Pradana, "PENERAPAN MEDIA AUGMENTED REALITY UNTUK MENINGKATKAN MOTIVASI BELAJAR ANAK USIA DINI," *Kumara Cendekia*, vol. 12, no. 2, p. 115, Jul. 2024, doi: 10.20961/kc.v12i2.86044.

[3] S. Sintaro, A. Surahman, and N. Khairandi, "APLIKASI PEMBELAJARAN TEKNIK DASAR FUTSAL MENGGUNAKAN AUGMENTED REALITY BERBASIS ANDROID," *TELEFORTECH J. Telemat. Inf. Technol.*, vol. 1, no. 1, Jul. 2020, doi: 10.33365/tft.v1i1.860.

[4] Ade Dwi Chayono and Rezki Kurniati, "Augmented Reality untuk Navigasi dan Pengenalan Fasilitas di Gedung Teknik Informatika Berbasis Android," *J. Sist. Inf. Dan Ilmu Komput.*, vol. 3, no. 3, pp. 01–18, Aug. 2025, doi: 10.59581/jusiik-widyakarya.v3i3.5428.

[5] D. Kamińska *et al.*, "Augmented Reality: Current and New Trends in Education," *Electronics*, vol. 12, no. 16, p. 3531, Aug. 2023, doi: 10.3390/electronics12163531.

[6] S. C. R. Riady, S. Sentinuwo, and S. Karouw, "Rancang Bangun Aplikasi Mobile Learning Anak Sekolah Minggu dengan Teknologi Augmented Reality Berbasis Android," *J. Tek. Inform.*, vol. 9, no. 1, Dec. 2016, doi: 10.35793/jti.9.1.2016.14807.

[7] Y. P. Utami and A. Budi, "RANCANG BANGUN APLIKASI MEDIA PEMBELAJARAN ANAK SEKOLAH MINGGU DENGAN TEKNOLOGI AUGMENTED REALITY BERBASIS ANDROID: (Studi Kasus: GBI Glow Fellowsip Center)," *J. Inform. Dan Bisnis*, vol. 11, no. 1, pp. 19–26, Sep. 2022, doi: 10.46806/jib.v11i1.881.

[8] S. Rahma, A. A. Leksono, and M. A. Zamroni, "Kontribusi Guru Dalam Memberikan Motivasi Belajar Pendidikan Karakter Peserta didik," *J. Educ. Learn. Innov.*, vol. 1, no. 1, pp. 18–31, Mar. 2024, doi: 10.59373/jelin.v1i1.16.

[9] I. Radu, "Augmented reality in education: a meta-review and cross-media analysis," *Pers. Ubiquitous Comput.*, vol. 18, no. 6, pp. 1533–1543, Aug. 2014, doi: 10.1007/s00779-013-0747-y.

[10] B. Harpad, "Penerapan Media Pembelajaran Alkitab Deuterokanonika Untuk Anak Sekolah Minggu Berbasis Augmented Reality Pada Stasi Santa Maria Jengan," vol. 28, no. 2, 2024.

[11] P. Milgram and F. Kishino, "A Taxonomy of Mixed Reality Visual Displays," *IEICE Trans Inf. Syst.*, vol. E77-D, no. 12, pp. 1321–1329, Dec. 1994.

[12] N. Garg, A. Kaur, and R. Dutta, "Marker-Based Augmented Reality in Unity: Enhancing Education Through Interactive Visualization," in *2025 3rd International Conference on*

Communication, Security, and Artificial Intelligence (ICCSAI), Greater Noida, India: IEEE, Apr. 2025, pp. 374–378. doi: 10.1109/ICCSAI64074.2025.11064199.

[13] I. G. A. Krisna Pranajaya, B. Pinontoan, and E. Ketaren, "DEVELOPMENT OF MARKERLESS BASED AUGMENTED REALITY INTERACTIVE LEARNING MEDIA OF 3D GEOMETRY SHAPES," *J. TIMES*, vol. 13, no. 1, pp. 28–35, Jul. 2024, doi: 10.51351/jtm.13.1.2024738.

[14] I. Purwanto Hadi and S. Kurniawan Dwi, "Implementasi Augmented Reality sebagai Media Pendukung Pembelajaran menggunakan Multimedia Development Life Cycle (MDLC)," *Smart Comp Jurnalnya Orang Pint. Komput.*, vol. 12, no. 1, Jan. 2023, doi: 10.30591/smartcomp.v12i1.4340.

[15] S. Solehatin, S. Aslamiyah, D. A. A. Pertiwi, and K. Santosa, "Augmented reality development using multimedia development life cycle (MDLC) method in learning media," *J. Soft Comput. Explor.*, vol. 4, no. 1, Jan. 2023, doi: 10.52465/joscex.v4i1.118.

[16] D. S. B. Ginting, R. Arrahmi, M. A. A. R. Saragih, M. D. Arbani Asfi Dalimunthe, Jernih, and A. Cahyani, "Implementation of Multimedia Development Life Cycle (MDLC) Method in Smart Comic Learning Based on Augmented Reality," in *2023 7th International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM)*, Medan, Indonesia: IEEE, Dec. 2023, pp. 116–121. doi: 10.1109/ELTICOM61905.2023.10443166.

[17] D. Yulianto, R. Hartanto, and P. I. Santosa, "Evaluation on Augmented-Reality-Based Interactive Book Using System Usability Scale and User Experience Questionnaire," *J. RESTI Rekayasa Sist. Dan Teknol. Inf.*, vol. 4, no. 3, pp. 482–488, Jun. 2020, doi: 10.29207/resti.v4i3.1870.