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FunAR-furniture augmented reality application to support practical laboratory experiments in interior design education

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ABSTRACT

Practical learning in the laboratory has been limited due to the COVID-19 pandemic. Conventional education must adapt to increasingly digital technological developments. The design of interactive learning media with augmented reality technology can be a solution and support the previous conventional learning. FunAR is a Furniture Augmented Reality Application developed using the analysis, design, development, implementation, and evaluation (ADDIE) method consisting of ADDIE. In its implementation, the FunAR application will provide basic information about existing equipment in Lab Furniture, accompanied by 2D images, and augmented reality technology that creates 3D objects from each piece of equipment in Lab Furniture. From 15 student respondents, the results reveal that distance, angle, and device specifications significantly impact camera marker reading. A distance of 20 cm to 80 cm and an angle of 25° to 100° can display 3D objects. Likewise, the camera's ability to process reading markers is better on smartphones with better hardware specifications. The results of the respondents showed that 80% of respondents were satisfied with the FunAR application.

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1. INTRODUCTION

Because of the considerable advancements in communication and information technology in recent years, the present generation of university students is reasonably familiar with multimedia technologies. Technologies have become integral parts of their lives, drastically altering how children learn new things [1]. Although obsolete teaching approaches and paradigms continue to be used and seem to be effective, most colleges are eager to adapt. They are already reaping the benefits of utilizing newly accessible multimedia technology to improve education techniques with the purpose of fostering deep learning and simplifying complicated subjects. This is backed by both practitioners and scholars who believe that combining digital learning tools with more conventional teaching methods may improve outcomes [2], [3]. According to cognitive theory of multimedia learning (CTML), the brain does not see a multimedia presentation of words, visuals, and auditory information as incompatible; rather, these components are dynamically selected and organized to generate cohesive mental creations [4], [5]. This suggests that humans make use of two distinct channels of processing information during learning, and that both channels undergo changes during active processing. Since we can assess more information when we use two channels instead of one, we propose that you do so whenever possible when representing multi-media. Because of this, the modality principles [6] imply that instructional resources that include multiple representation modes, such as graphics and text, or multiple sensory modes, may be employed successfully to improve the learning process. One possible development is expanding this concept to the digital realm as well.

There are several research on the application of augmented reality in educational settings in the literature [7]–[10]. However, only a few of them concentrate on special education [11]. Individuals with cognitive difficulties and communication, behavioral, or developmental issues need specialized and tailored teaching to gain either learning or functional skills [12]. Augmented reality (AR) technology assists kids with special educational needs to lessen behavioral issues, improve independence, and learn necessary skills for community integration [13]–[16]. Indeed, children with special educational needs benefit significantly from the usage of augmented reality since it offers them with real-life experiences [16]. On the other hand, it has been seen that students' preparedness, interest, motivation, academic results, and self-confidence improve as a result of augmented reality [17]–[19], as does their engagement with peers [20]. In light of the above, augmented reality plays an essential role in the learning of children with special educational needs by boosting skill and knowledge acquisition via an interactive environment adapted to their specific qualities. As a result, researching the adoption of AR in special education is critical for improving learning in these settings.

The AR synchronizes digital and real-world material that links the virtual and real worlds and may replace memory-based learning with fun driven learning, enabling more conceptual and meaningful learning. Web 2.0 technologies have been blended into learning and teaching to make classes more interactive with sharing content and idea. The AR and 3D virtual worlds (3DVWs) create an immersive environment by allowing pupils to see items from numerous angles concurrently [11]. Newer technology bring benefits and drawbacks. Due to a lack of expertise, teachers are typically hesitant to use new technologies, which fosters bad teaching practices. The AR's key value is learning-by-doing, which outweighs its downsides. AR is extensively employed in various industries, including medical [21], lab orientation [19], tourism [22], education [23], and training [24]. It's increasingly utilized in Science, Technology, Engineering and Mathematics (STEM) [25]. Several studies claim that AR improves learning performance, collaboration, student engagement, motivation, and interaction, contextual learning environments, and creativity [26]. AR encourages student involvement, which improves teaching and learning [27]. It lets pupils take responsibility of their learning, saving the instructor time wasted repeating explanations. In education of engineering, visual and physical representations models are essential. Without these, students must depend on imagination to comprehend complex topics.

This research addresses this gap by addressing the development of smartphone-based augmented reality apps as a supplement to traditional learning in interior design study programs [28]. This FunAR application can enhance students learning experience and increase their understanding of the many and complex equipment in the lab workshop by creating an active learning experience in the laboratory and providing students with independent learning tools outside of class hours. FunAR contains digital content of information, images, and 3D models that allow students to interact with applications and learning materials in books.

2. RELATED WORK

In many studies have indicated that augmented reality technologies improve student motivation throughout the learning process [29]. Engineering uses AR extensively. Context-aware mobile AR tool (CAM-ART) was created to educate building design, construction assembly projects, and civil engineering construction aspects [30]. AR applications allow engineers to compare as-built and as-planned project statuses. Recent research show AR is effective for teaching electrical and computer engineering. The usage of AR apps was employed to bridge the gap between theoretical explanations and experimental techniques. Physical object motions and learning were combined with a pedagogical virtual machine (PVM) [31]. The PVM gathered and processed data supplied to the embedded computer. Data were transformed into learning activities based on a specified design. The student may see the learning activity's process, monitor their progress, and get rapid feedback. AR-based applications for mobile robot assembly and exploration are in use [32]. The AR applications improved lab equipment interaction, conceptual comprehension, and learner engagement [33]. Vision-based control, AR, and touchscreen interface were used. When pointed at a lab testbed, the phone added graphics to live footage. It let students operate testbeds and do experiments. The gadgets measured, estimated, and controlled lab testbeds, unlike normal graphical interfaces.

