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Augmented Reality Based Competency Based Learning on Computer Network Learning in Vocational Education Vocational School

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ABSTRAK

Penelitian ini dilatarbelakangi oleh rumitnya materi pelajaran Jaringan Komputer, banyaknya guru yang mengajar mata pelajaran tersebut dengan latar belakang yang berbeda, dan tidak semua dapat dipraktikkan secara langsung karena keterbatasan fasilitas laboratorium, disertai model pembelajaran yang belum berbasis kompetensi juga membuat hasil belajar tidak maksimal. Penelitian ini bertujuan untuk mengembangkan media pembelajaran jaringan komputer tiga dimensi dengan menggunakan perangkat lunak Augmented Reality Assemblr Edu pada pendidikan kejuruan. Jenis penelitian ini yaitu pengembangan dengan menggunakan model ADDIE yang meliputi analisis, desain, pengembangan, implementasi, dan evaluasi. Metode pengumpulan menggunakan observasi dan wawancara. Instrument pengumpulan data menggunakan kuesioner. Teknik analisis data menggunakan analisis deskriptif kualitatif dan kuantitatif. Hasil penelitian menunjukkan media Augmented Reality berbasis pembelajaran berbasis Kompetensi menggunakan yang divalidasi oleh tim ahli media dan ahli materi menyatakan sangat valid, sedangkan siswa menyatakan baik dengan alasan media ini memudahkan mereka memahami materi dan termotivasi untuk mencoba dan belajar. Disimpulkan bahwa media Augmented Reality berbasis pembelajaran berbasis Kompetensi dapat digunakan dalam pembelajaran.

ABSTRACT

This research is motivated by the complexity of the subject matter of Computer Networks, the large number of teachers who teach these subjects with different backgrounds, and not all of them can be practised directly due to limited laboratory facilities, accompanied by a learning model that is not yet competency-based which also makes learning outcomes not optimal. This study aims to develop three-dimensional computer network learning media using Augmented Reality Assembly Edu software in vocational education. This type of research is created using the ADDIE model, which includes analysis, design, development, implementation, and evaluation. Collection methods using observation and interviews. The data collection instrument used a questionnaire. Data analysis techniques using qualitative and quantitative descriptive analysis. The results showed that Competency-based learning-based Augmented Reality media, validated by a team of media experts and material experts, was very valid. In contrast, students stated well because this media made it easier to understand the material and motivated them to try and learn. It was concluded that Competency-based learning-based Augmented Reality media could be used in learning.

1. INTRODUCTION

Learning in the 21st century has fundamentally changed by integrating technology into the learning process. Technology has opened the door for richer, more interactive, personalized learning experiences. Students can access educational resources instantly and flexibly through digital devices, apps, and online platforms (Arnaiz-Sánchez et al., 2023; Hussain, 2023; Washbrooke, 2023). Students can

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explore different media types, such as videos, interactive simulations, and other digital content, which provide a deeper understanding and engage multiple senses. In addition, technology has expanded the possibilities of collaboration and communication in learning (Pujiastuti & Haryadi, 2023; Ye & Xu, 2023). Students can interact with fellow students worldwide through online forums, share collaborative projects, and discuss through video conferencing. Teachers can also provide real-time feedback through digital tools, personalize students' learning experiences, and monitor their progress. Teacher creativity and innovation in learning are highly demanded to present an active and fun class. Innovative learning is an approach that integrates technology, creativity, and new learning strategies to enhance students' learning experience (Ambiyar et al., 2023; Setiawardhani, 2013). It involves using digital tools and platforms, such as mobile applications, computer simulations, and social media, to facilitate interaction, collaboration, and access to real-time information. In addition, innovative learning encourages students to take an active role in the learning process, emphasizing problem-solving, team-based projects, and competency-based learning (Efendi et al., 2019b; Qodr et al., 2021). The technology-integrated competency-based learning model, where students learn previous material outside of class and use class time to discuss and apply knowledge, is also an example of innovative learning (Efendi et al., 2019a; Septiani, 2020). The main purpose of innovative learning is to help students develop 21st-century skills such as critical thinking, collaboration, creativity, and digital literacy, which are indispensable in today's evolving and globalized world. The development of technology that is increasingly advanced, of course, affects various sectors of human life. This development also plays a role in the development of learning media. Learning media is becoming more interesting and concise even though it does not reduce the essence of the material. One of the developments in learning media that is currently new is learning media using Augmented Reality. Augmented reality (AR) learning media has become one of the interesting innovations in the digital era digital (Chen et al., 2022; Majid & Salam, 2021). Using AR technology allows students to experience a more interactive and immersive learning experience. AR combines virtual elements with the real world, creating a rich and immersive multimedia experience (Frydenberg & Andone, 2011; Krüger & Bodemer, 2022). In the context of learning, AR can bring abstract objects and concepts into a more tangible and interactable state. For example, through AR applications, students can view and manipulate 3D models of human organs, planets in the solar system, or molecular structures, allowing them to understand concepts visually and more deeply (Majid & Salam, 2021; Sung et al., 2019).

