

Android mobile 3D augmented reality engineering devices design using marker-based technique

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ABSTRACT

Engineering teaching and learning utilizing using augmented reality (AR) technologies is crucial with new technology adaptation. This study has developed an Android mobile based augmented reality of engineering device (ARED) with description using marker-based technique. Unity 3D, Vuforia, and Blender Animation were used to design 3D models of engineering devices on AR platforms. ARED is used to scan a marker and display an AR 3D model of engineering devices with its information. Ten engineering devices models were created using Blender Animation Tools and exported to Unity 3D which are Ups Power, Infrared Thermometer, Cisco Router, Multi-meter, Poe Switch, Clamp Meter, Power Supply, Arduino Uno, Raspberry Pi and Oscilloscope. ARED mobile app is successfully tested which presents users can interact with the 3D model using touch input to enhance their learning experience. Result presents user's evaluation analysis at 86.2% of ARED's effectiveness and impact for future education. The technical analysis shows that ARED can handle the optimum distance range between 35 to 100 cm, operation angle is best between 45 and 135 degrees and occlusion average maximum of 55%. The significance of the research is to improve the quality and process of engineering education by using AR and promotes the learning society's transition to digital learning with mixed reality in engineering, which creates a borderless learning environment.

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1. INTRODUCTION

Technology has become an increasingly important aspect of education. The use of technology in the classroom has become more prevalent, and online learning has grown in popularity. Advancements in technology like mixed reality have the potential to revolutionize the education system that benefits teachers for tailoring instruction to meet student needs [1]. Additionally, technology can help to make education more engaging and interactive. With the use of mixed reality, students can immerse themselves in interactive environments, which can make learning more engaging and memorable. Furthermore, technology can be used to create interactive and multimedia-rich educational content which can make learning more interesting and fun for students [2]. Over the last few years, AR has seen significant advancements in terms of affordability, usability, and complete integration. AR is a relatively new technology that is increasingly gaining traction. AR is a technology that combines real-world images, videos, and other media with computer-generated

information and imagery, whether directly or indirectly, and will be able to distinguish items in the real world that have been enhanced by computer-generated sensory input such as sound, visual images, or GPS data [3]. One critical difficulty in the AR environment is how a user may handle 3D structures displayed as virtual objects, which enriches the actual world environment with 3D digital features [4]. The primary goals of AR are to analyze changes in collected camera frames and to accurately integrate virtual data into the camera image depending on tracking results. A marker-based technique provides reliable tracking utilizing visual markers in a camera scene [5]. The moment the programmer begins utilizing a gadget that supports the marker-based AR method, the image of the physical environment collected by a camera is converted into a grey-scale image to speed up the image processing method [6]. Marker-based AR requires the deployment of a marker to activate augmentation. Markers are distinct patterns that AR cameras can instantly identify and analyze. They are also visually independent of their environment. For users to be able to scan markers from their device's camera feed, it typically requires software in the form of an application.

This research presents a prototype development and analysis of Mobile 3D augmented reality on engineering devices as education tools in engineering education. Users can interact with the 3D engineering device via their android mobile using AR to obtain information about the devices. The mobile camera was used to scan the markers to project the 3D image of the engineering device and its information. The AR application was built using Unity 3D. This marker was created using Vuforia. The model would first be created using Blender Animation Tools before exporting the model to Unity 3D. The identified problems that led to this research are, the first one is identification and characteristics of engineering equipment are less provided in today's technological environment, which places obsolete learning concepts, tedious and unappealing two-way learning, and teaching, at the forefront. This bore experienced students who are well-equipped with smartphones and electronic gadgets. Besides that, an unattractive approach to education, both in and out of the classroom, including through online classes. The process of learning and teaching may be complicated and difficult to comprehend. Lastly, lack of exposure to current technological advancement leads to presentation of a traditional and boring information delivery method. This broadened the gap between new AR technology on mobile apps and society. In response to the identified problems, there are three objectives that were initiated. The first one is to design 3D animations of AR on engineering equipment to display its information and description by using Unity 3D software. Next, to develop an AR platform for the engineering equipment 3D models that will visualize the information and description of the equipment on Android mobile system for students and educators that are addictive and engaging with a high degree of interactivity [7]. Lastly, to analyze the 3D AR engineering mobile system performance based on technical parameters analysis plus user experiences feedback evaluation based on the development augmented reality of engineering device (ARED).

