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Solar System Education Application Using Markerless Augmented Reality (AR) on The Android Platform

Bagas Afrian Harchristanto *
Informatics Study Program, Faculty of Science and Technology, Universitas Teknologi Yogyakarta, Yogyakarta Special Region, Indonesia.
Email: bagasafrian856@gmail.com

Wahyu Sri Utami
Informatics Study Program, Faculty of Science and Technology, Universitas Teknologi Yogyakarta, Yogyakarta Special Region, Indonesia.
Email: wahyu.utami@uty.ac.id

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Abstract: The solar system, a small component of the vast universe, encompasses celestial bodies including the Sun, its planets - Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune - along with 165 identified satellites. Many students find solar system studies engaging, as it enables understanding of the myriad celestial objects beyond our planet. Traditional learning methods, often limited to explanations and exercises by instructors, require students to be attentive and diligent in reading to master the subject. However, this can sometimes lead to monotony and disinterest. Previous research indicates that the use of educational media is a key factor in successful learning activities. Technology-based education systems make learning more dynamic and interesting by incorporating images, text, sound, and video. Augmented Reality (AR), which merges real objects with virtual elements in an interactive environment, allows virtual technology to appear seamlessly in the real world. This creates an illusion of virtual objects being present in front of the user, enhancing realism. Recent studies have resulted in the development of an AR application for learning and understanding the Milky Way galaxy's solar system. This application addresses the lack of comprehension in primary school students who traditionally use globes and pictures for solar system education. It operates without the internet, modernizing learning and capturing students' interest through its Android application format. The application functions optimally on Android devices with a minimum of 3GB RAM, performing more efficiently on devices exceeding these specifications.

Keywords: Augmented Reality; Android; Application; Educational Media; Solar System.

1. Introduction

The solar system, a minuscule part of the expansive universe, consists of an array of celestial bodies including the Sun, its planets - Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune - along with 165 identified satellites. Additionally, the solar system contains other objects such as asteroids, dwarf planets, meteoroids, comets, and interplanetary dust, all obeying Newtonian dynamics principles [1]. Solar system education, introduced in primary education and further elaborated in middle school, is perceived as engaging by many students. It provides an understanding of the numerous celestial bodies beyond Earth. The traditional learning process typically involves explanations and exercises provided by educators, requiring students to be diligent in reading and attentive during lessons to master the content effectively. However, this approach can sometimes lead to monotony and student disengagement [2].

Educational media serve as tools in the educational process, illustrating or elucidating facts, concepts, principles, or procedures to make them clearer, more comprehensible, and tangible, thereby facilitating learners' understanding. With educational media, previously abstract or complex information can be presented visually, audibly, or interactively, enriching the learning experience, and aiding in concept comprehension [3]. If educational content is delivered engagingly, students are more likely to be involved and focused on the learning material, finding motivation and interest in the subject. Research by Faradila & Aimah [4], supports the notion that educational media is a crucial factor in successful learning processes. A good learning environment, supported by appropriate educational media, can foster student interest, and enhance the teaching-learning process.

In the rapidly evolving field of technology, advancements are continuously transforming education, especially in creating more interactive and comprehensible content, methods, and materials [5]. Current global developments in education demand a shift in thinking, preparing for an uncertain future filled with challenges. This not only encompasses the moral duty of educators to inspire and motivate students to learn significant knowledge and skills but also to stimulate innovation, creativity, adaptability, and flexibility in everyday life [6][7]. The increasing use of computers and technology in education signifies a shift from manual to more time-efficient methods [8]. According to Simatupang *et al*., the most influential aspects of computer and information technology in education are networking and internet usage, offering limitless access to information and diverse learning media beyond text and images, including graphics, animations, videos, and audio [9].

Augmented Reality (AR) represents a fusion of real-world objects with virtual elements, operating interactively to bring virtual technology into the real world in a coherent manner [10][11]. Utilizing advancements in 3D visuals, AR is increasingly employed in educational media application development [12]. This medium facilitates student learning by providing an engaging, interactive, and fatigue-free understanding of materials [13]. The integration of AR in education aims to revolutionize the learning process of the solar system, which traditionally relied on textbooks, by introducing an interactive, smartphone-based learning experience.