The use of AR in learning can also increase student engagement. They can participate in the learning process, create AR projects, or collaborate in AR content development (Eldokhny & Drwish, 2021; Rukayah et al., 2022). AR-based media can stimulate students' creativity and allow them to apply their knowledge realistically. However, it is important to note that the use of AR in learning should be relevant and integrated with the curriculum (Uriarte-Portillo et al., 2022; Washbrooke, 2023). In addition, the accessibility of technology and adequate training for teachers also need to be considered for the use of AR to be successful. Augmented reality learning media provides an exciting opportunity to enhance students' learning experience by combining the physical world with virtual elements (Lubis & Wangid, 2019; Tuwoso et al., 2021). It encourages deeper understanding, student engagement, and creativity in learning in the digital age.

Augmented Reality is the application of combining the real world with the virtual world in the form of two or three dimensions projected in a real environment simultaneously. Augmented Reality is often called tethered (Noll et al., 2017; Shahroom & Hussin, 2018). This application is often applied in a game. Augmented Reality, as an alternative learning media, is expected in a learning activity that can be more interesting for students. Another benefit is a more advanced learning media utilizing current technological developments. Augmented reality can be one solution to overcome modules or trainers that are quite expensive and cannot be purchased by schools. Students can still do practicum by seeing the goods as the original, but in virtual form. The application of this technology aims to enable students to conduct experiments to increase learning motivation. Its use can communicate objects in cyberspace into a positive display so that it looks pretty good; it will feel like being in a much more substantial experience. Computer networking is a compulsory subject studied in vocational high school vocational education. This subject aims for each student to understand and practice material ranging from the concept of computer networks to being able to design a topology, perform IP subnetting calculations and also be able to operate the network to be interconnected using devices such as routers, switches, and computers. Based on preliminary analysis and relevant research conducted, some problems are often faced in learning Computer Network courses, namely limited practice time in computer laboratories (Bradley & Kendall, 2014; Efendi et al., 2021; Efendi & Ali, 2019; Segec et al., 2019). In this subject, students must gain practical experience configuring and operating computer networks. More reasonable time in computer labs can be a serious obstacle in enabling students to truly understand the concepts being taught (Liu & Mu, 2022; Maurer, 2017). Students may need more time to carry out all necessary practical exercises,

address technical issues that arise, or conduct additional experiments to deepen their understanding (Warschauer et al., 1996; Yassir et al., 2022). In addition, the limited amount of equipment in the computer lab may also limit students' access to practice independently, which means each student only gets limited practice time. The Competency-Based Learning (CBL) learning model is an educational approach that focuses on demonstrating specific skills or competencies rather than the traditional emphasis on the timing of the learning process. The competency-based learning model allows learners to progress according to their ability to master the required competencies. Furthermore, flexibility in time and place is one of the important aspects of the competency-based learning model. This model utilizes technology to provide flexibility in when and where learning takes place. Online platforms and resources allow learners to access materials and engage in learning activities at their convenience, thus facilitating a learning experience that can be customized at their own pace.