Mobile augmented reality (MAR) has become a reality due to the proliferation of smartphones, tablets, and wearables, affordable Internet connectivity, and advances in cooperative networking, computer vision, and mobile cloud computing [8]. MAR applications have proliferated rapidly in global mobile application markets because of the availability of free software development kits and content production tools, some of which allow non-programmers to build MAR apps [9]. Mobile devices have a wide range of sensors and can receive help from remote servers to construct more complicated MAR applications. Based on proximity sensors, visual references, maps, and precise environmental information, MAR devices can deliver a lot of real-time information. GPS and detailed mapping make navigation easier. Visual analysis and growing image collections enable object recognition. Advanced graphics show user interfaces. These qualities allow real-time merging of the actual and virtual worlds and information overlay of the user's environment for various purposes [10]. Three recent technological developments have boosted MAR research. First is the rise of dedicated MAR devices like Microsoft HoloLens, Google Glass, Magic Leap, and Epson Moverio BT-300,1 combined with powerful developer tools like ARCore and ARKit. Mobile device performance and sensor integration advancements. Third, computer vision (CV) improvements. MAR benefits entertainment, advertising, education, navigation, maintenance, and more [11].

Researchers indicated that AR has great potential and benefits in teaching and learning contexts due to its rapid growth [12]. In a three-dimensional world, we use two-dimensional media for teaching. AR with educational content makes learning fun and effective [13]. Many AR applications are related to education [14]. AR is used in many sectors like medical and engineering where AR graphics visualize three-dimensional objects. A study found that AR models engage pupils more than screen-based orthogonal and graphical graphics. Engineering graphic courses benefit from the tangible and AR approach. Another experiment created a mechanical engineering teaching application. It employs Web3D and AR scenarios to visualize 3D things to promote learning. The experiment may be educational [15]. Digital graphics is one of the fastest-changing IT fields. Characters are significant to computer graphics researchers because they convey information to viewers [16]. Unity Technologies' Unity 3D engine creates video games and simulations for computers, consoles, and mobile devices using an easy-to-use programming environment

[17]. The engine creates 3D, 2D, interactive simulations, and other experiences. Film, automobiles, architecture, engineering, construction, and education have used the engine outside of video games. It's easy for beginners but powerful for experts. Unity lets developers generate applications for PC, Mac, Web, IOS, Android, and Windows Phone without infrastructure changes. AR apps and games may be created with the Unity 3D Vuforia SDK plug-in [18]. It lets Vuforia SDK extension plug-ins detect and track under the ports, enabling AR apps and games. It has numerous game development box functions. Unity 3D can add sunshine, fog, wind, sky box, water, ambient music, and animated video to the virtual scene [19]. It is a professional game engine including images, audio, and a level development interface. Developers may create 3D video games, architectural visualization, real-time 3D animation, and mobile, desktop, online, and console apps using the Unity 3D engine [20]. Unity uses C#. Unity uses only object-oriented scripting languages. Variables, functions, and classes are the main syntax in scripting languages [21].

Android has become the world's most popular operating system for many reasons. Android Studio, Google's official IDE, is based on JetBrains' IntelliJ IDEA software and designed for Android programming. Android Studio supports Mac, Windows, and Linux [22]. Android Studio features code templates, Gradle-based build system, Github integration, and an emulator to develop Android apps [23]. APK files of Android Studio applications are uploaded to Google Play [24]. Marker-based Augmented Reality (MBAR) is a technology that combines computer vision and computer graphics techniques to create an immersive and interactive augmented reality experience. One of the earliest MBAR systems, ARToolKit, was developed in 1999 at the University of Washington and utilized a 2D marker recognition technique based on the identification of fiducial markers. ARToolKit was able to track the markers in real-time and became a popular platform for the development of augmented reality applications [25]. Since then, MBAR technology has evolved to include a variety of marker recognition and tracking techniques, including natural feature tracking, optical flow, and image recognition. Image recognition, also known as template matching, involves matching a template image of the marker to the current camera frame to determine the location and orientation of the markers [26]. In education, MBAR has been used to create interactive learning experiences, where virtual objects and simulations are overlaid onto real-world scenes to provide a more engaging and interactive learning experience [27]. MBAR offers many benefits, such as its ability to provide a more immersive and interactive experience and its potential to enhance learning and problem-solving skills, there are also challenges associated with technology.