One of the reasons for doing this study was the realization that students' penchant for their mobile devices may be put to productive use. Preventing students from being sidetracked by their personal use of mobile devices in the classroom can be done by encouraging their productive use in the classroom, for example, to increase student participation and foster an interactive setting conducive to deep learning [34]. Because of its ability to let pupils see and manipulate interactive models, AR is a useful tool for educators. As a result, we decided to employ AR apps on mobile devices as a means of better conveying introductory concepts in digital system design. Mobile technology may be used positively to improve student engagement and create an interactive learning environment [34]. The AR is an amazing teaching tool because it allows students to see and manipulate interactive models in a creative, engaging way [35]. This prompted us to adopt mobile AR to improve digital system design instructions. We turned teacher-focused finite-state machine (FSM) lessons into student-focused mobilized lessons, as indicated. This helped pupils obtain visual and conceptual knowledge and understand how they interact with classroom technology. Students may easily comprehend ideas in computational settings with intuitive interfaces and high engagement.

3. RESEARCH METHOD

This section discusses the stages of developing the proposed AR-based learning approach in detail. This study uses the ADDIE methodology to develop the FunAR application until it is evaluated. This approach is preferred by scientists since it allows for the incremental development of interactive applications. The ADDIE methodology has five phases: analysis, design, development, implementation, and evaluation [36]. Figure 1 shows the ADDIE model, which consists of the analysis, design, development, implementation, and evaluation phases.

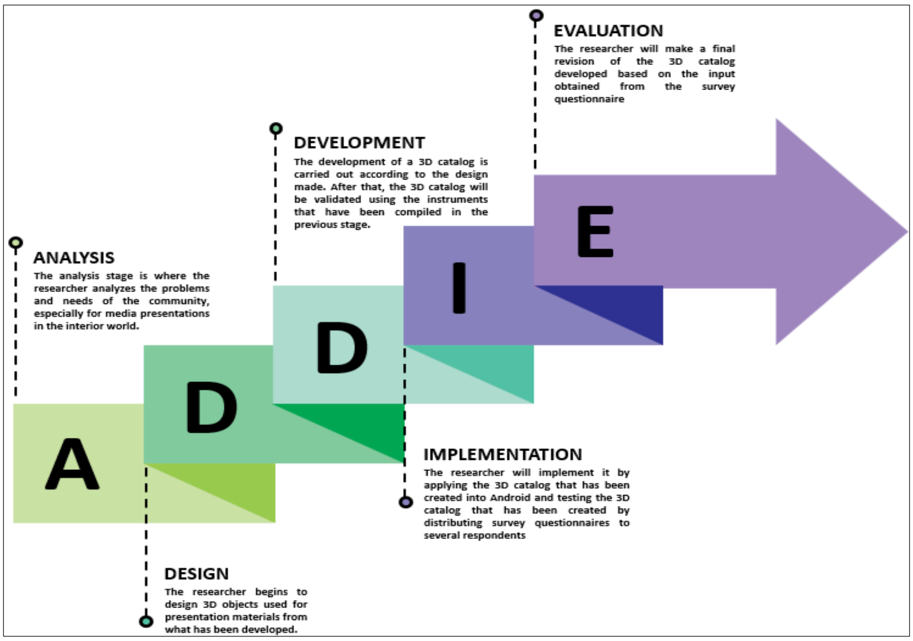


Figure 1. ADDIE method for FunAR app development

3.1. Analysis

At the analysis stage, a literature study is carried out to find the publications of previous studies that still have research relevance and what things can still be developed into this application. Research also aims to identify the objectives, intent, audience, content, and learning strategies. After the analysis is done, the next step is to determine the purpose of developing this application, namely to develop a new way of learning the introduction of workshop equipment in the Lab by using augmented reality multi markers in catalogs or books. This application will include information about workshop equipment, 3D models of equipment, and audio to attract users' interest. Multi marker technique is used to display 3D models based on each piece of equipment according to each marker.

3.2. Design

After completing the analysis stage, and data or information regarding the required content has been collected, the next step for application development is to design an interface design and application environment that is focused and adapted to the needs of university students and the existing course outline. The interface design of this application is made as attractive and interactive as possible. Font and button sizes should be easy to read and easy for users to understand. The selection of buttons and background colors adjusts the criteria of augmented reality material content and lab workshop, the design must be user-friendly. Images of equipment used in the application are based on items in the lab workshop, such as palm routers, planers, table saws, scroll saws, wood lathes, and 3D printers. For 3D models, use various assets that already exist on several websites that provide 3D assets according to images or photos of equipment that will be implemented in this augmented reality application. Information about each piece of equipment is taken from some information on the website or e-commerce.