Integrating IT-based media in competency-based learning models has an important role in improving the effectiveness and efficiency of learning. Information and communication technology (ICT) can provide various advantages in supporting the achievement of competencies by learners. Integrating augmented reality (AR) media in competency-based learning models can provide a more in-depth learning experience and enrich student interaction and learning materials (Mubai et al., 2020; Nidhom et al., 2022; Widiaty et al., 2021). Using augmented reality technology, learners can experience interactive simulations that approach real situations related to the competencies being studied. By using network simulation software or virtualization platforms, students can practice their skills independently without requiring a lot of physical equipment. It also allows students to experiment with various network configurations and complete practical exercises outside of laboratory time. The use of technology to enhance the classroom teaching and learning experience has been promoted. One of these technologies is augmented reality, which allows the overlaying of virtual information on real scenes with the aim of enhancing the user's perception of reality. The aims of this study is to develop three-dimensional computer network learning media using Augmented Reality Assembly Edu software in vocational education.

2. METHOD

The development learning model used in this study is the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) learning design model, which is arranged in a programmed manner with a systematic sequence of activities in an effort to solve problems in learning related to learning media that are in accordance with the needs and characteristics of students. ADDIE is a model in which the stages are arranged or organized and systematic, which is for the use intended to create the desired end result. The main purpose of this development model is intended as a means of designing and developing an effective, efficient product and other learning resources (Branch, 2010). The process carried out during the research is described with a work breakdown structure (WBS), including research objectives, research sections, and activities carried out according to the ADDIE research and development methodology stages, as shown in Figure 1.

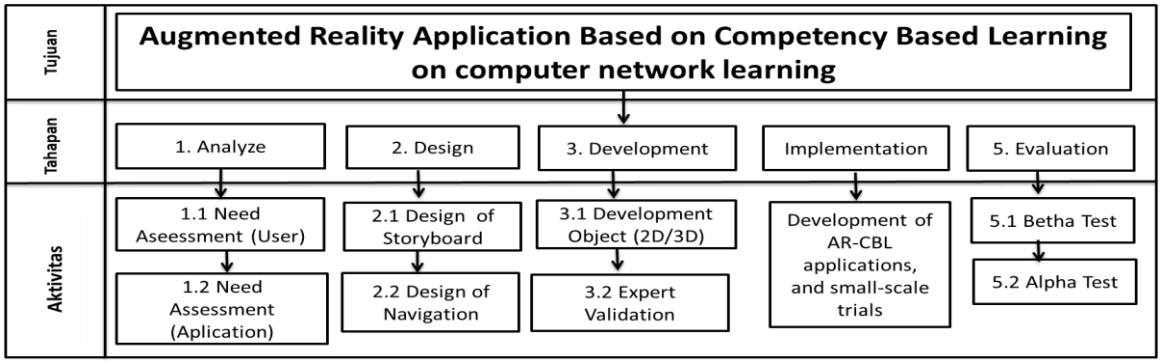

Figure. 1 Work Breakdown Structure

Analyze the data collection method at the analysis stage using observation and interviews. This method is used to understand teaching and learning activities at SMK Mitra, which aims for application planning. The observation period was carried out for two weeks. In addition to making observations, the author also interviewed teachers in the curriculum field as sources. The observation tool used is a notebook to record important information from the results of observation and interview activities at

partner schools. In addition, library research was conducted to obtain secondary data that supports this research, such as journals and books as reference materials in searching, collecting, and studying information related to computer network learning, as well as theories that support the creation of applications that apply Augmented reality technology. The application system design is carried out at the Design stage, creating a running application using a storyboard sketch and estimating the design work. Develop; during this phase, researchers will ask several teams of experts to validate this research and get their suggestions. Implement; at this stage, the researcher pours the results of the design that has been designed into the storyboard and the software commonly used, namely Assemblr Studio. Evaluate; at this stage, the application is revised after validation of the suggestions and input from the expert team. If the application can meet the criteria and is correct, the application is tested in alpha or beta.

3. RESULT AND DISCUSSION

Result

These results explain the development process and results of the development of Augmented Reality learning media based on the Blended Learning competency model in SMK Computer Network learning, including five steps by the ADDIE development model, including Analysis, Design, Development, Implementation, and Evaluation.

