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How to Create Augmented Reality (AR) Applications Using Unity and Vuforia Engine to Teach Basic Algorithm Concepts: Step-by-Step Procedure and Bibliometric Analysis

Dwi Novia Al Husaeni, M. Munir, R. Rasim*

Universitas Pendidikan Indonesia, Bandung, Indonesia
*Correspondence: E-mail: dwinoviaalhusaeni14@upi.edu

ABSTRACT

Increasingly developing technology causes the need for more interactive and interesting learning methods to increase. Therefore, this research was carried out to provide step by step how to develop Augmented Reality (AR) applications using Unity and Vuforia Engine. The Research and Development method was used in this research to document each step in the AR application development process in Unity with the Vuforia Engine. Apart from that, bibliometric analysis was carried out in this research to determine research trends regarding AR. Selecting the Unity application and Vuforia Engine made it easier to develop AR applications because the steps involved are not too complicated and many features can be accessed for free. Based on the results of bibliometric analysis, publications regarding AR are increasing every year, especially during the 2014-2024 period, with the peak of publications occurring in 2023, reaching 6,835 publications. This research can help educators in creating innovative and creative learning media, especially by utilizing AR technology.

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1. INTRODUCTION

In the digital era, which is increasingly developing rapidly, Augmented Reality (AR) has become a technology that has great potential in the field of education, especially in elementary schools (Syahril *et al*., 2023). AR technology allows combining the real world with interactive digital elements, thereby creating a more interesting and contextual learning experience (Wu *et al*., 2013). One of the main challenges, especially in elementary education, is conveying abstract concepts, such as algorithms, to students in a way that is easy to understand. Algorithms, as the core of programming and computational logic, are often considered difficult by novice students because of their abstract and theoretical nature. Thus, AR can be an innovative solution for presenting algorithm concepts visually and interactively, which is expected to simplify the learning process.

The use of AR technology in education has received great attention in recent years. Previous research shows that AR is not only able to improve students' understanding of concepts but also motivates them to learn in a more active and in-depth way (Kuswinardi *et al*., 2023; Hadi & Zahrani, 2024; Saputra & Lorena, 2021; Budiman, 2016; Bacca *et al*., 2018). AR in programming classes can improve students' cognitive abilities through immersive and participatory learning experiences (Lin & Chen, 2020). This finding is supported by research by del Cerro Velázquez & Morales Méndez (2021) which shows that AR is effective in helping students understand abstract concepts in mathematics and science through interactive simulations. However, these studies generally do not touch much on basic algorithm learning, especially those tailored to the needs of novice students. This is where AR developed through Unity and the Vuforia Engine has the potential to offer a new approach to teaching algorithms through step-by-step simulations that students can follow.

For this reason, this research offers novelty by developing an AR application based on Unity and Vuforia Engine which is specifically designed for basic algorithm learning. Unity and Vuforia Engine were chosen because of their high flexibility and compatibility, making it possible to create AR applications that are interactive and easily accessible by various devices. Through this application, students can visualize basic algorithm concepts such as loops, conditions, and logic, which are often difficult to understand only through text or image explanations.

Therefore, the main objective of this research is to design a step-by-step Augmented Reality (AR) application using Unity and Vuforia Engine which functions as an interactive learning medium in teaching basic algorithm concepts. The expected impact of this research is not only limited to creating Android-based AR applications but also to a broader contribution to the world of education. It is hoped that the development of this application can help educators create innovative and creative learning media, especially by utilizing AR technology. Thus, this research has the potential to provide a relevant contribution to the development of educational technology that is innovative, responsive, and supports student needs in the digital era.

2. METHODS

The method used in this research is the Research and Development (R&D) method. This method is used because it makes it possible to develop AR applications and document each step in the AR application development process in Unity with Vuforia Engine.

Bibliometric analysis was also carried out in this research to determine trends in augmented reality research over the last 10 years, namely during the 2014-2024 period. "Augmented Reality" is used as a search keyword for article data in this research. The Scopus

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database is used as a tool to collect articles. The article data used are articles of the type of Conference proceedings, journals, book series, books, and trade journals.

3. RESULTS AND DISCUSSION

Augmented Reality (AR) is a technology that combines digital elements such as images, sound, and other sensory data into the real world in real-time (Carmigniani *et al*., 2011). AR technology allows users to see the surrounding environment with additional information or virtual objects generated by computers (Arena *et al*., 2022). Android applications that apply AR technology can be created using Unity with Vuforia Engine. In this research, we discuss step by step how to create an AR application in Unity with the Vuforia Engine, starting from the installation stage to the build stage.

3.2. Research Trends on The Topic of Augmented Reality

Figure 1 shows the trend of article publications related to the topic of Augmented Reality (AR) in the 2014-2024 period. Based on **Figure 1**, research on AR has increased significantly every year. The peak of this research occurred in 2023, with 6,835 Scopus-indexed documents published. In 2024, the number of publications regarding AR decreased, which is likely due to the data collection time which was carried out in November 2024. Therefore, the number of publications in 2024 still has the potential to increase.