3.3. Development

After the design stage is complete and the content has been collected, the next step is the development of application products by importing the required content into the unity software. This relies on information from earlier sketches or mockups in the design process. The developer team must complete a prototype to ensure the augmented reality application product works in the required time. Unity software will be used to develop applications based on content and mockups at the design stage. The Vuforia SDK is used as a marker database to be used as a reader of augmented reality cameras. Vuforia is an AR SDK that can track images of targets, objects, and ground surfaces using computer vision techniques. As such, it is imperative that any remaining issues be fixed before the prototype can be used by the customer.

3.4. Implementation

After the development stage is complete and the application prototype has been created, then we do a trial with the implementation of the marker that has been prepared. The implementation stage is carried out locally and tests various existing features to determine whether there are still errors. The implementation is carried out on a small scale with various trials, from the effect of the camera's distance with the marker until differences in smartphone devices with different specifications.

3.5. Evaluation

The results of the implementation stages produce test data that can be evaluated. The trial was carried out on a small scale by several students of the interior design study program. Respondents were selected based on lab workshop users. So, it can be measured how well the benefits of this FunAR augmented reality application as an interactive learning medium rather than traditional learning. Designing and creating something Our primary goal when designing the infrastructure for this AR classroom platform was to ensure that it was both accessible and engaging for students. The development phase involves different steps, such as asset collection or 3D object modeling, database creation on Vuforia, and GUI elements. Figure 2 shows the application development process until it is exported into an android or iOS application.

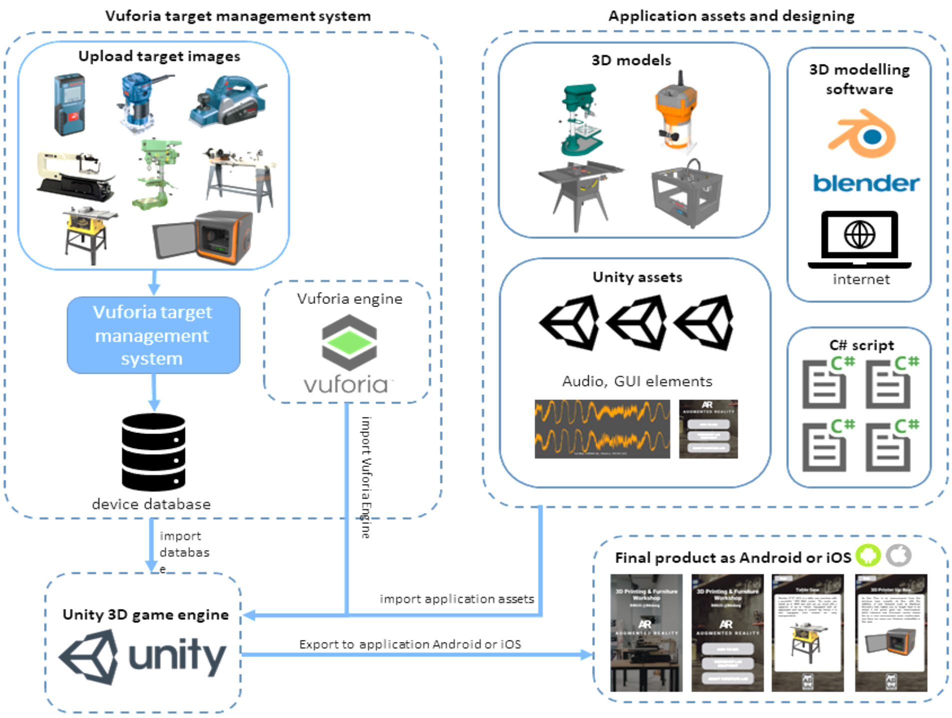


Figure 2. Application design and development FunAR has a target database management system

In the Vuforia target management system section, each model's target image or marker is collected and uploaded via the Vuforia website to become a database before being imported into the unity software. The Vuforia target management system (VTMS) detects the feature points in these image targets and uses them to identify these target pictures in the actual world. Each submitted marker will be rated for each target picture based on its feature point and quality. These target pictures are accessible through cloud-based databases as well as on-premises devices. Using the Vuforia development portal, we imported a database of device-based targets into the unity 3D environment. To design 3D model assets, we use 3D design software, such as blenders, and other free internet resources. All AR app design and development content is integrated into unity 3D.