Analyze Stage

In the custody of this analysis, what is done is to identify problems. Problem identification is obtained through observation, interviews, and documentation to educators and students related to rationalization stating that the development of AR-CBL medial is appropriate and feasible to do. The analysis includes analyzing user needs, AR-CBL application needs, user identification, application objectives, and determining the specifications of the equipment used. Analysis of user needs to teachers and students, finding that learning has not been maximized due to learning material that is complex and difficult to understand so that it requires optimal time and a less attractive learning approach, and also an atmosphere of independent learning is less available so that it causes less student interest and motivation in learning. The needs analysis of the application generates information related to determining the identity of the application user, the type of application, the purpose of the application offered, and the general specifications of the device to be used. This comes from the first identification phase.

Analysis in the form of User Identification produces information that the target of AR-CBL media is all students, teachers, and guardians of students at partner schools. Based on observations made during the application, the nature of the application created is the development and application of Augmented Reality technology in computer network learning. This application uses Augmented Reality technology on the Android operating system to interactively visualize the information needed in computer network learning, such as learning outcomes, application guides, learning materials, quizzes, and evaluations. Teachers and students, and student guardians can also access and know AR-CBL media. General Specifications of Tools Used The hardware used in making AR-CBL applications can be seen in Table 1.

Table 1. Spesification of Devices

No	Device	Spesification	Dekription
1	Laptop	Processor	Intel Core i3-6006U CPU @2.00Ghz
	ACER One 14 Z-476	Memory	4GB DDR3
		OS	Windows 10 Enterprise 64-bit
		Storage	1 TB HDD
		Display/VGA	14 HD Graphics 1366 768
2	Smartphone	Device	Samsung Galaxy A23
	Android	Chipset	Qualcomm Snapdragon 680
		CPU	Octa-core (4x2.4 GHz Kryo 265)
		GPU	Adreno 610
		OS	Android 12, One UI 5.1

Design Stage

The second stage, the design stage, aims to design the application architecture to design the Storyboard and Navigation Structure. The designer will analyze the learning content delivered through AR and ensure that the content meets the learning objectives set. Researchers also consider how AR content can increase learners' understanding and engagement.

Navigation design in AR learning media. This involves thinking about how learners move between objects or sections within the AR environment. The design stage ensures that navigation is intuitive, easy to understand, and does not interfere with learning. In addition, the researcher is also responsible for designing an interface design that fits the AR experience. In this stage, the layout of interface elements such as buttons, icons, text, and other visual indicators are synchronized so that they are easily accessible and provide clear instructions to learners. Overall, activities in the design stage include content analysis, interaction design, navigation planning, and interface design that create an effective AR experience and facilitate optimal learning for learners. The story board is show in Table 2.

Table 2. Story Board

No	Menu	Description
1	Splash scene home page	Displays the first page of the app login to switch to the next Scene
2	Main Menu Page	Displays the main menu page and several menu button options, namely the learning outcomes menu, guide menu, material menu and exercise menu.
3	Learning Outcomes page	Display details of learning outcomes page, description of learning flow, description of learning stages
4	Guidance Page	This page displays an image of the instructions page and how to use the application and there is a button to return to the previous page.
5	Material Page	Displays The menu to explain material related to computer network learning, there are several integrated materials
6	Practice/Quiz Page	Displays a menu for taking quizzes, as an evaluation and measurement tool for student understanding achievement.
7	Exit	Displays a button and pop-up yes to exit the app and no to return to the main menu page.

After making the storyboard and designing the navigation, prototype 1 of the AR-CBL media was made. At the stage of making prototype 1, this media uses Assemblr studio to make media starting from inputting 2D and 3D assets of computer network devices that come from Asemblr assets and assets that come from other 3D applications/asset providers, then entering videos to add a visualization of network topology. At the stage of making this media, the first step is to choose the topic of the subject matter that is suitable for the media used, that set criteria including information content that is in accordance with the learning experience of students, writing style, use of images, colors used, and good organization of material, after that make an initial design of the presentation of computer network learning media using assembler edu. One of the design images of computer network material is shown in Figure 2.