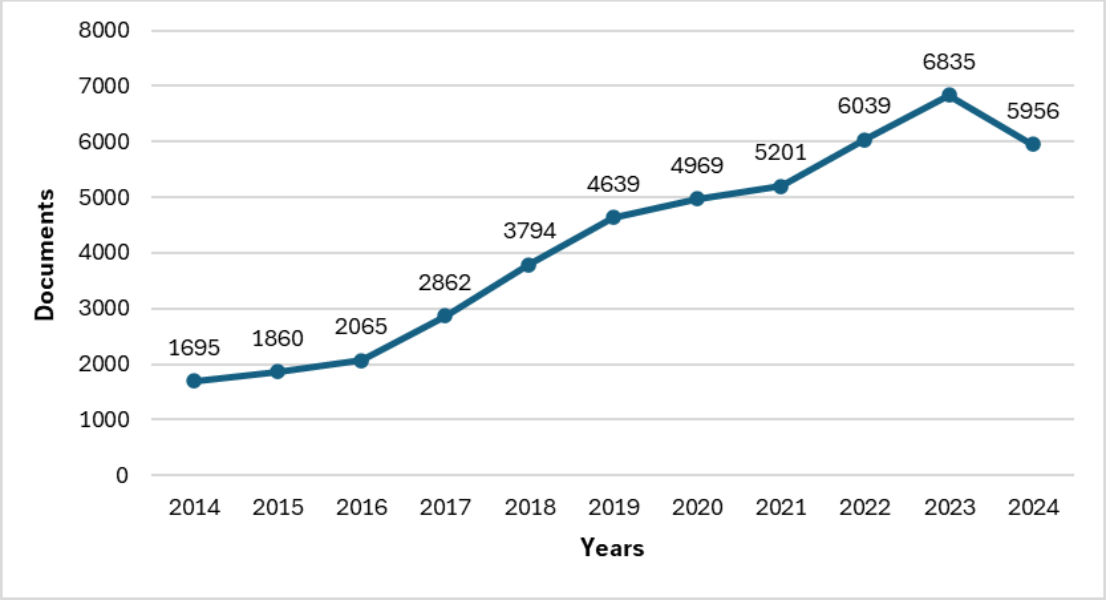

Figure 1. Publication trends on augmented reality topics for the 2014-2024 period.

The increase in research on AR can be caused by the increasing development of technology in everyday life (Zonneveld *et al*., 2020). Apart from that, the increase in the number of publications regarding AR is also driven by the great potential that this technology has in various fields, such as education. The use of AR technology in education has been widely implemented (Nikimaleki & Rahimi, 2022; Hidayat *et al*., 2021, Fakhrudin *et al*., 2017). For example, AR technology in education is used as a tool to teach abstract material. Thus, it is easier for students to understand (Hafizah, 2023; Fitria, 2023). AR allows combining the real world with interactive digital elements, creating a richer and more immersive user experience. Technological advances and increased accessibility of AR-enabled hardware, such as smartphones and AR glasses, are driving the growth of research in this area.

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3.1. Vuforia Engine Setting

Before we enter Unity, it is a good idea to prepare a database and several marker images that will be used for the AR application. The following are the steps to create an AR application marker card in Vuforia.

(i) Install Vuforia Engine SDK via the link https://developer.vuforia.com. After installing, create a Vuforia account first as shown in **Figure 2**. When finished, we can log in using the previously registered account, as shown in **Figure 3**.

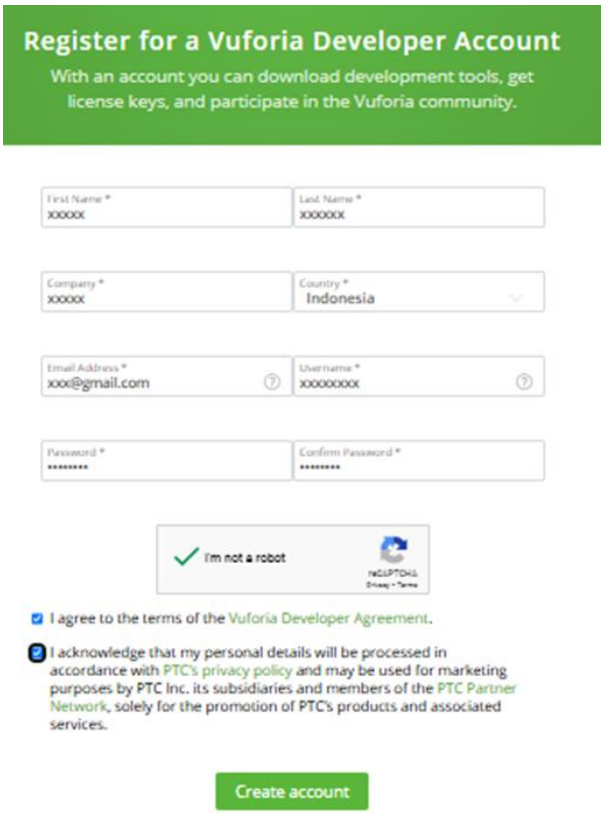

Figure 2. Create a Vuforia account

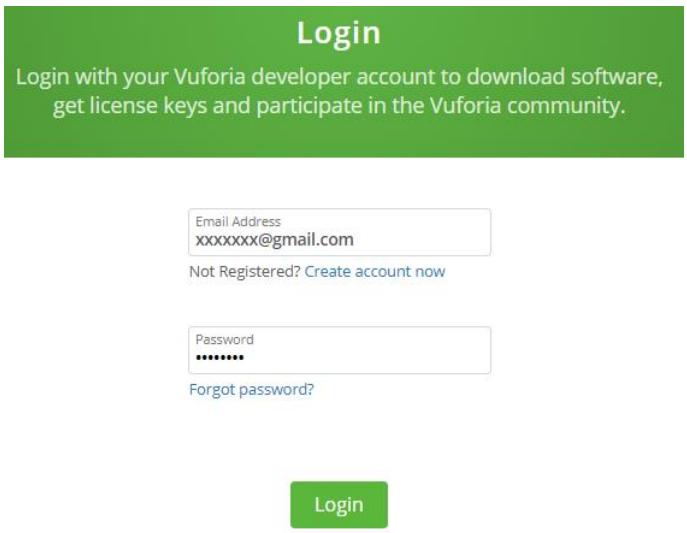

Figure 3. Login to the Vuforia engine.

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(ii) Create a new database in Vuforia by going to Target Manager - Generate Database - enter the database name - Generate as shown in **Figure 4**. Once successful, the created database appears on the Target Manager page as presented in **Figure 5**.