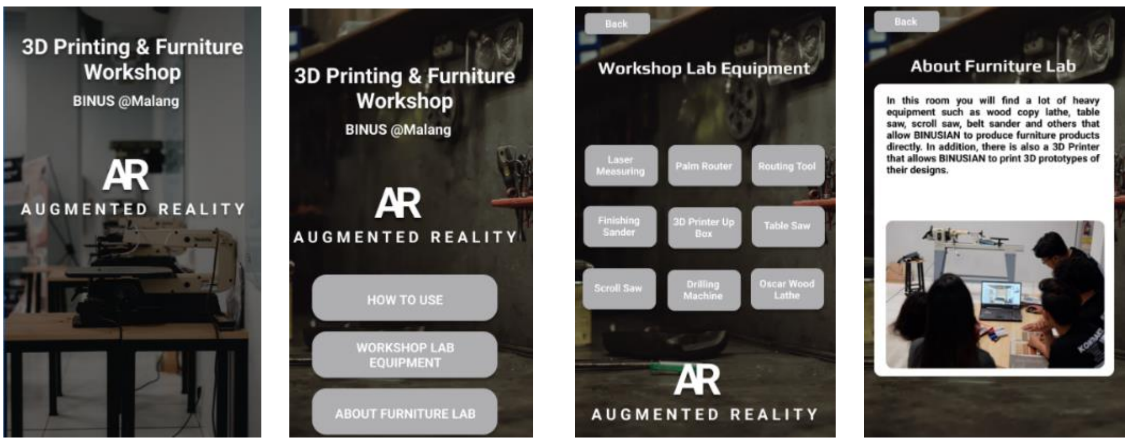
4. RESULTS AND DISCUSSION

This section, we will discuss the development of the FunAR augmented reality application in detail, along with images and graphics, to the evaluation stage of the prototype trial. FunAR application as an interactive learning media to help students better understand lab workshop equipment than traditional learning before. The following discussion is based on the ADDIE method that researchers use. The stages of analysis have been explained in the method chapter, and then the design and development stages will be discussed in this sub-chapter. At this stage, the researcher will describe the process and design of the designed application display. Furthermore, several tests and measurements of the application being developed are carried out in the Implementation and Evaluation stage. The detailed discussion is described as:

4.1. Design and development the apps

Based on the literature study obtained, it is necessary to design an application mockup with various supporting content, such as button colors, words, and phrases that are easy to read, to application backgrounds that adjust the content from the lab workshop. To design a mockup of the FunAR application, researchers used the Figma tool, which can be accessed via the website or installation software. By making a mockup design first, researchers can visualize the application's appearance from each page, in Figure 3. The application visualization mockup is shown in the Figure 3(a) main page display, Figure 3(b) main menu display, Figure 3(c) workshop lab equipment menu display, and Figure 3(d) information about furniture lab display, the researcher includes three buttons, namely "how to use" about how this application is used for interactive learning media, the "workshop lab equipment" button about what equipment is learned to understand the equipment in the lab workshop better, the "about furniture lab" button is a page display that contains information about the lab workshop. On Figure 3(c), "workshop lab equipment" page display, there are various buttons that will move the display to a page for each piece of equipment and its information.

Figure 4, is a display of the FunAR application showing photos of some of the tools in the workshop along with an explanation of each. In this section, the researcher only displays 4 of the tools in the application. In Figure 4(a) routing tool, Figure 4(b) bench drilling machines, Figure 4(c) table saw, Figure 4(d) 3D printer up box, the names of the equipment that we use as content in this interactive learning media are: Laser measuring, palm router, routing tool, finishing sander, 3D printer up box, table saw, scroll saw, drilling machine, and oscar wood lathe. The image below shows some page visualizations of each piece of equipment and its information. The AR button can be pressed and call up the camera and augmented reality functions.



(a) (b) (c) (d)

Figure 3. Visualization the FunAR application on (a) main page display, (b) main menu display, (c) workshop lab equipment menu display, and (d) information about furniture lab display

(a) (b) (c) (d)

Figure 4. Visualization of the lab workshop in (a) routing tool, (b) bench drilling machines, (c) table saw, and (d) 3D printer up box and its information

4.2. Testing and implementation results

The trial respondents in this study were students of interior design study program in one class with an age range of 19 to 20 years, totaling 15 individuals, with the division of 4 female students and 11 male students, like in Figure 5. These students were selected to learn about the user experience of the FunAR application introduced through augmented reality technology. The researcher chose student respondents in one class to conduct a trial in the scope of education on a small scale. The number of respondents can certainly be more, tens, hundreds, or even thousands in a wider scope.

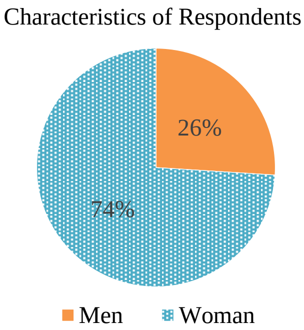
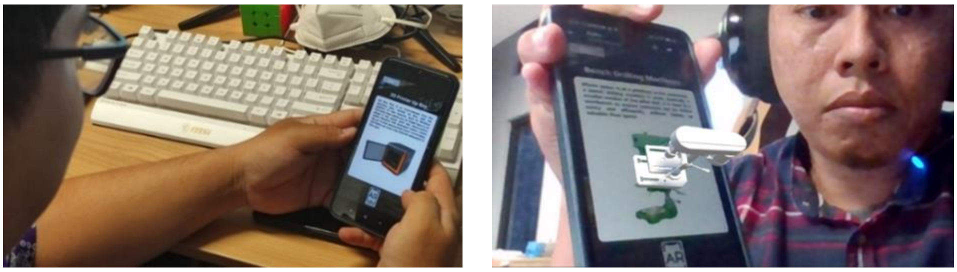


Figure 5. Comparison diagram of the number of respondents between male and female students

In Figure 6, researcher testing the FunAR application as an interactive learning medium using augmented reality technology aims to find out whether there are still errors in the application used, whether all buttons can function normally, whether the information that appears can be read clearly, whether the application is following the learning materials needed by students. Figure 6(a) shows a photo of an interior design study student trying the FunAR application, and 3D equipment models can appear with augmented reality technology features in Figure 6(b).