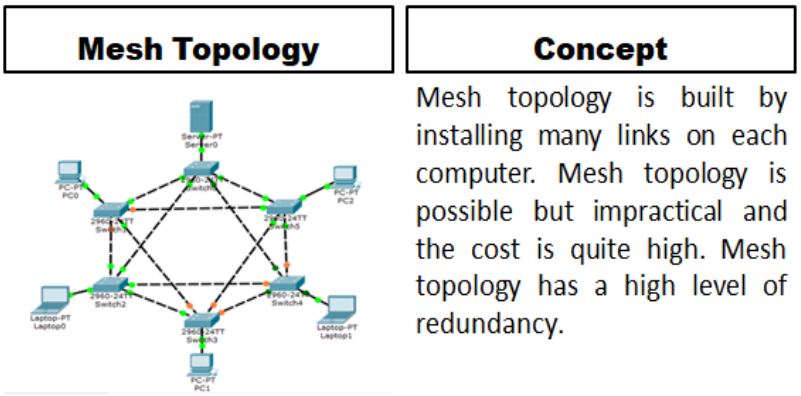

Figure 2. Material Design

The navigation structure describes the organization and relationship between pages that form a series of information flows, ranging from the application of Augmented Reality technology to information on menus and learning materials, using the ADDIE development model. The navigation tree is built using a hierarchical navigation tree. The hierarchical navigation tree is branched to display information based on certain criteria. The home page is called the master page and its branches. Desain of structure navigation is show in Figure 3.

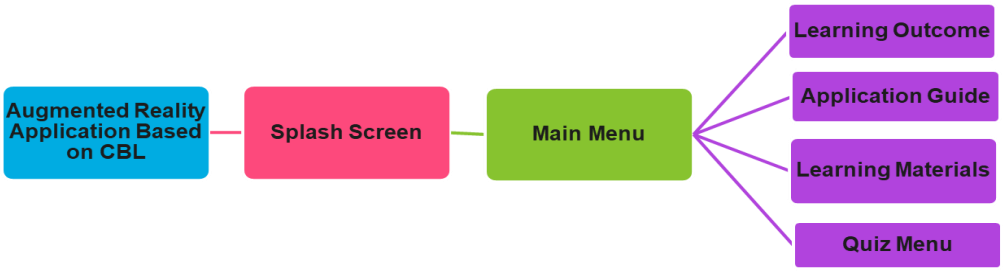

Figure 3. Desain of Structure Navigation

Development Stage

The Development stage results in developing applications that are designed as expected. If the product designed in the design section is complete, it is processed again in this section. Defined as making prototypes1 or developing augmented reality learning media application objects as tools in learning computer networks based on competency-based learning models (AR-CBL). The Development stage will contain AR-CBL media validation activities by five expert validators to get constructive criticism and suggestions for better 3-dimensional learning media. Criticism and input from validators become a reference for researchers to make prototype two media ready to be tested on students. The results of prototype one were first tested on teachers who teach computer network subjects to be validated by expert validators. Expert validators consist of material and media experts, namely 1 Undhari Informatics Engineering lecturer, 1 Educational Technology lecturer, and 3 Computer Network subject teachers. The results of the assessment of the prototype still have improvements, namely the title is made interactive, given an explanation in the form of audio or video, and the indicators on the worksheet are listed and given an evaluation.

This stage of development results in developing applications that are designed as expected. If the product designed in the design section is complete, it is processed again in this section. Defined as the process of making or developing AR-CBL learning media application objects as technology-based learning media that are expected to present a pleasant classroom learning atmosphere. In other words, researchers realize the design prepared at the design stage. Overall, are five validators involved in assessing the validity of AR-CBL learning media, consisting of 3 material expert validators, namely two lecturers from educational technology and one teacher of computer network subjects at partner vocational schools. Moreover, two learning design expert validators are lecturers of the Educational Technology study program. The results of the validation of learning devices are presented in Table 3.

Table 3. Media Validation Result Score (Material)

No	Aspect	IndiCator	frequency	
			1	2
1	Curriculum	Media presented in accordance with the curriculum	4	1
		Media is in line with the curriculum and integrated HOTS	5	0
		The purpose and benefits of learning media are clearly conveyed	4	1
2	Learning	Media can be used in small and large groups	5	0
		Media titles attract and motivate learners	4	1
		Use of media involves active participation of learners	4	1
3	Material	The content of the material is in accordance with the Basic competencies (KD) and Indicators	3	2
		The language in the media used is in accordance with the understanding of students	4	1
4	Interaction	The media is easy to use	4	1
		Percentages	37	8
		Persentase [P] = $\frac{\sum R}{N} x\ 100\ \%$	82.22	17.78