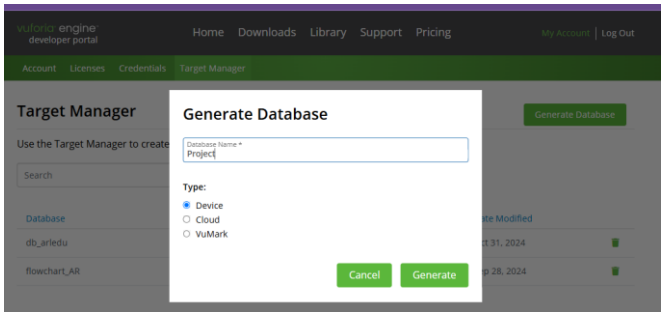

Figure 4. Create a new database in Vuforia.

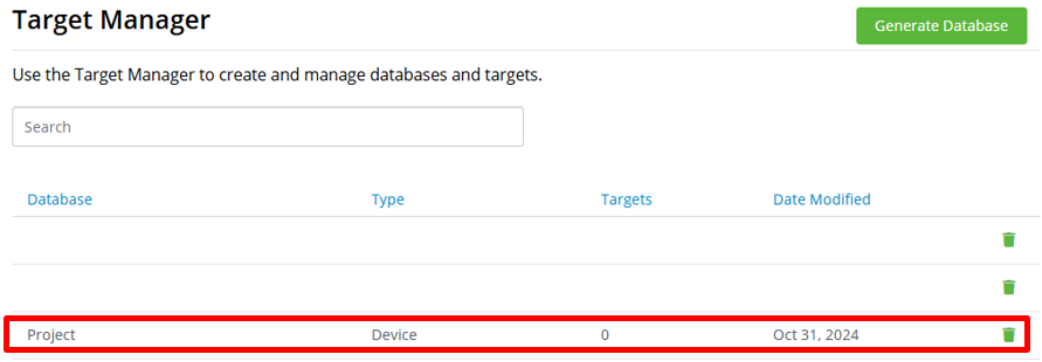

Figure 5. Create database success.

(iii) After successfully creating a new database, we can upload the marker image that we created previously by entering the database and selecting "add target." After that, upload the marker image that has been created, enter the width (example: 1), select the marker name, and click "add" as shown in **Figure 6**. If successful, the display that appears is shown in **Figure 7**. It is recommended to create a marker AR and choose striking colors. Thus, it is easy for the system to read, such as green, yellow, blue, etc.

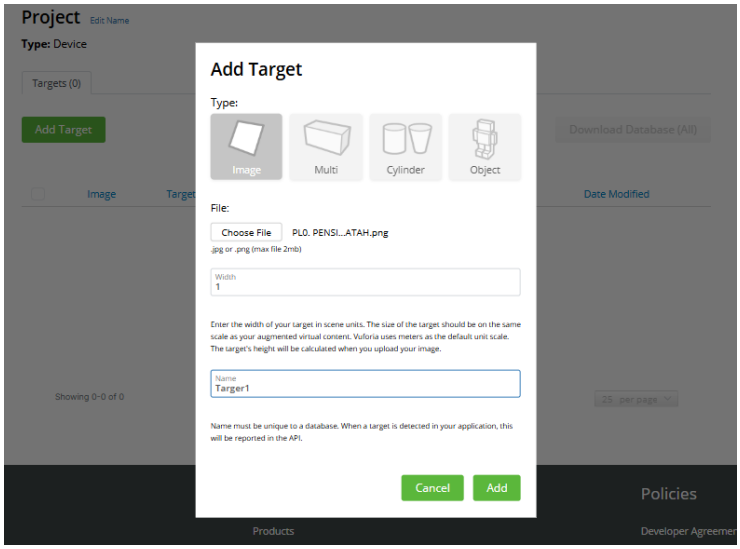

Figure 6. Create marker

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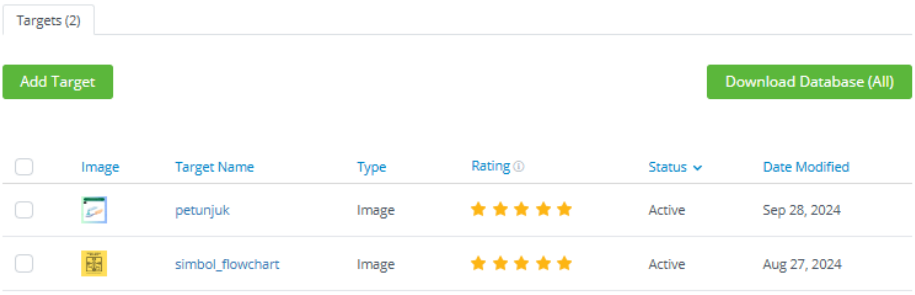

Figure 7. Create marker success.

(iv) If you have done the previous steps, you can start downloading all the marker images created by clicking "Download Database" as shown in **Figure 8**.

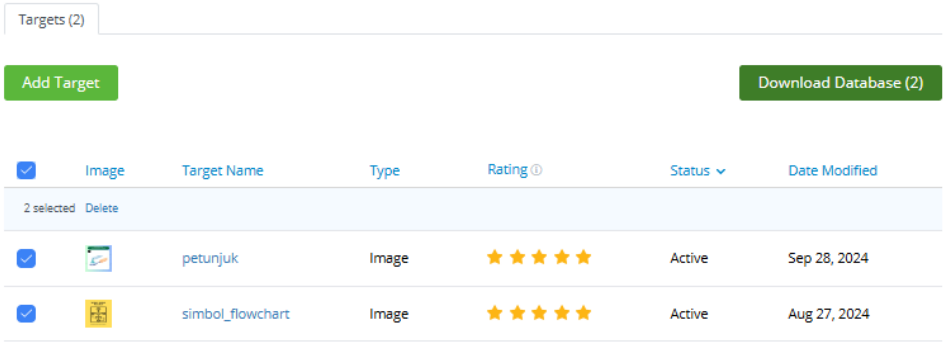

Figure 8. Download the Vuforia database.