Testing the application prototype that has been made is very important to do, the aim is to find out the functionality of each feature of the application that has been made and visualizes the interactive display so that it can be a learning medium in supporting traditional education. Several other trials, such as camera angles with markers, camera distance tests with markers, testing the speed of the 3D model emergence process, and testing with devices with different hardware specifications, were carried out.



(a) (b)

Figure 6. Testing the FunAR application and displaying 3D object models from augmented reality in (a) student trying the FunAR application and (b) 3D equipment model

4.2.1. Distance testing and angel

Testing the distance between the camera and the marker is carried out to determine how effectively a smartphone camera can read the closest and farthest distance markers and display a 3D model object. In Table 1, the test is measured in (cm), starting with the closest distance of 20 cm, then increasing to 40 cm, 60 cm, 80 cm, and up to 100 cm. At a distance of 20 cm, the marker can be read well by the smartphone camera and brings up 3D objects. Likewise, with the increase in distance to 40 cm, 60 cm, and 80 cm, the marker can still be read by the smartphone camera to bring up 3D objects. However, the marker could not be recognized at a distance of 100 cm since insufficient data existed to correctly identify the marker's design. When measuring distances, of course, the measurement time for the appearance of 3D objects is also carried out in milliseconds (ms). In Table 1, variations in distance measurements also produce time variations measured in ms.

In Table 2, the test is carried out using the angle between the camera and the cross-section of the marker. The angle variations taken are from 0°, 25°, 50°, 75°, to 100°. In testing from angles of 25°, 50°, 75°, and 100°, the camera can read the information contained in the marker and process it so that 3D objects appear. However, at an angle of 0°, the camera cannot read information from the marker so that 3D objects do not appear on the smartphone layer.

Table 1. Results of marker distance test

Distance (cm)	Time (ms)	Result
20	00.21	Detected
40	00.35	Detected
60	00.47	Detected
80	01.03	Detected
100	-	Not detected

Table 2. Results test of the angel camera and marker

Angle	Result
0°	Not detected
25°	Detected
50°	Detected
75°	Detected
100°	Detected

4.2.2. Tracking speed testing

The tracking speed test is based on data from Table 1, distance, and time data. The data processing is shown in Table 3, where distance is converted from (cm) to (m), and the time from ms to seconds (s). The purpose of converting the units of the data is to simplify and adjust to the (1).

$$V = \frac{s}{t} \tag{1}$$

Information: *V*=speed (m/s), *s*=distance traveled (m), *t*=travel time (s).

The information in Figure 7 comes from Table 3, after it has been processed using the tracking speed result. Speed measurement uses (1), as the researcher bolted above. Measurements are made based on the distance between the smartphone camera and the time the 3D object appears. The distance that the researchers measured started from 0.2 m, 0.4 m, 0.6 m, 0.8 m, and 2 m, with an average measurement of 0.5 m.

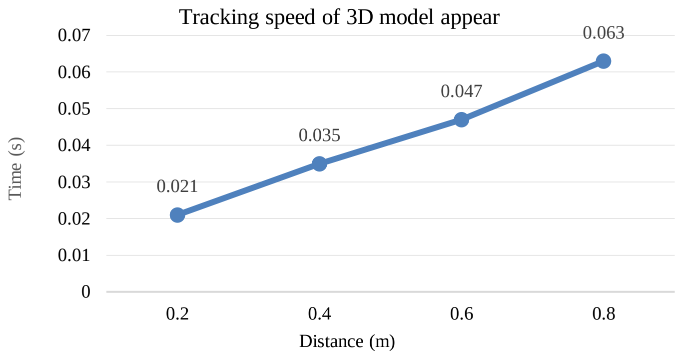


Figure 7. Tracking speed chart of 3D model appear

Table 3. The results of the table tracking speed

No.	s	T	V
1	0.2 m	0.021 s	9.52 m/s
2	0.4 m	0.035 s	11.43 m/s
3	0.6 m	0.047 s	12.76 m/s
4	0.8 m	0.063 s	12.69 m/s
Amount	2 m	0.166 s	46.4 m/s
Average	0.5 m	0.041 s	11.6 m/s

4.2.3. Comparison of two devices

Testing is also carried out using two devices with significantly different hardware specifications but the same android OS. The two smartphone devices are android Xiaomi Redmi Note 8 with 4 GB RAM and POCO X3 RAM 8 GB. The hardware differences between these two smartphones are firstly on the camera, Xiaomi Redmi Note 8 has a 48 MP camera, POCO X3 has a 64 MP camera. After testing, it can be seen in Table 4 that the difference between the two hardware devices does not seem to have much impact on the measurements made. However, on closer inspection, android OS with higher RAM and a better camera shows faster processing times like in the chart tracking time Figure 8.