Based on the data in Table 3, the media development is by the applicable curriculum at partner vocational schools, has fulfilled the desired indicators per learning objectives, and the media can be used individually and in groups so that students can do it actively. Of the five validators, both stated very good

and good, so they recommended to be reproduced, applied to other materials, and referred to other teachers. Validators provide input on interesting titles and usage tutorials so that general people, teachers, and students who do not use master technology can easily use it. Based on the validity criteria sourced from Lestari 2011, it is in the very good category because it reaches a percentage of 84.44% and a good category of 17.78%. These two percentages indicate that the validator strongly agrees that the application can be applied to learning. At the same time, the frequency of validity tests from expert validators can be presented in Table 4.

Table 4. Score of Media Validation Results (Graphics/Display)

No	Aspect	Indicator	frequency	
			1	2
1	Media Display	Color combination on media Media size	5	1
		Media is clear and easy to understand and interesting	5	1
		Alternative media for learning	5	1
		The media is durable and not easily damaged	5	1
		Easy to carry and portable media	4	1
2	Media Leaning	Media suitability with learning outcome	5	1
		Can be replayed for learning	5	1
3	Learner Engagement	Learners participate in the learning process	5	1
		Can be used by teachers and students	5	1
		The media can motivate learners	4	1
		Total	37	8
		Percentages [P] = $\frac{\sum R}{N} x\ 100\ \%$	82.22	17.77

According to media experts, computer network learning media, Augmented reality learning media based on competency-based learning is complete and good because it starts with a color display, can be used anytime, anywhere as long as there is an internet network, anyone can create, and use it and what is no less interesting will make students active, want to try and easily understand it. This media only needs additional assessment or evaluation to test students' understanding. Based on the assessment of dimensional AR_CBL learning media by media experts and by material experts (teachers and media experts), each aspect has almost the same value, which is very valid; there are only differences in the title point, conformity with indicators, the language used and ease of use. Based on the results of this assessment, overall, the media developed meets the criteria of easy to use, attractive appearance, according to the concepts taught, innovative, and motivating student learning with very good qualifications. This means that teachers are able to develop AR-CBL media with very good qualifications and are suitable for use.

Implementation Stage

At the Implementation stage, the AR-CBL learning media revision and improvement process is carried out. At this stage, small-scale trials were carried out by teachers who teach computer network learning subjects, media experts, and material experts and received input in the form of more interesting titles and more specific indicators, and some even wanted the addition of videos and assessment test components. Improvements were made in recombining elements in Assemblr studio, including the application of AR, the application of markers, the appearance of 3D objects, the creation of program code, and the creation of applications in the form of .apk. At this stage of implementation, small-scale field trials were also carried out to get responses from users ---- as well as collect initial data from users. In implementing the interface in this application, several pages are needed to handle each process and make it easier to make applications. Each page is interrelated and has its own function.

The results of the application at the implementation stage, AR-CBL media, have been implemented and run on Android-based smartphones. Implementation of video content creation, 3D objects, background design, and material design until the coding implementation process that has been carried out is displayed in accordance with the system design in the initial display design. Gamabr 4 is the result of the development in the design stage of the Augmented Reality Application as a learning medium for the splash screen page and the main page. The main page is the first page that appears when you first open the application. On this page, there are four main menus, namely achievements, guides, materials, exercises, and exit buttons. The splash screen is the first page when the application is opened before moving to the main menu page with a time delay of 10 seconds. The next page is the main page which contains the main menu in AR-CB. The splash screen and main menu page can be seen in **Figure 4.**

Figure 4. Splash Screen and Main Menu

For the implementation results of the display on the scan menu that has scanned with one of the markers in the experimental results. The marker scan process can scan the photo section in the main menu in Figure 6. Features that bring up 3D object visualization or video have been successful and can bring up information about material integrated with existing computer network learning, as seen in Figure 5.