3.3. Unity Application Setting

After finishing creating markers in Vuforia, we can continue creating AR applications in Unity. The steps to create an AR application in Unity are as follows:

(i) Install the Unity application via the official website or the link https://unity.com/download.

(ii) Open the installed Unity application, then create a new project as shown in **Figure 9**. Select 3D (Built-in Render Pipeline) and change the project name according to the project you want to create. In the final step, click "Create Project".

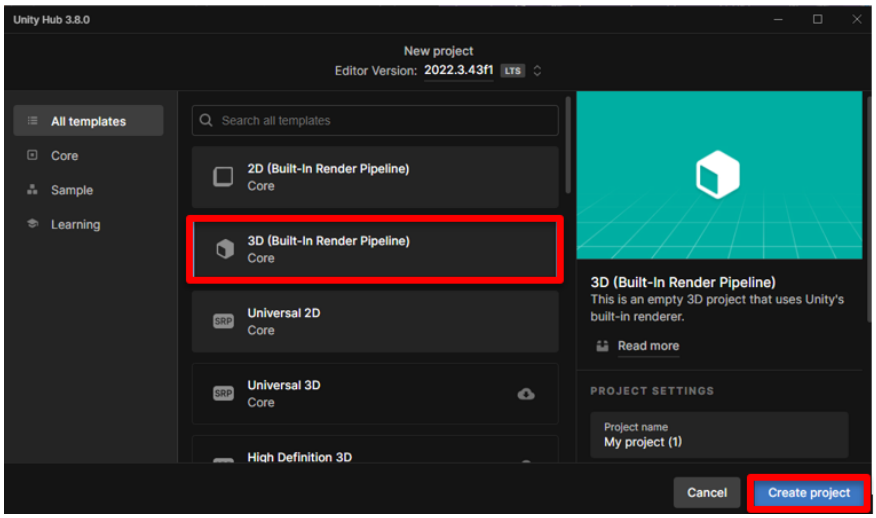

Figure 9. Create a new project in unity.

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(iii) Import the Vuforia Engine package into Unity by clicking “Select Asset - Import Package - Custom Package.” After that, navigate to the path to the Vuforia Engine SDK package that was downloaded previously, as shown in **Figure 10** and **Figure 11**. When finished, click "Open," and the display seems in **Figure 12**. After the display appears as in **Figure 12**, click “Import” to continue the import process, and wait until the process is complete.

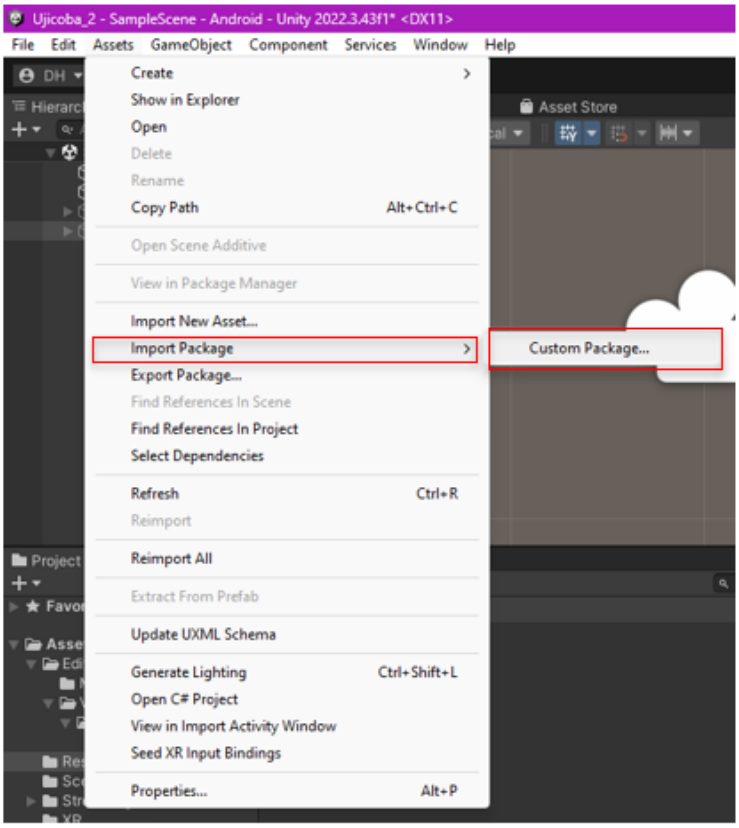

Figure 10. Import Vuforia package in unity.

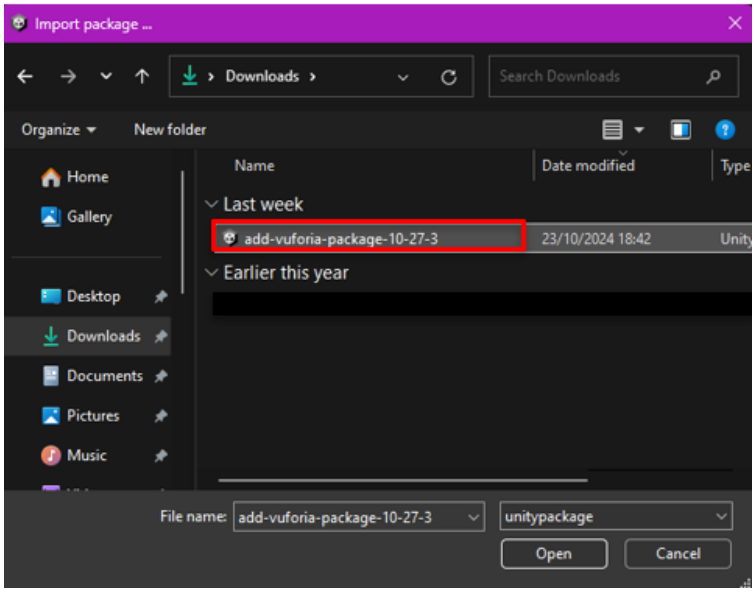

Figure 11. Select the Vuforia Engine SDK file that has been downloaded.