2. Research Method

2.1. Research Requirements

This stage involves an analysis of the requirements necessary for developing the Augmented Reality (AR) system, encompassing both software and computer specifications [14]:

Table 1. Computer Specifications Used

Component Type	Component Used
Processor	Intel® Core™ i5-10210U
RAM	8 GB DDR4
Storage	512 GB SSD
Screen Resolution	1920 x 1080 pixels
System Type	X64 – based PC

Table 2. Android Specifications

Component Type	Component Used
Android Version	10
RAM	6 GB
Storage	128 GB
Screen Resolution	1080 x 2340 pixels
Camera	48 MP

Table 3. Software Specifications Used

Component Type	Component Used
Operating System	Windows 11 - 64 Bit
UI Model Build	Figma
Game Engine	Unity 3D 2021.3.16f1
Software Development Kit	Vuforia SDK

2.2. MDLC Method

The development of the solar system AR application employs the Multimedia Development Life Cycle (MDLC) method. This approach integrates video, audio, and animations, creating a complex and engaging unity during the design process. The MDLC method consists of six stages: concept, design, material collecting, assembly, testing, and distribution 0.

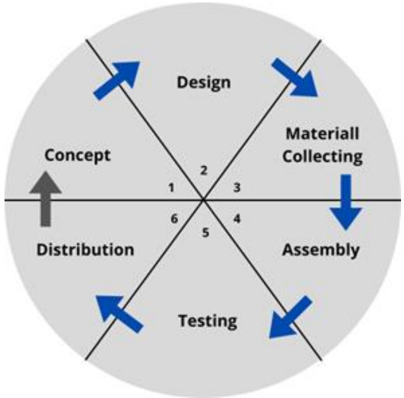

Figure 1. Multimedia Development Life Cycle (MDLC) Method

1) Concept: This stage determines the goals and target users of the program (user identification) [14], aiming to ensure the educational media is utilized efficiently and effectively [16].
2) Design: Specifications regarding the program architecture, style, appearance, and material requirements are developed at this stage. The design utilizes Figma for creating the user interface of the AR application [17].
3) Material Collecting: This stage involves gathering materials such as clip art, animations, videos, audio, icons, 3D objects, and others as per the design requirements [17].
4) Assembly: This stage focuses on compiling everything required for creating the AR application. The majority of the materials are multimedia files like images, icons, and sound, assembled to form a functional application [16].
5) Testing: Upon completion of the AR application, it undergoes trial runs to ensure accuracy and suitability before public deployment [16].
6) Distribution: The final stage involves packaging the completed application as an Application Package File (APK) and releasing it on the Android platform with appropriate licensing. The application is stored on devices like Android-based smartphones, flash drives, or can be downloaded from the Playstore [18].

2.3. Research Framework
The research framework connects the visualization of one variable with another, systematically structuring the study for broader acceptance. This framework systematically organizes the research objectives for improved clarity and effectiveness. Based on Figure 2, the problem identified in this research is the inefficiency in learning the solar system using physical globes or 2D printed media. The proposed solution is a 3D object display in the form of an AR application accessible on Android devices. The researcher will collect data such as planet models and sizes, along with relevant information, to be displayed in the AR application. The final output is an AR application showcasing the planets in 3D on Android smartphones, designed to facilitate efficient learning of the solar system without the need for physical globes, thereby reducing costs and space requirements. This framework is presented in Figure 2.