2. RESEARCH METHOD

2.1. Marker-based vs markerless

Marker-based augmented reality (AR) is often preferred over markerless AR in certain situations due to several reasons. First, marker-based AR is simpler to implement since it does not require sophisticated computer vision algorithms. This makes it a good choice for AR applications that need to be developed quickly or on a tight budget. Second, marker-based AR can provide high accuracy in terms of placing virtual content, as the markers provide a clear reference point. This can be particularly useful in applications where precise positioning is important, such as in medical, industrial, or military contexts. In addition, marker-based AR provides a more straightforward user experience, as the markers act as a clear reference point for the virtual content. This can be helpful in situations where the user needs to quickly understand the relationship between the physical and virtual elements. Moreover, marker-based AR can be less expensive since it does not require complex computer vision algorithms, making it a good choice for budget-sensitive projects. Finally, marker-based AR systems are often more portable since they do not require a high-performance computing system or expensive sensors. Overall, marker-based AR can be a good choice for AR applications that require a simple, accurate, and budget-friendly solution with clear and straightforward user experience. It is particularly useful in applications that require high accuracy in positioning virtual content, where a clear reference point is necessary for the user, and where portability and cost-effectiveness are important considerations.

2.2. Flowchart

Figure 1 shows the system application flowchart designed for ARED. When users launch the application, they will be presented with a main menu from which there are three options to choose from. The option is standard mode, user guide and exit. The first menu option is standard mode which is MBAR mode. Users are to choose 10 image targets of the engineering devices and scan the image target to display the corresponding engineering device 3D model with its information. Users can interact with the 3D model and the information by using touch control. Next, the user guide option is a window where it shows guidelines on how to use this application. Lastly, the exit option is to quit the application.

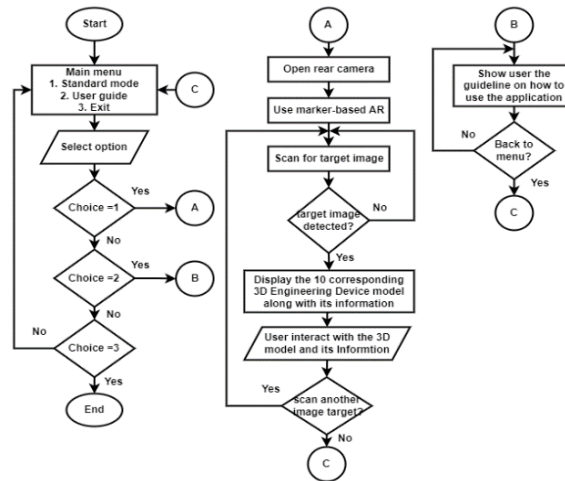
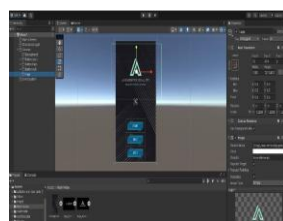


Figure 1. Application flowchart

2.3. Architecture diagram

Figure 2-4 depict the system architectural diagram, which includes input, process, and output. The input is a process of producing the ARED application, which involves all processes such as 3D model design using blender, User Interface and AR application development using Unity 3D and Image Tracker using Vuforia. Furthermore, it shows the process which is how the user can access ARED by installing the android application and scanning the targeted image. Lastly, for the output, when the corresponding marker is identified, the 3D model of the marker is superimposed on the smartphone's screen.

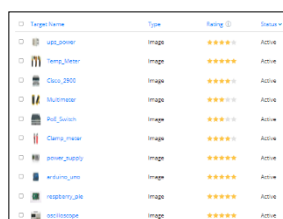
Figure 2 illustrates the process of developing an augmented reality (AR) application using Unity 3D and various supporting tools. Figure 2(a) shows the development of the application's user interface in Unity 3D, where interactive elements such as buttons, menus, and navigation tools are designed to enhance user interaction within the AR environment. Figure 2(b) presents the creation of engineering equipment 3D models using Blender Animation Tools. This step involves designing accurate and detailed representations of engineering tools or machinery to be used in the application. In Figure 2(c), the image targets are uploaded into the Vuforia Engine. These image targets serve as visual markers that, when recognized by the camera, trigger the display of corresponding 3D content. Finally, Figure 2(d) illustrates the overall development of the AR application in Unity 3D, where the user interface, 3D models, and image targets are integrated to produce a fully functional augmented reality experience.



(a)



(b)



(c)



(d)

Figure 2. Input by using Unity 3D; (a) application's user interface development, (b) design of engineering equipment 3D models using Blender animation tools, (c) upload image targets in Vuforia engine, and (d) development of the augmented reality application

Figure 3 illustrates the user interaction process with the augmented reality (AR) application on a smartphone. Figure 3(a) shows the scanning of an image target, or marker, which represents the engineering equipment. The smartphone's camera detects this marker to initiate the AR experience. Once the marker is recognized, the application overlays the corresponding 3D model onto the real-world view. Figure 3(b) depicts the AR application being installed on the smartphone. This step ensures that users have access to the necessary software to run the AR experience, enabling them to visualize and interact with the virtual engineering models through their mobile devices.