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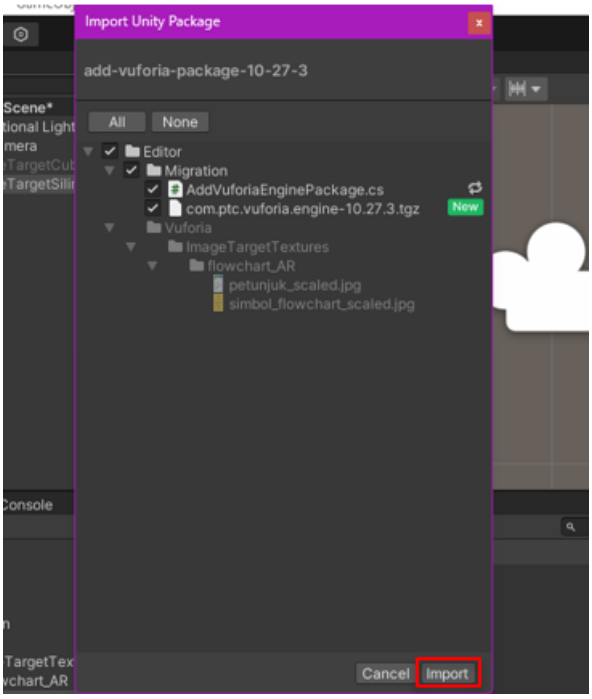

Figure 12. Import the downloaded Vuforia package

(iv) After the package has been imported, select the Game Object - Vuforia Engine - AR Camera tab. Don't forget to delete the Main Camera in the Hierarchy, because we use the AR Camera (see **Figure 13**).

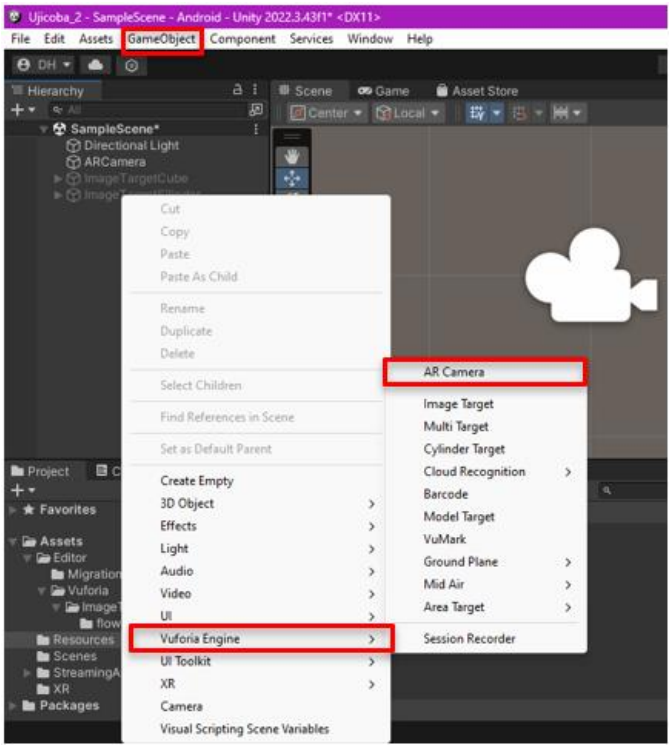

Figure 13. Using AR Camera and Delete Main Camera.

(v) Insert the downloaded Vuforia database into Unity by opening the downloaded database, as shown in **Figure 14**.

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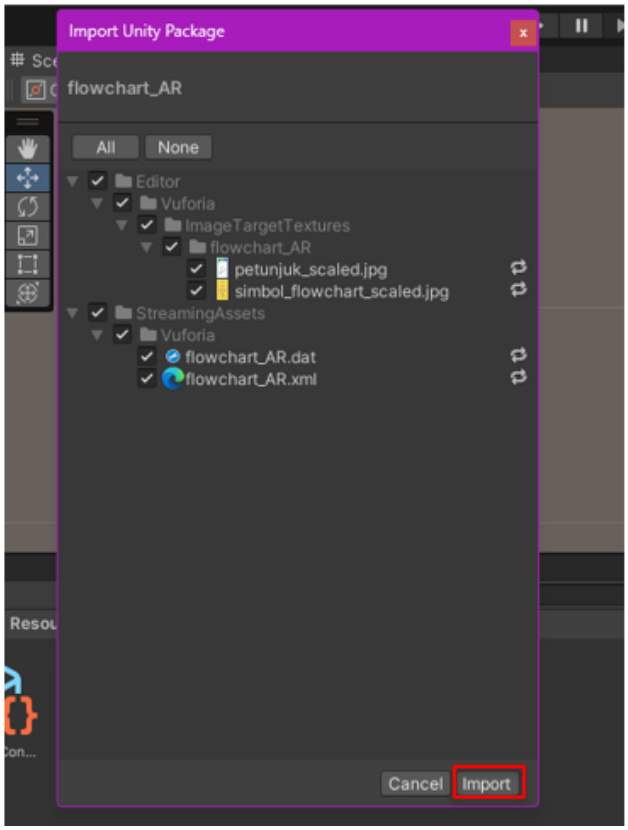

Figure 14. Import database.

(vi) After that, we can enter the Vuforia license key by opening the Vuforia website (remember to always log in first). Go to the license menu, then copy the available license key as shown in **Figure 15**. This license key is entered into Unity and functions to activate the Vuforia SDK features in your application. Without a license key, you cannot fully use the Vuforia SDK.