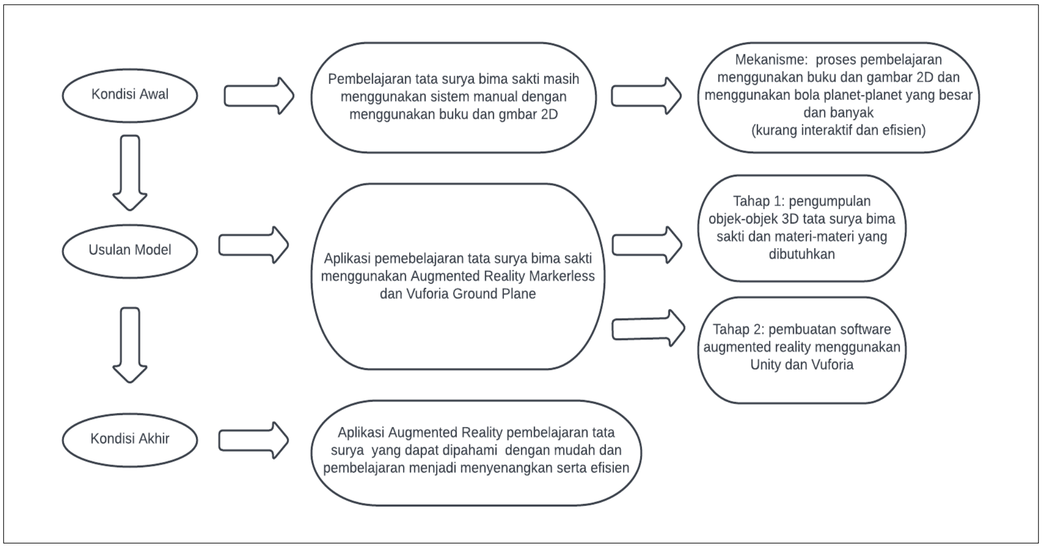

Figure 2. Research Framework

2.4. Augmented Reality Application Workflow
The developed AR furniture catalog system involves capturing customer data through marker scanning using the AR Furniture app. The app then sends a marker request to the Vuforia database for validation. If the marker matches, the app displays the 3D furniture product to the customer. This process is illustrated in Figure 4.

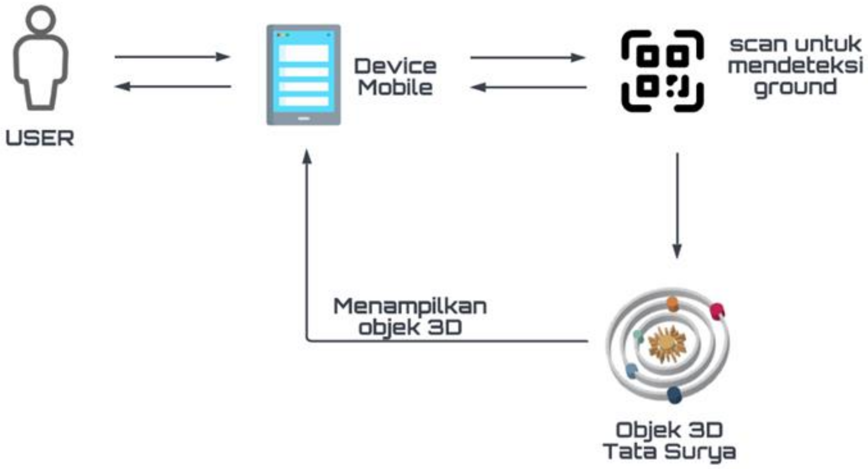

Figure 3. Workflow of the Markerless Augmented Reality Application

3. Result and Discussion

3.1 Results
The outcome of the application implementation is a crucial phase in this project, realizing the initial design to meet set objectives and requirements, and also representing the results of testing before evaluation.

3.1.1 Application Interface
The implementation of the homepage is the application of the designed page that displays a welcome message and the title of the application, including a primary button named "To Infinity". The interface of the homepage is illustrated in Figure 4.

Figure 4. Homepage Interface

The main menu page implementation showcases the solar system's planets available in the application or system, including the Sun, Mercury, Venus, Earth, etc. This page also features a 'Start AR' button to initiate scanning, an exit button, a planet button displaying each planet's main menu page along with its information, and a slide button to view subsequent planets. The interface of the main menu page is shown in Figure 5.

Figure 5. Main Menu Page Interface

Figure 6. Application Exit Validation Interface

The AR Camera page implementation is where the selected 3D Augmented Reality planet object is displayed. This page also features 3D along with back, rotate, sound, and information buttons to reveal descriptions and audio information about the planet, including zoom-in and zoom-out features for detailed viewing. The AR Camera page interface is visible in Figure 7.