Figure 3. Process (a) scan the image target (marker) of the engineering equipment using smartphone's camera and (b) AR application being installed on smartphones



Figure 4. Output for smartphone's screen and 3D model with its information

2.4. Prototype design

Figure 5 illustrates the prototype model of the ARED apps which consists of three crucial components to ensure the application runs properly for smartphone display (A), camera (B) and image target (C). The image target was set to 10 specified engineering equipment. The target image (C) will be scanned and tracked by the camera (B) thus activating the AR software to display the 3D model on the smartphone's display (A). In addition to displaying the 3D model on the smartphone's display (A), users could interact with it and read the accompanying information. Consequently, 10 distinct image targets will yield a 3D model of each of the 10 different engineering equipment.

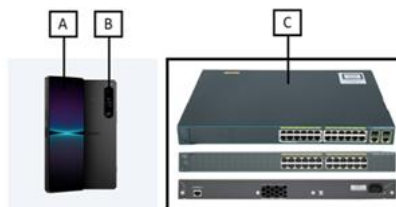


Figure 5. Prototype design

2.5. Hardware

Choosing the hardware is the initial step in determining the platform on which ARED will be deployed. Considerations for AR application hardware include the display resolution, camera megapixels, processor, and RAM. The AR device platform chosen for ARED to run is an android smartphone. The specifications of smartphones used are listed in Table 1.

Table 1. Smartphone specification

Hardware	Specification
Display resolution	1,080×2,220
Camera	16 Megapixels
Processor	Exynos 7885 Octa-core
RAM	4 GB

2.6. Software

The software used to build ARED plays a crucial part in designing AR applications. A collection of software listed in table 2 below must work together to create the AR environment system. Unity 3D Engine is used as the primary tool for creating the AR application. This engine is used in conjunction with Blender Animation Tools, which is used to generate high-quality 3D models that are essential for an immersive AR experience. Additionally, Android Studio, a widely used IDE, is used to execute the program on Android smartphones. This software enables the ARED system to be compatible with a wide range of android devices.

Table 2. Software version

Software	Version
Windows OS	Windows 10 Pro 64-bit
Unity 3D engine	Editor 2022.1.23f1
Blender animation	Blender 3.4
Vuforia engine	Vuforia Engine 10.12
Android SDK	Android 5.1 Lollipop SDK 22
Android OS	Android 9 Pie

3. RESULTS AND DISCUSSION

3.1. Mobile application design

Equations This program allowed users to view a 3D engineering device model. Using AR, users can scan an image target with their smartphone's camera to generate an AR environment with 3D models superimposed on the smartphone's screen. The 3D engineering device model reacts in real time and follows the AR marker, allowing users to rotate and scale it via touch input to view it from various angles. Furthermore, the information about each corresponding engineering device will be displayed to the user for them to learn about that specific device. The layout of the ARED mobile app's user interface is depicted in Figure 6. Figure 6(a) a screenshot of the application's main menu, Figure 6(b) a user guide on how to use the application, and Figure 6(c) marker-based image tracker instructions, are all provided in Figure 6. The user interface is the interaction between the device and the user.



Figure 6. User Interface (a) main menu interface, (b) marker tracker and (c) Interaction interface

Figure 7 depicts the output of the 'Image Tracker' marker-based AR, in which users point the camera to the marker and the system overlays the corresponding 3D model of the engineering device and its information. A total of ten image targets were developed. Figure 7(a) is Power Supply, Figure 7(b) is multi-

meter, Figure 7(c) is Poe Switch, Figure 7(d) is Ups Power, Figure 7(e) is Cisco Router, Figure 7(f) is Raspberry Pi, Figure 7(g) is Oscilloscope, Figure 7(h) is Arduino Uno, Figure 7(i) is Infrared Thermometer, and Figure 7(j) is Clamp Meter.