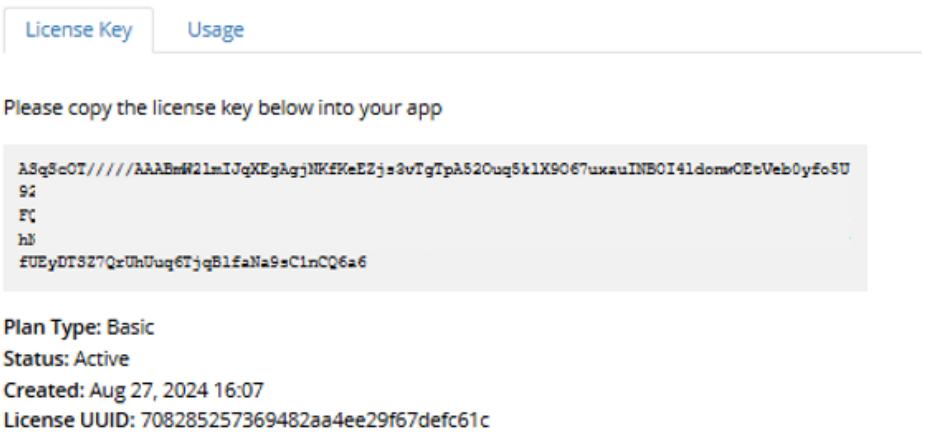

Figure 15. Input the Vuforia license key in Unity.

(vii) After that, go back to Unity, and select the Game Object - Vuforia Engine - Image Target tab, as shown in **Figure 16**. In the Inspector panel, under Image Target Behavior, select Type, then select From Database and click Add Target, as shown in **Figure 17**.

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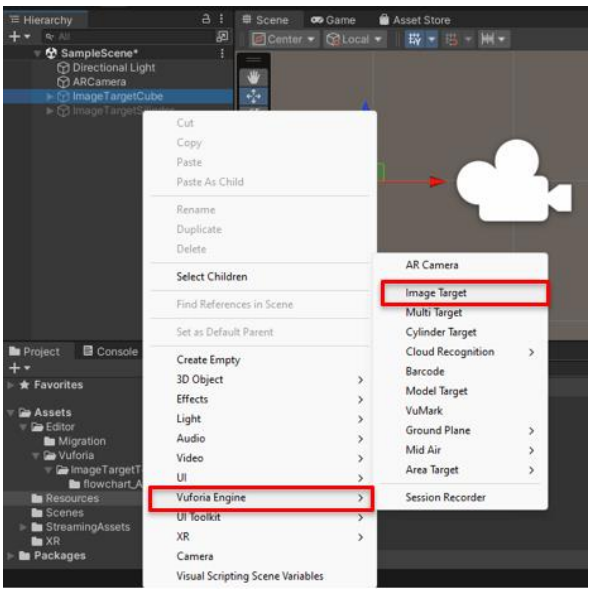

Figure 16. Create a game object.

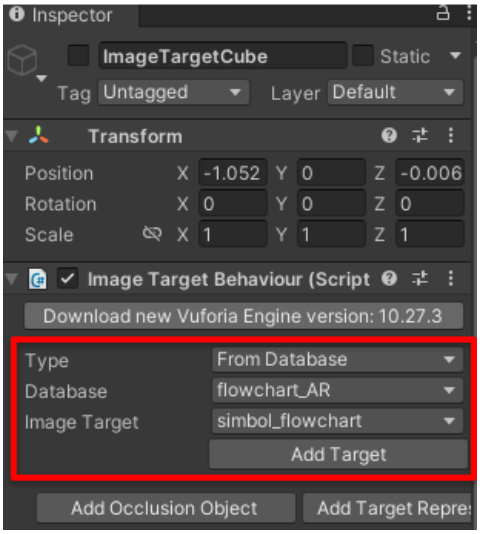

Figure 17. Add target

(viii) In the Hierarchy pane, click Image Target. Next, in the database, select the database and target image that we have registered, as presented in **Figure 18**.

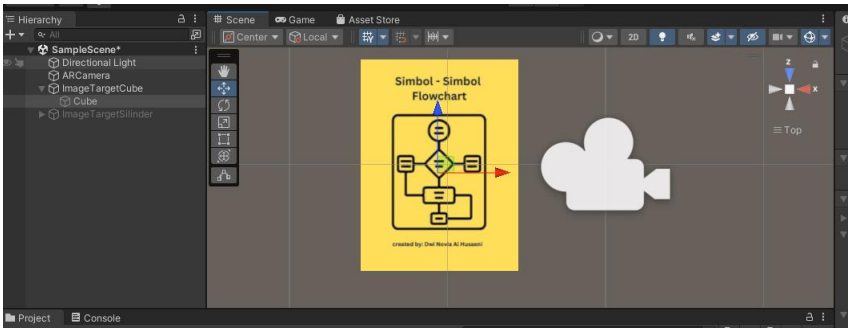

Figure 18. Target image.

(ix) Enter the license key in Vuforia Configuration by going to the Windows menu, and then selecting Vuforia Configuration as shown in **Figure 19**. After that, enter the copied license key into the license key column as shown in **Figure 20**.

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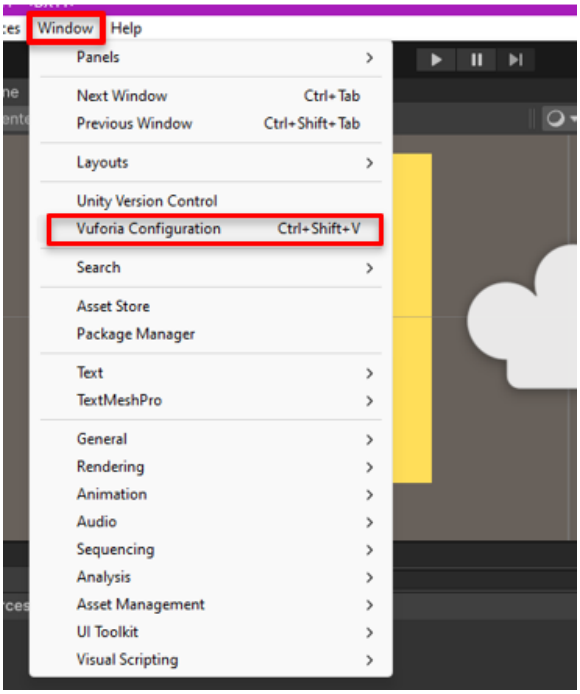

Figure 19. Open Vuforia configuration.