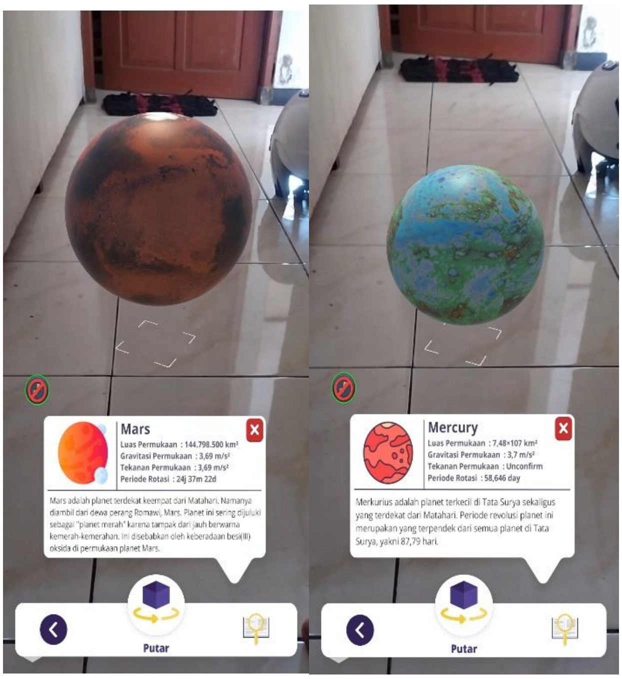

Figure 7. AR Camera Page Interface

3.1.2 Testing

Table 4. Android Specifications for Testing

Device	CPU	RAM	Rear Camera
Xiaomi POCO M3	Octa-core (4x2.0 GHz Kryo 260 Gold & 4x1.8 GHz Kryo 260 Silver)	6 GB	48 MP
Xiaomi Redmi 6	Octa-core 2.0 GHz Cortex-A53	4 GB	12 MP
Realme C1	Octa-core 1.8 GHz Cortex-A53	2 GB	13 MP
Realme 3 Pro	Octa-core (2x2.2 GHz Kryo 360 Gold & 6x1.7 GHz Kryo 360 Silver)	4 GB	16 MP

Blackbox testing is used to evaluate the functionality of the program and detect system execution or function errors comprehensively. Each test case involves input provision to observe the application's output, ensuring the results align with the application's design. This testing also aims to identify potential errors, facilitating immediate rectification. Table 5 presents the black box testing results for the "AR Solar System" application.

Table 5. Black Box Testing Results

No.	Menu	Test Cases and Results	Conclusion
1	Home Page	Displays the Home page and the To Infinity button	Succeed
2	To Infinity button	Displays the main menu page containing the Exit Application and Start AR buttons as well as a brief description of each planet	Succeed
3	AR Start Button	Displays the AR Camera, Caption button, Rotate 3D Object Button and activates the camera to scan the Ground	Succeed
4	Exit Application Button	Displays an application exit approval pop-up	Succeed
5	Planetary slides	Shift the planet selection and select the planet as desired	Succeed
6	Button Description (information)	Displays descriptions and information about 3D objects	Succeed
7	Return button from Start AR to Main Menu	When the back button on the AR Camera is clicked, the system should return to the main menu	Succeed
8	Object Rotate Button	Rotate the object clockwise	Succeed
9	Vuforia Ground Plane	Detecting Ground	Succeed
10	AR Camera	Displays 3D objects on the smartphone screen	Succeed
11	Sound Button	Plays sounds regarding planetary information	Succeed

3.1.3 Response Time Loading Testing

Response time loading tests were conducted on Android devices with the above specifications. This testing is crucial as the program contains numerous 3D objects affecting the time required to load each component. The reaction time loading tests were completed in four ways: loading the camera, rendering 3D, opening the application, and playing audio [14].

Table 6. Response Time Loading Test Results

Test Process	Response Time Loading Second			
	Xiaomi POCO M3	Xiaomi Redmi 6	Realme C1	Realme 3 Pro
Loading opens the application	2	2	2	2
Loading opens the camera	2	3	2	2
Loading 3D object rendering	2	3	4	4
Loading while playing audio	2	2	2	2

Testing response time loading on 4 Android devices with different specifications indicates that higher-spec devices achieve faster feature loading in the application [14].

3.2 Discussion

The study demonstrates that the three-dimensional augmented reality application in Jepara wood furniture catalog, developed using the waterfall method, brings significant benefits in supporting this research. This application simplifies the process for potential furniture buyers to view products in 3D format, eliminating the need for physical store visits. Moreover, it aids consumers in easily locating furniture stores. During the application development process, Unity software was utilized for creation, with Visual Studio Code as the text editor. The programming language employed was C#, and Vuforia was used for marker image data storage. The application features several main menus, such as AR Scan to display furniture products in 3D with size details, an information menu containing comprehensive data about renowned furniture stores in Jepara, and a guide menu providing instructions on how to use the application. The implementation of augmented reality successfully provides a solution for consumers wishing to view furniture products directly without physical store visits.