Table 4. Results of comparison two device

Lab equipment marker	Time required for device camera scanning (seconds)	
	Xiaomi Redmi Note 8 4GB RAM	POCO X3 8GB RAM
Laser measuring	00.23	00.15
Palm router	00.21	00.17
Routing tool	00.25	00.19
Finishing sander	00.24	00.18
3D Printer UP BOX	00.21	00.17
Table saw	00.22	00.15
Scroll saw	00.25	00.19
Drilling machine	00.23	00.16
Oscar wood lathe	00.23	00.15

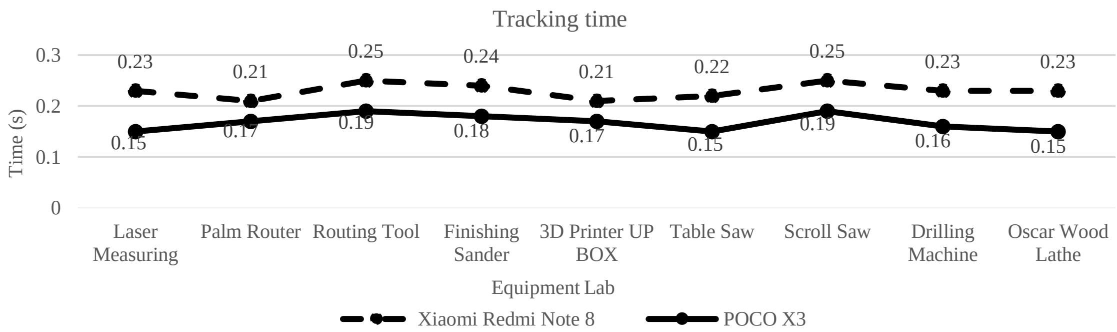


Figure 8. Chart of tracking time with two device comparison

4.2.4. Evaluation

After the FunAR application trial has been carried out, further evaluation needs to be conducted to determine the respondent's assessment. The evaluation was carried out by distributing questionnaires to respondents who tried this AR application to assess whether the FunAR application could be an interactive learning medium supporting previous traditional learning. The respondents who filled out this questionnaire were the same 15 students who had tested this application. The questionnaire contains several questions to assess the application like in Table 5. The results of the questionnaire can be seen in Figure 9. From the data, the respondents easily use the menu or features of the FunAR application with a percentage of 80%, namely, 12 people and 3 people are still confused. The information in the application significantly from the results of the respondents has shown that 74% or 11 students are easy to understand. However, there are still 4 students who find it difficult to understand the information content of this application. From these data, respondents are satisfied with the application that we made with percentage of 80%, namely 12 people, and 3 people are dissatisfied.

Table 5. Survey content of experiment

Question	Content
Q1	Is this application easy to use for those of you who are using it for the first time?
Q2	Does the information from this application already fulfill for learning media?
Q3	In your opinion, are you satisfied using this application as a learning medium?

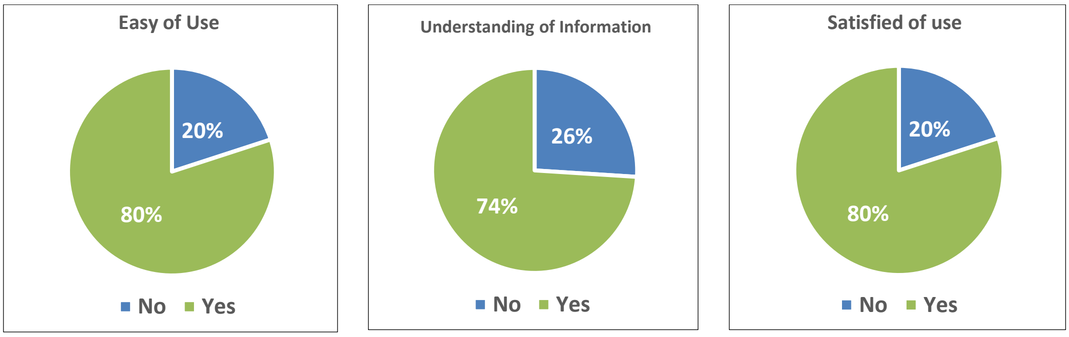


Figure 9. Chart from survey content of experiment

5. CONCLUSION

Rapid technological developments, such as in education, can help to learn activities previously conventionally used to use interactive learning media using AR technology. The FunAR augmented reality application aims as an interactive learning medium to support previous conventional learning. The FunAR application introduces the equipment in the lab workshop fundamentally with various information and interactive 3D models of each equipment. Various trials were conducted, such as testing the distance between the camera and the marker, the camera angle with the marker, and using two devices with different specifications. The results show that in the trial distance above 100 cm, the camera cannot read the information contained in the marker, so it does not display 3D objects. 3D objects appear in the test distance between 20 cm to 80 cm. In the angle test, 3D objects will appear at angle measurements of 25° to 100°, but the process is limited to 0° angle measurements. In the trial of the two devices, the difference in the test results was not too significant. However, it can be seen that android devices that have more RAM, up to 8 GB, show a better process in terms of time measurement. The evaluation results from 12 respondents showed that the majority agreed that the FunAR application was easy to use 80%, and 74% of the information in the FunAR application was easy to understand. It is hoped that this interactive learning media can help increase student interest in interior design study programs. From the various test results, in further research, applications can be developed better, adding animations, and adding other information features.

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REFERENCES

[1] S. H. Tanalol, D. N. M. Nizam, Z. H. A. Sani, A. Baharum, A. Tahir, and I. A. Zolkifly, "Jawi using multi-maker augmented reality," *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 10, no. 5, pp. 2892–2898, Oct. 2021, doi: 10.11591/eei.v10i5.2464.