Figure 7. Image tracker output for: (a) power supply, (b) multi-meter, (c) Poe switch, (d) Ups power, (e) Cisco router, (f) Raspberry Pi, (g) Oscilloscope, (h) Arduino Uno, (i) infrared thermometer, and (j) clamp meter

3.2. User evaluation analysis

A total of 46 people were chosen to test the ARED application. Their responses are collected through a series of questions via Google Forms. Each participant is presented with four categories of questions to acquire opinions on various topics. The categories are the user's background, user's experience with AR and user's experience with ARED application. Likert scale analysis is used to evaluate responses to Likert-type questions, which are commonly used in surveys and questionnaires [28]. It involves the distribution of responses on a scale that ranges from strongly agree to strongly disagree, to understand the attitudes, perceptions, and opinions of a group of people and identify patterns and trends in the data. This method is used to get participant exposure to AR in general and their experience using ARED application. Figure 8 illustrates the participant's age percentage surveys for the participant's demographic. Most of the participants are between 19-30 years old with 73.9%. While the respondents with ages above 30 are 15.2% and only 10.9% of those under 18 years old.

Figure 9 shows the occupation of the participants. Most of them are students with 71.7%, while 19.6% are working, and 8.7% of respondents are retired. Survey questions were designed to ascertain the Participant's general knowledge of AR. Figure 10 illustrates Participant's replies if they ever heard of AR before. The results indicate that 93.5% of participants have heard of AR. Only 6.5% have not heard of AR. Figure 11 displays respondents' experience rate with AR on a Likert scale of 1 to 5, 1 being not familiar and 5 being very familiar. 65.2% of participants picked level 5 as they are very experienced with AR. Next, 15.2% picked level 4 and 8.7% of respondents evaluated themselves on level 3 which they know a little about AR. 4.3% ranked themselves on level 2, whereas 6.5% of respondents picked level 1 as they are not familiar with AR at all. Most of the respondents have used or experienced some type of AR before.

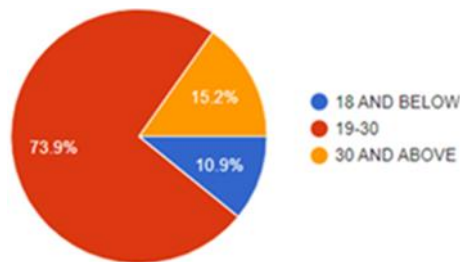


Figure 8. Age of participants

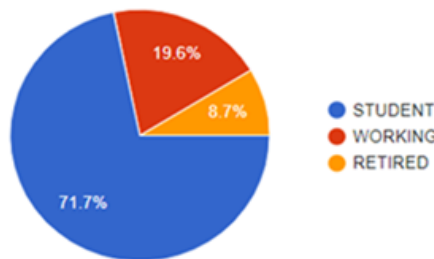


Figure 9. Occupation of participants

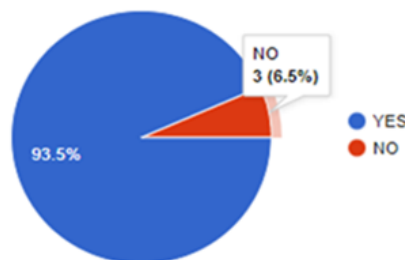


Figure 10. Knowledge on augmented reality

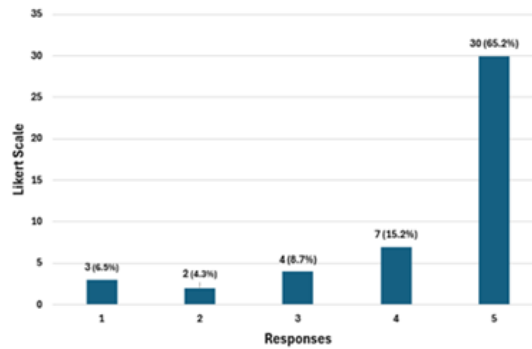


Figure 11. Experience on augmented reality

Figure 12 illustrates the analysis of participants’ responses to whether AR is important in the future. 82.6% of respondents indicated that AR would be beneficial in the future, while 17.4% expressed uncertainty. Participants agree that AR technology is important in the future. Based on the survey, the results of this study have provided valuable insights into the perceptions and experiences of young, student participants regarding AR. Most participants were found to be young, students had a high knowledge of AR, had prior experience with AR, and believed that AR is important for the future. This suggests that this demographic is well-informed and engaged with AR technology and has a strong understanding of its potential applications and benefits. Figure 13 shows the response on the easiness to handle ARED, on a scale of 1 to 5, from very difficult to very easy based on their opinion regarding their experience with ARED application. The highest vote is level 5 (very easy) with 27 votes, second is level 4 (easy) with 14 votes. Lastly, third is level 3(Intermediate) with 5 votes. It is possible to draw that ARED is easy to use.