Figure 20. Copy the Vuforia license key in Unity.

(x) Add objects that will be displayed on the AR camera. We can get objects from Unity by clicking the Game Object - 3D Object tab, and then selecting the desired object. Alternatively, we can also search for objects by extension. unitypackage on Google, as shown in **Figure 21**. In this example, we insert a 3D object in the form of a cube that has been provided by Unity. Thus, the results are shown in **Figure 22**.

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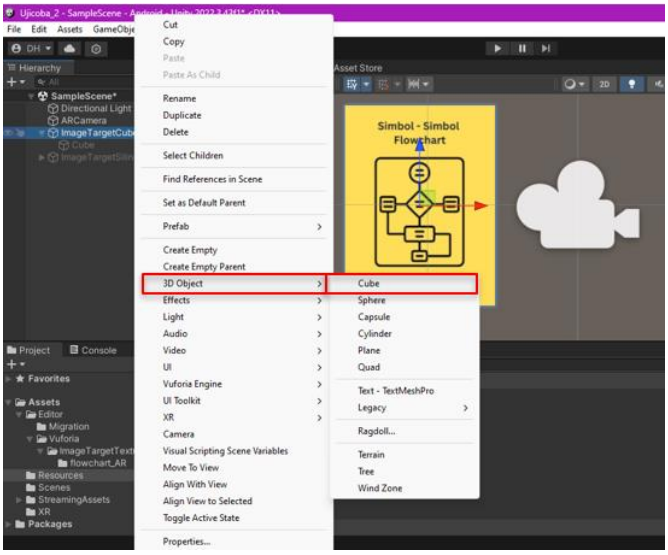

Figure 21. Add 3D object.

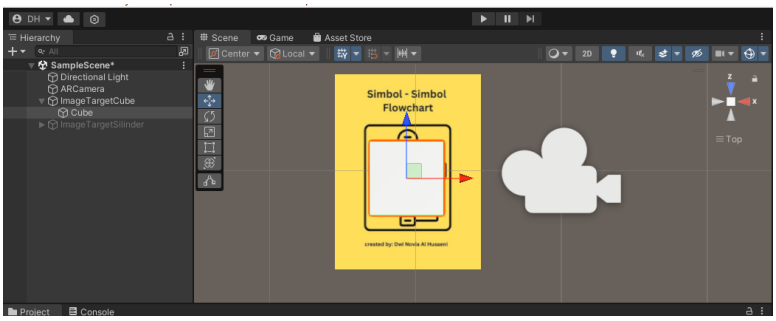

Figure 22. 3D unity cube object.

(xi) After the object appears, you can adjust the position of the object. Thus, it is directly above the target image.

3.3. Build Application Setting

After completing creating an AR application in Unity, we can immediately build the application into Android application format in the following:

(i) Click File - Build Settings as shown in **Figure 23**. When finished, the resulting display seems to be in **Figure 24**.

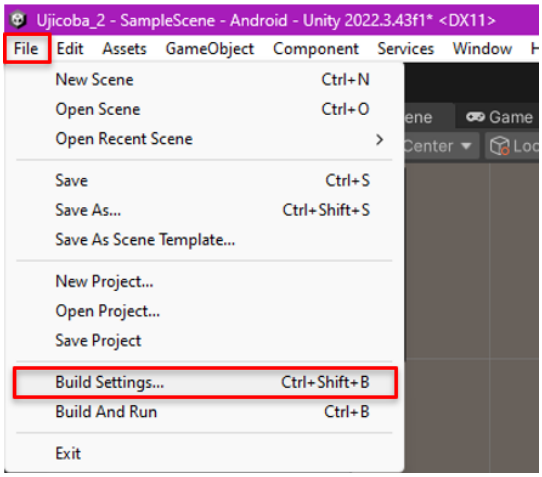

Figure 23. Open build settings.

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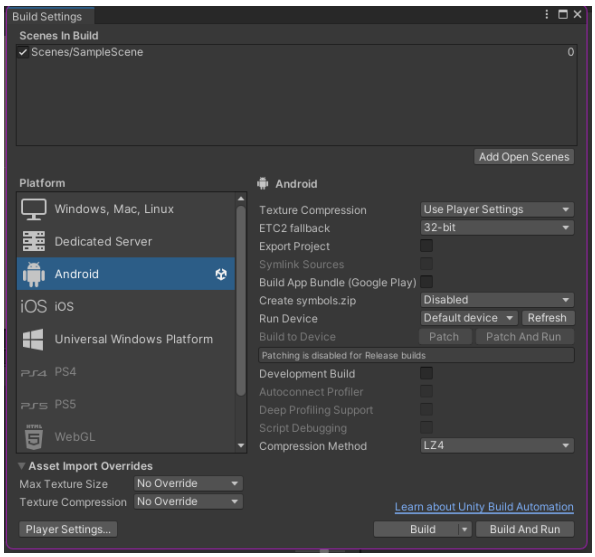

Figure 24. Open build setting success.

(ii) Activate the scene that has been created, and then select Android because we create an AR application for the Android platform. Next, click "Build". Make sure you have the Android SDK installed. The Android SDK can be downloaded via Unity Hub by selecting the install option, then clicking the gear icon, and selecting "Add Module", as shown in **Figure 25**. Next, install Android Build Support, and Open JDK, as well as Android SDK and NDK Tools (see **Figure 26**).