[2] D. A. Sprenger and A. Schwaninger, "Technology acceptance of four digital learning technologies (classroom response system, classroom chat, e-lectures, and mobile virtual reality) after three months' usage," *International Journal of Educational Technology in Higher Education*, vol. 18, no. 1, p. 8, Dec. 2021, doi: 10.1186/s41239-021-00243-4.

[3] S. S. Panwhar *et al.*, "E-learning: teachers perspective towards modern tools of teaching," *Pakistan Journal of Medical and Health Sciences*, vol. 12, no. 3, pp. 938–941, 2018.

[4] N. Refat, M. A. Rahman, A. T. Asyhari, I. F. Kurniawan, M. Z. A. Bhuiyan, and H. Kassim, "Interactive learning experience-driven smart communications networks for cognitive load management in grammar learning context," *IEEE Access*, vol. 7, pp. 64545–64557, 2019, doi: 10.1109/ACCESS.2019.2915174.

[5] G. Groshans, E. Mikhailova, C. Post, M. Schlautman, P. Carbajales-Dale, and K. Payne, "Digital story map learning for STEM disciplines," *Education Sciences*, vol. 9, no. 2, p. 75, Apr. 2019, doi: 10.3390/educsci9020075.

[6] R. Low and J. Sweller, "The modality principle in multimedia learning," in *The Cambridge Handbook of Multimedia Learning, Second Edition*, 2nd ed., Cambridge University Press, 2014, pp. 227–246.

[7] D. Sahin and R. M. Yilmaz, "The effect of augmented reality technology on middle school students' achievements and attitudes towards science education," *Computers and Education*, vol. 144, p. 103710, Jan. 2020, doi: 10.1016/j.compedu.2019.103710.

[8] M. Sirakaya and D. A. Sirakaya, "Trends in educational augmented reality studies: a systematic review," *Malaysian Online Journal of Educational Technology*, vol. 6, no. 2, pp. 60–74, 2018, doi: 10.17220/mojet.2018.02.005.

[9] J. Bacca, S. Baldiris, R. Fabregat, S. Graf, and Kinshuk, "Augmented reality trends in education: a systematic review of research and applications," *Educational Technology and Society*, vol. 17, no. 4, pp. 133–149, 2014.

[10] H. Köse and N. Güner-Yildiz, "Augmented reality (AR) as a learning material in special needs education," *Education and Information Technologies*, vol. 26, no. 2, pp. 1921–1936, Mar. 2021, doi: 10.1007/s10639-020-10326-w.

[11] M.-B. Ibáñez and C. Delgado-Kloos, "Augmented reality for STEM learning: a systematic review," *Computers & Education*, vol. 123, pp. 109–123, Aug. 2018, doi: 10.1016/j.compedu.2018.05.002.

[12] K. S. Tang, D. L. Cheng, E. Mi, and P. B. Greenberg, "Augmented reality in medical education: a systematic review.," *Canadian medical education journal*, vol. 11, no. 1, pp. e81–e96, Mar. 2020, doi: 10.36834/cmej.61705.

[13] N. Tuli, A. Mantri, and S. Sharma, "Impact of augmented reality tabletop learning environment on learning and motivation of kindergarten kids," in *AIP Conference Proceedings*, 2022, vol. 2357, p. 040017, doi: 10.1063/5.0080600.

[14] M. Seel, M. Andorfer, M. Heller, and A. Jakl, "KARLI: Kid-friendly augmented reality for primacracy school health education," in *Proceedings - 2022 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops, VRW 2022*, 2022, pp. 610–611, doi: 10.1109/VRW55335.2022.00156.

[15] P. Reisinho, C. Silva, M. Vairinhos, A. P. Oliveira, and N. Zagalo, "Tangible interfaces and augmented reality in a nutrition serious game for kids," in *SeGAH 2021 - 2021 IEEE 9th International Conference on Serious Games and Applications for Health*, Aug. 2021, pp. 1–8, doi: 10.1109/SEGAH52098.2021.9551852.

[16] C. L. Toledo-Peral *et al.*, "Virtual/augmented reality for rehabilitation applications using electromyography as control/biofeedback: Systematic literature review," *Electronics (Switzerland)*, vol. 11, no. 14, p. 2271, Jul. 2022, doi: 10.3390/electronics11142271.

[17] J. D. Udayan, G. Kataria, R. Yadav, and S. Kothari, "Augmented reality in brand building and marketing – valves industry," in *2020 International Conference on Emerging Trends in Information Technology and Engineering (ic-ETITE)*, 2020, pp. 1–6, doi: 10.1109/ic-ETITE47903.2020.425.

[18] C. Z. Y. Yin, T. Jung, M. C. T. Dieck, and M. Y. Lee, "Mobile augmented reality heritage applications: Meeting the needs of heritage tourists," *Sustainability (Switzerland)*, vol. 13, no. 5, pp. 1–18, Feb. 2021, doi: 10.3390/su13052523.

[19] M. Nadeem, A. Chandra, A. Livirya, and S. Beryozkina, "AR-LaBOR: design and assessment of an augmented reality application for lab orientation," *Education Sciences*, vol. 10, no. 11, pp. 1–30, Nov. 2020, doi: 10.3390/educsci10110316.