4. Related Work

This study encompasses a range of prior research focused on the diverse applications of Augmented Reality (AR) technology. For instance, research by Latif & Loppies (2019) successfully implemented AR in an application serving as an educational tool for the study of human anatomy, employing 3D visualizations to simplify the learning and teaching process [19]. Similarly, Saefuddin (2022) designed an AR application aimed at the learning of the morphology of endemic Indonesian flowers, specifically focusing on their reproductive organs, and presenting these in a 3D format [20]. Another study by Made *et al* (21) investigated the use of AR for introducing geometric shapes in 3D, achieving a positive reception with an 82.44% approval rating in user questionnaires, indicating its 'Good' category effectiveness. Further [21], Falia & Wardhani (2021) applied AR technology as a promotional medium for a workshop, which notably increased sales at the Nanda Kreasi welding workshop [22]. Additionally, Endea & Agustina (2019) leveraged AR for the introduction of computer hardware components through interactive 3D visualizations [23]. These studies collectively illustrate that AR technology can be effectively applied across various domains, demonstrating its versatility and potential in enhancing both educational and commercial experiences.

5. Conclusion

The research conducted has led to the development of an innovative Augmented Reality (AR) application focused on the education and introduction of the Milky Way galaxy's solar system. This application addresses the challenge of limited understanding among elementary school students regarding the solar system, which was previously taught using traditional globes and pictures. Designed as an Android application, it operates independently of internet connectivity, offering a modern and engaging approach to learning that captivates students' interest. The application is optimized for Android devices with a minimum of 3GB of RAM, ensuring smooth and efficient functionality. On devices exceeding this specification, the application performs even more effectively. However, a noted limitation of this AR educational application is the absence of quizzes and games that could assess and enhance students' comprehension of the solar system. Incorporating these interactive elements could provide a more comprehensive and engaging learning experience, further benefiting the users' understanding of the subject matter.

References

[1] Kusuma, S.D.Y., 2018. Perancangan Aplikasi Augmented Reality Pembelajaran Tata Surya dengan Menggunakan Marker Based Tracking. Jurnal Informatika Universitas Pamulung, 3(1), pp.33–38.

[2] Tantriadi, Y., 2013. Pembuatan Ensiklopedia Interaktif Tata Surya untuk Anak SMP. Jurnal Ilmiah Mahasiswa Universitas Surabaya, 2(1).

[3] Astuti, I.A.D., Dasmo and Sumarni, R.A., 2018. Pengembangan Media Pembelajaran Berbasis Android dengan Menggunakan Aplikasi Appypie di SMK Bina Mandiri Depok. Jurnal Pengabdian Kepada Masyarakat, 24(2), pp.695–701. Available at: http://jurnal.unimed.ac.id/2012/index.php/jpkm/article/view/10525.

[4] Faradila, S.P. and Aimah, S., 2018. Analisis Penggunaan Media Pembelajaran untuk Meningkatkan Minat Belajar Siswa di SMA N 15 Semarang. In: Prosiding Seminar Nasional Mahasiswa Unimus, pp.508–512.

[5] Sugianto, C.A., 2018. Aplikasi Edukasi Tata Surya Menggunakan Augmented Reality Berbasis Mobile. Informatics Research and Development, pp.30–39.

[6] Hasna, A., 2023. Pengembangan Materi Pemanfaatan Berbagai Aplikasi Handphone Dalam Pembelajaran.

[7] Sihombing, Y., Haloho, B. and Napitu, U., 2023. Problematika Guru Dalam Pemanfaatan Media Pembelajaran. Jurnal Pendidikan Mandala, 8(2), pp.710–718. Available at: http://ejournal.mandalanursa.org/index.php/JJUPE/index.

[8] Sagita, S.M. and Amalia, R., 2014. Pembelajaran Tata Surya Menggunakan Teknologi Augmented Reality. Official Journals of Universitas Indraprasta PGRI, 7(3), pp.224–235.

[9] Simatupang, D.S. et al., 2023. Pentingnya Pemanfaatan Teknologi Informasi dalam Bidang Pendidikan di Desa Mekar Asih. Jurnal Pengabdian Kepada Masyarakat Abdi Nusa, 3(2), pp.41–46.

[10] Dewi, Rr.V.K., Sunarsi, D. and Akbar, I.R., 2020. Dampak Penggunaan Teknologi Informasi Dan Komunikasi Terhadap Minat Belajar Siswa Di SMKGanesa Satria Depok. Jurnal Ilmiah Wahana Pendidikan, 6(4), pp.1001–1007.