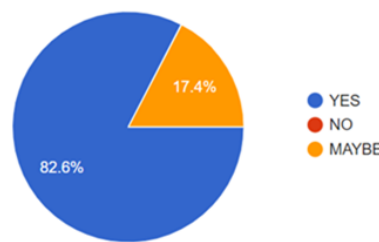


Figure 10. Knowledge on augmented reality

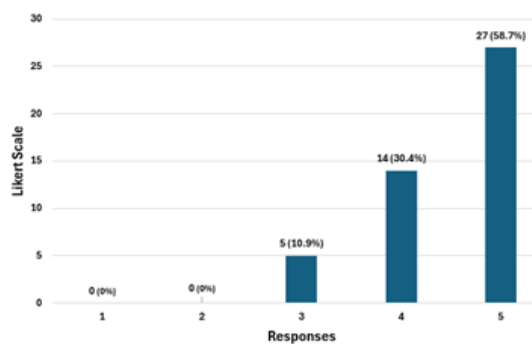


Figure 11. Experience on augmented reality

Figure 14 illustrates the participant's satisfaction with the overall design of ARED. Answers are graded on a scale of 1 to 5, from poor to excellent. Most of the respondents, 47.8% of them rate level 5 (excellent) is satisfied with the design. 37% of the respondent’s rate level 4 (good). 10.9% give a rating of level 3 (intermediate) and only 4.3% give a level 2 (bad) rating. Figure 15 illustrates the responses to the

issue of whether ARED helps the user in understanding the engineering devices. This is evaluated on a scale of 1 to 5, with 1 being the least helpful and 5 being the most helpful. Only 4.3% of participants state that ARED is ineffective which picked level 2, while 6.5% state that they are neutral with level 3. Meanwhile, 26.1% of participants agree that ARED helps them understand with level 4 and the majority 63% voted for level 5 indicating ARED are very helpful in understanding engineering devices. It can be said that ARED are useful in helping users understand engineering equipment when using it.

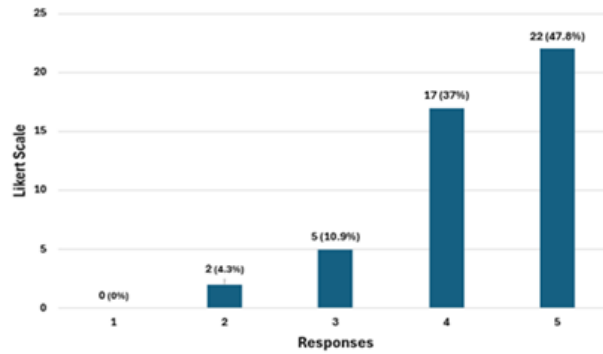


Figure 14. ARED’s design rate

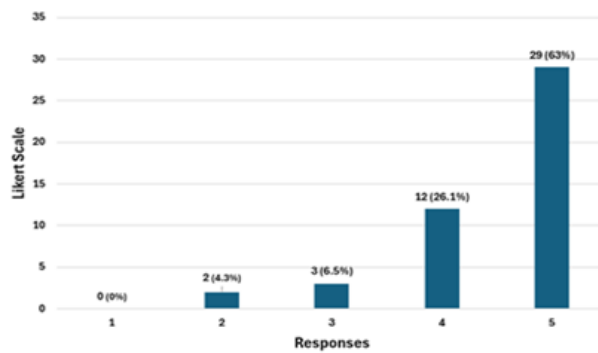


Figure 15. Help to understand engineering device survey

Figure 16 represents the participant's opinions on whether AR will be used as an educational tool in the future. 82.6% of participants favor the possibility, while the remaining 17.4% are doubtful. The majority agree that AR can be a crucial tool for future education. Figure 17 shows a comparison of participants' preferences between AR and conventional books. According to the pie chart, 84.8% of participants prefer AR over books, while the remaining 15.2% prefer books over AR. This indicates that AR attracts more interest than books according to participants.