Figure 5. Scan Menu Display When Scanning Markers

Evaluation Stage

Evaluate By using the black-box testing method, namely alpha testing, one of the tests for applications that have been made in order to find out the convenience of users of applications that have been made that can be used properly and correctly, beta testing is carried out with a panel of teachers and students from partner schools by filling out a questionnaire after using the "AR-CBL" application. Before the application is distributed and used by users, the application testing process is carried out first so that the application that has been built can run all content and functions as designed by the author. This test can also minimize errors, which can cause user inconvenience in using this application. Alpha Testing is testing done by the developer or software maker before the software reaches the user. Testing is done with the Black Box method. Black Box testing is used to test the system to determine whether the software made is as expected. The purpose of Black Box testing is to find malfunctions in the program. Testing using the Black Box method only observes the results of execution through test data and checks the software's functionality. In Black Box testing on this application, the button functions are tested in the application. Each button is tested for the suitability of the output results and the absence of errors found. These tests are summarized in Table 5. Moreover, it can be concluded that this functionality test runs as expected, which is all successful.

Table 5. Alpha Testing with the Blackbox Method

No	Test Grade	Test Item	Type	Results
1	App installation	App installed on Android smartphone Blackbox	Blackbox	Success
2	splash screen	Splash screen page appears when the app starts	Blackbox	Success

No	Test Grade	Test Item	Type	Results
3	The start button	Start button on spalshscreen page	Blackbox	Success
4	Main menu page	Background Image	Blackbox	Success
5	Learning Outcomes Menu	Button to learning outcome page	Blackbox	Success
6	Learning video materials	Additional video material related to learning	Blackbox	Success
7	Learning Audio Material	Additional audio material related to learning	Blackbox	Success
8	Instructions menu page	Background Image	Blackbox	Success
9	Quiz Menu Page	Background Image	Blackbox	Success
10	Exit Button	Background Image	Blackbox	Success

Base on Table 5 show data results, further research is needed on a larger scale to determine the feasibility of learning media using 3D. 73% of students said they wanted to learn using 3D, with 20 participants saying very good, four saying good, one saying enough, and no participants objected to using it. The data stating that students want to learn further using 3D shows that they are motivated to learn Computer Networks using 3D. Tracking Marker testing on the development of augmented reality learning media based on competency-based learning models can help test the accuracy and stability of the marker tracking system used in learning media. Tracking Marker testing includes preparing markers that will be used in augmented reality learning media. Test the accuracy and stability of marker tracking using appropriate tracking software. Test marker tracking in various lighting conditions and different marker positions to ensure the tracking system can work well in various conditions. Test the augmented reality learning media by using the tested Marker and make sure the virtual object display can appear accurately on the Marker. Testing results of tracking method is show in Table 6.

Table 6. Testing Results of Tracking Method

Metode Tracking	Testing Distances (cm)								Distances	
	5	10	20	30	40	50	80	250	Min	max
Marker Based Tracking (Indoor)	T	Y	Y	Y	Y	Y	Y	T	8 cm	85 cm
Marker Based Tracking (Outdoor)	T	T	Y	Y	Y	Y	Y	T	6 cm	82 cm
Markerless (Indoor)	Y	Y	Y	Y	Y	Y	Y	Y	5 cm	295 cm
Markerless (Outoor)	Y	Y	Y	Y	Y	Y	Y	Y	5 cm	285 cm

Base on Table 6, the first test of Distance to Light Intensity test was conducted outside the school partner's classroom with an angle of 90°. The amount of light intensity is 1605 lux. The conclusion obtained in Table 2 is that at a light intensity of 1605 lux, the system successfully detects 3D objects. The marker-based tracking method has a minimum detection distance of 8 cm and a maximum of 82 cm, and the markerless method has a minimum detection distance of 5 cm and a maximum of 285 cm. The second test of the intensity of the light source was conducted in a classroom with a light source in the classroom and an angle of 90. The amount of light intensity is 553 lux. The test results, as shown in Table 6, concluded that at a light intensity of 195 lux, the system succeeded in detecting objects. The marker-based tracking method has a minimum detection distance of 8 cm and a maximum of 85 cm, and the markerless method has a minimum detection distance of 5 cm and a maximum of 295 cm. Testing Tracking Marker and markerless AR-CBL media against light intensity is done to determine the effect of detection distance and light intensity on the success of marker-based tracking methods and markerless methods in producing 3D objects making AR-CBL media. Regarding the test results, distance and light intensity affect the tracking method in the augmented reality system because distance affects the system's success in displaying objects. Regarding the success of displaying objects, ideal distances for both methods are classified as minimum and maximum.