[20] Z. Wang *et al.*, "A comprehensive review of augmented reality-based instruction in manual assembly, training and repair," *Robotics and Computer-Integrated Manufacturing*, vol. 78, p. 102407, Dec. 2022, doi: 10.1016/j.rcim.2022.102407.

[21] C. Rodríguez-Abad, R. Rodríguez-González, A. E. Martínez-Santos, and J. del C. Fernández-de-la-Iglesia, "Effectiveness of augmented reality in learning about leg ulcer care: A quasi-experimental study in nursing students," *Nurse Education Today*, vol. 119, p. 105565, Dec. 2022, doi: 10.1016/j.nedt.2022.105565.

[22] I. Paliokas *et al.*, "A gamified augmented reality application for digital heritage and tourism," *Applied Sciences (Switzerland)*, vol. 10, no. 21, pp. 1–18, Nov. 2020, doi: 10.3390/app10217868.

[23] J. Quintero, S. Baldiris, R. Rubira, J. Cerón, and G. Velez, "Augmented reality in educational inclusion. A systematic review on the last decade," *Frontiers in Psychology*, vol. 10, no. AUG, Aug. 2019, doi: 10.3389/fpsyg.2019.01835.

[24] J. M. Sáez-López, R. Cózar-Gutiérrez, J. A. González-Calero, and C. J. G. Carrasco, "Augmented reality in higher education: An evaluation program in initial teacher training," *Education Sciences*, vol. 10, no. 2, p. 26, Jan. 2020, doi: 10.3390/educsci10020026.

[25] M. C. Costa, J. M. Patricio, J. A. Carranca, and B. Farropo, "Augmented reality technologies to promote STEM learning," in *Iberian Conference on Information Systems and Technologies, CISTI*, Jun. 2018, vol. 2018-June, pp. 1–4, doi: 10.23919/CISTI.2018.8399267.

[26] J. Garzón, "An overview of twenty-five years of augmented reality in education," *Multimodal Technologies and Interaction*, vol. 5, no. 7, p. 37, Jul. 2021, doi: 10.3390/mti5070037.

[27] R. Lam and K. Muldner, "Manipulating cognitive engagement in preparation-to-collaborate tasks and the effects on learning," *Learning and Instruction*, vol. 52, pp. 90–101, Dec. 2017, doi: 10.1016/j.learninstruc.2017.05.002.

[28] A. A. Shari, S. Ibrahim, I. M. Sofi, M. R. M. Noordin, A. S. Shari, and M. F. B. M. Fadzil, "The usability of mobile application for interior design via augmented reality," in *2021 6th IEEE International Conference on Recent Advances and Innovations in Engineering, ICRAIE 2021*, Dec. 2022, pp. 1–5, doi: 10.1109/ICRAIE52900.2021.9703984.

[29] J. Yip, S.-H. Wong, K.-L. Yick, K. Chan, and K.-H. Wong, "Improving quality of teaching and learning in classes by using augmented reality video," *Computers & Education*, vol. 128, pp. 88–101, 2019, doi: 10.1016/j.compedu.2018.09.014.

[30] A. A. Fauzi, K. Ali, and R. Amirudin, "Enhancing construction technology course using mobile augmented reality," *Proceedings Of New Academia Learning Innovation (NALI) Symposium 2018* 2018, pp. 10-14.

[31] S. M. AlNajdi, M. Q. Alrashidi, and K. S. Almohamadi, "The effectiveness of using augmented reality (AR) on assembling and exploring educational mobile robot in pedagogical virtual machine (PVM)," *Interactive Learning Environments*, vol. 28, no. 8, pp. 964–990, Nov. 2020, doi: 10.1080/10494820.2018.1552873.]

[32] N. A. A. Nordin, N. A. A. Majid, and N. F. A. Zainal, "Mobile augmented reality using 3d ruler in a robotic educational module to promote stem learning," *Bulletin of Electrical Engineering and Informatics (BEEI)*, vol. 9, no. 6, pp. 2499–2506, Dec. 2020, doi: 10.11591/eei.v9i6.2235.

[33] J. A. Frank and V. Kapila, "Mixed-reality learning environments: Integrating mobile interfaces with laboratory test-beds," *Computers and Education*, vol. 110, pp. 88–104, Jul. 2017, doi: 10.1016/j.compedu.2017.02.009.

[34] M. Nadeem, M. Blumenstein, and M. Biglari-Abhari, "Exploring the impact of in class writing exercises in an engineering course," in *Proceedings of 2018 IEEE International Conference on Teaching, Assessment, and Learning for Engineering, TALE 2018*, Dec. 2019, pp. 342–349, doi: 10.1109/TALE.2018.8615411.

[35] Afnan, K. Muhammad, N. Khan, M. Y. Lee, A. S. Imran, and M. Sajjad, "School of the future: A comprehensive study on the effectiveness of augmented reality as a tool for primary school children's education," *Applied Sciences (Switzerland)*, vol. 11, no. 11, p. 5277, Jun. 2021, doi: 10.3390/app11115277.

[36] I. Tahyudin and D. I. S. Saputra, "A response analysis of mobile augmented reality application for tourism objects," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 7, no. 6, pp. 3500–3506, Dec. 2017, doi: 10.11591/ijece.v7i6.pp3500-3506.

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