[11] Listiawan, T., Hayuningrat, S. and Anwar, M.K., 2017. Pengembangan media pembelajaran berbasis Augmented Reality pada materi bangun ruang. Jurnal Pendidikan dan Pembelajaran Matematika, 8(2), pp.1–10. DOI: https://doi.org/10.29100/jp2m.v8i2.2022.

[12] Irfansyah, J. and Anifah, L., 2022. Media Pembelajaran Pengenalan Hewan untuk Siswa Sekolah Dasar Menggunakan Augmented Reality Berbasis Android. Journal of Engineering, Technology, and Applied Science, 4(2), pp.86–96. DOI: https://doi.org/10.36079/lamintang.jetas-0402.384.

[13] Miftahussa'adah, M., Markos, S. and Susanti, R., 2023. Analisis Kebutuhan Pengembangan Media Pembelajaran Menggunakan Augmented Reality pada Mata Pelajaran Ekonomi. Jurnal Intelektualita: Keislaman, Sosial dan Sains, 12(1), pp.110–116. DOI: https://doi.org/10.19109/intelektualita.v12i1.17425.

[14] Batubara, A.A., Triase and Sinaga, I.A., 2023. Penerapan Teknologi Augmented Reality Untuk Rangkuman Isi Buku Pada Perpustakaan Fakultas Berbasis Android. KLIK: Kajian Ilmiah Informatika dan Komputer, 4(2), pp.995–1001. DOI: https://doi.org/10.30865/klik.v4i2.1253.

[15] Zahra, S.A. and Majid, N.W.A., 2023. Pengembangan Aplikasi Game Sistem Tata Surya Untuk Siswa Sekolah Dasar Menggunakan Metode MDLC. JPSP: Jurnal Penelitian Sains dan Pendidikan, 3(2), pp.195–206. Available at: https://e-journal.iain-palangkaraya.ac.id/index.php/mipa/ [Accessed Date].

[16] Nurrahman, C., 2022. Implementasi Augmented Reality Menggunakan Unity untuk Menampilkan Objek 3D Mobil dengan Metode Multimedia Development Life Cycle (MDLC). Jurnal Universitas Palangka Raya.

[17] Yulianto, B.D., Kristina, D., Anggraeni, N. and Sesilia, F., 2022. Artikel Kuis Media Pembelajaran Adobe Animate dengan Metode MDLC. Available at: https://www.researchgate.net/publication/364995024.

[18] Kurniasari, A.A., Puspitasari, T.D. and Mutiara, A.D.S., 2023. Penerapan Metode Multimedia Development Life Cycle (MDLC) Pada A Magical Augmented Reality Book Berbasis Android. Antivirus: Jurnal Ilmiah Teknik Informatika, 17(1), pp.19–32. DOI: https://doi.org/10.35457/antivirus.v17i1.2801.

[19] Latif, A. and Loppies, S.H.D., 2019. Penerapan Teknologi Augmented Reality pada Aplikasi Pembelajaran Anatomi untuk Siswa Sekolah Menengah Pertama Berbasis Android. MUSTEK ANIM HA, 8(2), pp.141–147. DOI: https://doi.org/10.35724/mustek.v8i2.2534.

[20] Saefudin, M. et al., 2022. Aplikasi Pembelajaran Morfologi Organ Reproduksi Bunga Endemik Indonesia Menggunakan Augmented Reality Berbasis Android. Jurnal Universitas Muhammadiyah Jakarta.

[21] Made, I., Widyantara, O., Wiharta, D.M. and Widiadnyana, P., 2022. Implementasi Aplikasi Mobile Augmented Reality untuk Pengenalan Materi Bangun Ruang. Jurnal Teknologi Informasi dan Ilmu Komputer (JTIIK), 9(2), pp.313–322. DOI: https://doi.org/10.25126/jtiik.202295032.

[22] Falia, I. and Wardhani, S.A.K.W., 2021. Penerapan Teknologi Augmented Reality pada Media Promosi Bengkel Las Nanda Kreasi Berbasis Android. *Multidisciplinary Applications of Quantum Information Science (Al-Mantiq)*, *1*(1), pp.29-35. DOI: HTTPS://DOI.ORG/https://doi.org/10.32665/almantiq.v1i1.328.

[23] Endra, R.Y. and Agustina, D.R., 2019. Media Pembelajaran Pengenalan Perangkat Keras Komputer Menggunakan Augmented Reality. EXPERT: Jurnal Manajemen Sistem Informasi dan Teknologi, 9(2), Des. DOI: https://doi.org/10.36448/jmsit.v9i2.1311.