Occlusion testing on augmented reality learning media is conducted to evaluate how virtual objects displayed on top of physical objects can remain stable and not shift when other objects obstruct physical objects. Testing is done by varying the distance between virtual and physical objects to see if there is a significant shift when other objects obstruct physical objects. Testing is also done by varying the size of virtual and physical objects to see if a significant shift occurs when another object obstructs the physical object. Occlusion of testing is sow in Table 7.

Table 7. Occlusion Testing

Obstructed Marker Area	Sampel Marker yang diuji									
	1	2	3	4	5	6	7	8	9	10
10 %	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
30 %	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
50 %	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
70 %	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
80 %	T	T	T	T	T	T	T	T	T	T
100 %	T	T	T	T	T	T	T	T	T	T

Base on Table 7 this occlusion test covered 10% to 100% of the marker. This test uses a Samsung Galaxy A23 smartphone against ten tested sample markers. Based on the occlusion test results can be seen in Table 7. When the marker is closed by 10% to 70%, marker detection runs normally. When the marker is closed by 75%, marker detection starts to slow down. When the marker is closed at 80%, the marker cannot be detected, and the 3D AR-CBL object cannot be displayed. The occlusion test results on ten different sample markers conclude that the marker should not be covered by more than 75%.

Discussion

This discussion will be explained the results of testing with six devices with different operating systems and the screen resolutions of each device. From the test results above can be known the advantages and disadvantages of this computer hardware application. The advantages of this application are as follows: 1) With this application, the learning method becomes more interesting because the objects displayed look more real with the AR technique; 2) The application of one marker to one object can make it easier for users to be able to recognize application markers; 3) The application display uses the latest Assembly studio User Interface (UI), making it easier to understand; 4) There are additional audio, video, and interactive features to facilitate the delivery of information to users. The disadvantages of this AR-CBL media are as follows: 1) The use of this media will be maximized if the user's internet network is in good condition (4G); 2) To run this application, good device specifications are required, such as camera, GPU and RAM. and a large enough screen resolution; 3) Marker detection is still quite long to detect markers, and the level of similarity of 3D objects with the original five senses is not 100% similar.

This learner response is to what was conveyed that learning media has functions and uses as described in the literature review, namely clarifying observations, providing interaction and reciprocity that motivates students to try again and again and raises learning (Noll et al., 2017; Washbrooke, 2023). The response to the existence of three-dimensional media (3D) is also in line with previous research which states that computers and internet technology have made significant progress throughout the world, including in education (Huang et al., 2018). And this study has also found that the AR-CBL application supports an intuitive and interesting learning process for children with special needs by combining the real world and the virtual world. This is in line with the findings of (Nidhom et al., 2022; Widiaty et al., 2021). The implications of this study indicate that the use of the richest reality (augmented reality) in competency-based learning can improve students' skills in understanding and applying computer network concepts in vocational education. By combining virtual content with the real world, augmented reality can provide a more interactive learning experience and motivate students to participate actively. The use of augmented reality in learning allows students to experience realistic situations and contexts that are impossible to achieve with traditional learning methods. Students can interact directly with virtual objects and see the real implications of their decisions and actions. This can enrich their learning experience and help them develop a better understanding of computer network concepts.

The implementation of augmented reality in learning requires adequate technological infrastructure, including appropriate hardware and software. Limited access to this technology can be an obstacle in applying this learning model widely. In addition, the cost of implementing and maintaining augmented reality technology can also be an obstacle. This augmented reality learning media based on competency-based learning can be recommended for future investigation to improve student learning outcomes in computer network subjects in elementary schools to provide direction to elementary school instructors to improve student achievement. More research should be conducted worldwide to understand the impact of further mobile augmented Reality learning media with metaverse on student learning outcomes.

4. CONCLUSION

The augmented reality based Competency-Based Learning (AR-CBL) application has been built based on the research that has been done. AR-CBL media received positive responses from students and teachers. Students can quickly gain new experiences in learning computer networking material and independently understand it and access it in any condition they want. Learning in this way is considered more exciting and fun. Increased knowledge of various technology-based learning media should be able to be utilized so that teaching materials are more easily understood by students, as well as being able to offer learning materials more interestingly and efficiently and to promote learning models in the era of globalization.

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