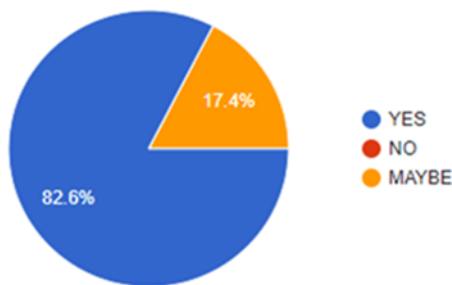


Figure 16. Future educational tools

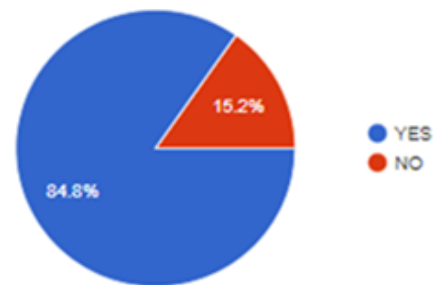


Figure 17. Prefer ARED than books

The analysis done on ARED has found one big outcome that is many people support AR will be important for education. The result is based on respondents of age 30 and below which is categorized as the future of our generation. Most of them are students, which makes it more accurate to evaluate the education system. As most of them, 93.5% have at least a basic knowledge of AR. Furthermore, many respondents 65.2% picked level 5 on the Likert scale and reported having some experience with AR, which supports the idea that AR is becoming more prevalent in society and people have access to it. In addition, 82.6% agreed on the importance of AR in education. The results of this analysis suggest that there is strong support among young people for the use of AR in education and that they see it as having the potential to improve the education system. Next, analysis of participants' experience with ARED application. 58.7% and 30.4 pick levels 5 and 4 respectively indicate ARED is easy to use which means AR application can be easily adopted and learned by a broad of people. This can also be said on ARED design likeability because levels 5 and 4 added up to 84.8% like the ARED design. The data also suggests that the ARED application was effective in helping participants understand engineering devices, with 63% picking level 5 and 26.1% picking level 4 on the Likert scale of understanding. This indicates that the ARED application was able to effectively convey complex engineering concepts and make users learn about engineering devices. Furthermore, a significant percentage of participants (82.6%) agreed that AR has the potential to be a future educational tool. This aligns with the finding that 84.8% of participants expressed a preference for the ARED AR application over books, further emphasizing the potential for AR to be a valuable educational tool. The data suggests that the ARED application is well-designed, easy to use, and effective in helping users understand engineering devices. Additionally, the data support the potential of AR as an educational tool, with a significant percentage of participants agreeing that AR has the potential to replace conventional books.

3.2. Technical analysis

The technical design analysis of the ARED augmented reality application has been conducted to evaluate the variables that determine how accurately the system operates effectively to detect an AR marker. The test was done using a 6-inch screen to display the marker. Marker distance testing is carried out by measuring the distances between the camera and the image target using measuring tape to get the optimum distance range (cm). The result is shown in Figure 18. As the graph portrayed, the optimum distance for the camera and marker is between 35 to 100 cm. Figure 19 shows the operational angles for the camera to detect the image target. It shows that different types of engineering device image targets have different minimum and maximum angle degrees. This angle applies to both the x and y-axis. The result suggests that the optimum operation angle is at best between 45 to 135 degrees.

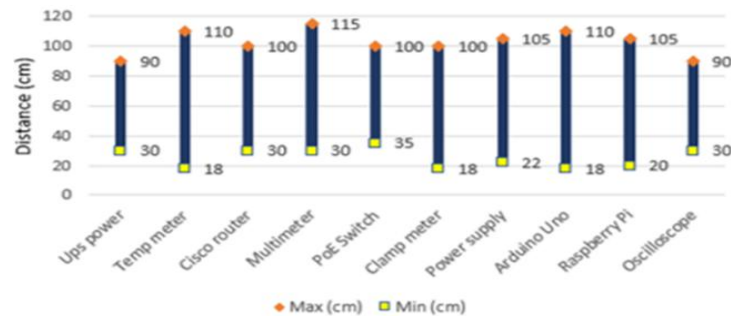


Figure 18. Optimum distance range

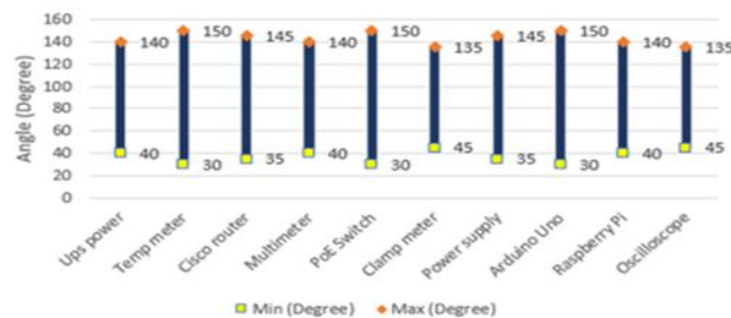


Figure 19. Operation angle

An AR marker occlusion test is used to check how well an AR system works when a marker is partly or fully covered. The test checks if the system can still track the marker and keep the virtual content aligned with the real world when it's partially or fully occluded. The occlusion covering the target image must be less than the percentage listed in table 3 below for the camera to detect the AR marker. The occlusion should be 55% or less for the AR camera to detect and can handle.