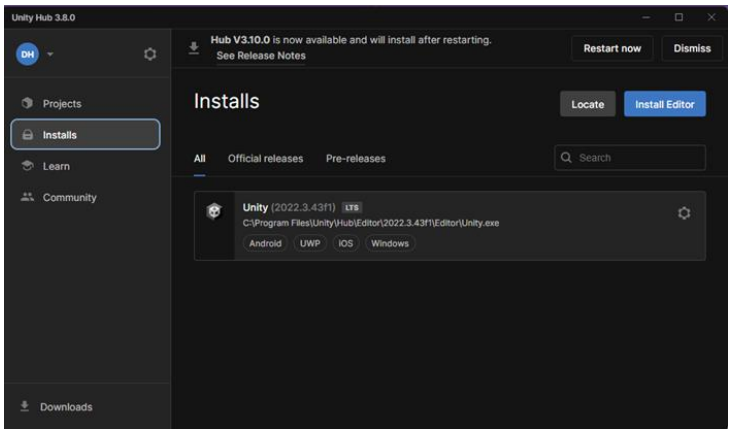

Figure 25. Install Android SDK.

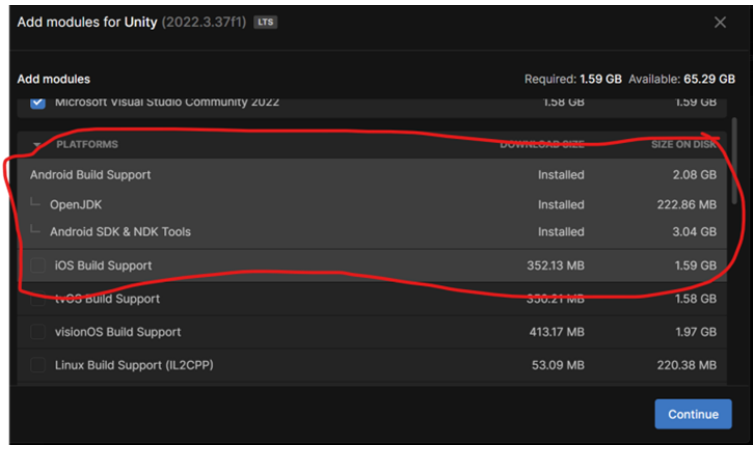

Figure 26. Install Android build support.

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(iii) In Unity, select Services - General Settings - Player, then set the Minimum API Level to the Android 12 version or adjust it to the Android version of your smartphone, as shown in **Figure 27**.

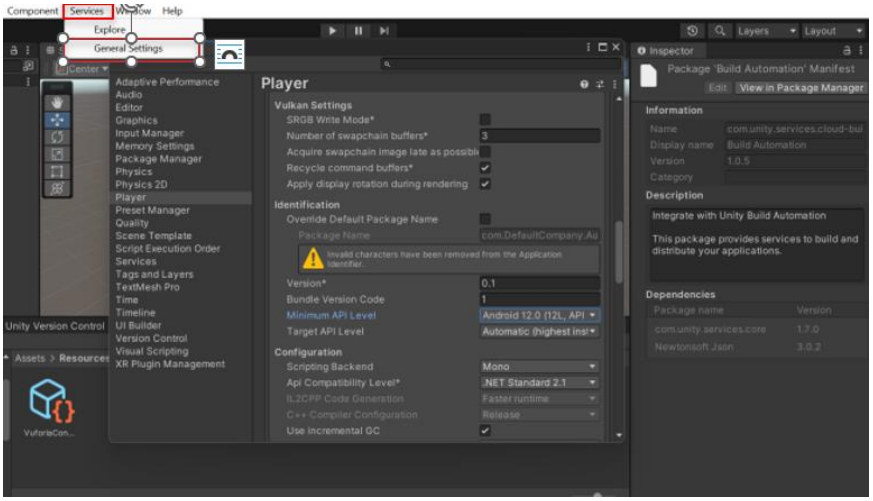

Figure 27. Android version settings.

(iv) After that, return to the File menu - Build Settings - Android, then select Build. The output of the build process produces a file with the extension ".apk", as shown in **Figure 28**.

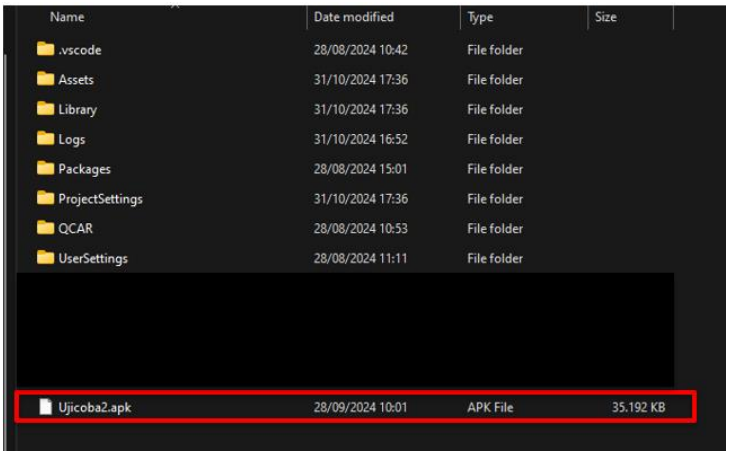

Figure 28. Augmented reality application.

(v) If you already have a file in .apk format on your laptop or computer, the final step is to install the .apk file on your Android phone and you can start using the application you have created.

4. CONCLUSION

This research aims to provide step by step how to develop Augmented Reality (AR) applications using Unity and Vuforia Engine. Through a series of systematic and structured steps, this research succeeded in producing an interactive and educational AR application. The research results show that developing AR applications using Unity and Vuforia Engine is an innovative step that can enrich learning methods. Apart from that, this research also reveals that the number of publications regarding AR is increasing every year, which is due to increasing interest in AR technology which is proven to be able to create more interesting and effective learning experiences. It is hoped that further research can explore the potential use

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of AR technology in various fields, not just limited to education. The choice of Unity and Vuforia Engine has also proven to make the AR application development process easier because the steps involved are not too complicated and many features can be accessed for free. Thus, it is hoped that the use of AR technology in education can continue to develop and provide greater benefits for educators and students.

5. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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