Table 3. Occlusion percentage

Image target	Occlusion (%)
Ups power	<55
Infrared Thermometer	<70
Cisco router	<60
Multimeter	<55
Poe switch	<20
Clamp meter	<60
Power supply	<65
Arduino Uno	<60
Raspberry Pi	<70
Oscilloscope	<55

Vuforia target star rating is a system that rates the quality of markers used in AR. It scores the markers based on factors like resolution, contrast, and texture. The higher the rating, the better the marker is for the AR system to track and overlay virtual content. Figure 20 shows the Vuforia star rating. The result shows the more detailed the marker is, the higher the Vuforia star rating.

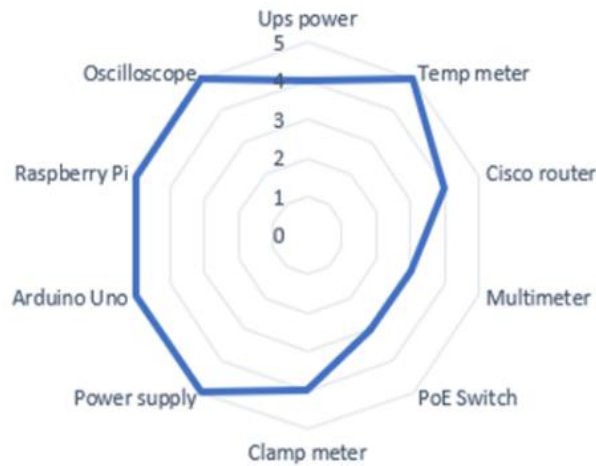


Figure 20. Vuforia star rating

The technical parameter analysis of the ARED application includes several tests to evaluate the system's performance. Marker distance testing was conducted by measuring the distances between the camera and the image target using a measuring tape. The results showed that the optimum distance range for the camera and marker was between 35 to 100 cm. Additionally, the operation angles for the camera to detect the image target were evaluated and it was found that different types of engineering device image targets have different minimum and maximum angle degrees for both the x and y-axis. The optimum operation angle was found to be between 45 to 135 degrees. An AR marker occlusion test was also conducted to check how well the AR system works when a marker is partly or fully covered. The results showed that the occlusion covering the target image must be less than 55% for the camera to detect the AR marker. Furthermore, the Vuforia Target Star Rating system was used to rate the quality of markers used in AR. The results showed that the higher the rating, the better the marker is for the AR system to track and overlay virtual content. The more detailed the marker is the higher the Vuforia star rating. The optimum star rating is 3 stars. This result was compared to a previous research and find the benchmark of the technical parameter of the marker0based augmented reality are all in the same range [29].

4. CONCLUSION

As a conclusion, a successfully design of ARED application which analyzed the future learning concept has been analyzed. ARED is expected to be significantly more important and widely used in future education. According to the survey on ARED, the majority said it helps them in understanding engineering devices. They also agree that AR should be the future educational tool. This is because the ease-of-use ARED present attracts the towards AR more than conventional books. ARED has been successfully developed by using Unity 3D software, Vuforia Engine and Blender Animation Tools. The immersive and interactive nature of AR can increase student engagement and motivation, making learning more enjoyable. Additionally, AR can provide students with hands-on learning experiences that would otherwise be difficult or impossible to replicate in a traditional classroom setting. As technology continues to advance and the cost of AR equipment decreases, it is likely that more and more educational institutions adopt AR as a teaching tool. Finally, AR could support personalized learning by allowing students to interact with virtual tutors and learn at their own pace. Further research and development are needed to improve the system's performance and address any remaining technical challenges. One suggestion for future work on marker-based AR could be to improve the accuracy and reliability of the tracking method. This could involve developing new algorithms or techniques for identifying and analyzing markers in real time and testing them in various environments and with different types of markers. Additionally, research could be done on how to make the marker-based AR experience more seamless and natural for users, such as by incorporating intuitive gestures or voice commands for interacting with digital information. Another suggestion could be to research the integration of machine learning and artificial intelligence in marker-based AR. This could enable the system to learn from users' interactions and preferences and provide more personalized and relevant information.

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C : **C**onceptualization

M : **M**ethodology

So : **S**oftware

Va : **V**alidation

Fo : **F**ormal analysis

I : **I**nterpretation

R : **R**esources

D : **D**ata Curation

O : **O**riginal Draft

E : **E**diting

Vi : **V**isualization

Su : **S**upervision

P : **P**roject administration

Fu : **F**unding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state there is no conflict of interest.

DATA AVAILABILITY

Data is available upon request with approval.




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