Development of Augmented Reality (AR) based Learning Media for Vocational High School Students

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ABSTRACT
In this modern era, technology has become integral to various aspects of life, including education. 21st-century education emphasizes "The 4Cs" competencies - Communication, Collaboration, Critical Thinking, and Creativity. However, in Vocational High Schools (SMK), there are challenges in learning less interactive and innovative media, especially in Building Construction & Utilities (KUG) subjects. Based on observations at SMK Negeri 6 Bandung, less interesting learning media causes students' understanding of the material to be low. This research aims to develop learning media based on Augmented Reality (AR), which can increase students' understanding and involvement in KUG subjects at SMK Negeri 6 Bandung. AR technology was chosen because it combines three-dimensional virtual objects with the real world, providing a more interactive and immersive learning experience. The research method used is Research and Development (R&D) with Thiagarajan's 4D development model, which includes the Define, Design, Develop, and Disseminate stages. This research was conducted in the even semester of 2023/2024 involving 200 students from five Building Modelling and Information Design (DPIB) classes at SMK Negeri 6 Bandung. The research results show that the AR application developed received positive student responses. The quality aspect of the application is considered good, with an average value of 3,104. Other aspects, such as clarity, detail, and convenience, also received good ratings, although they still require further improvement. Responses to the material delivered via the AR application show that aspects of relevance and interest in the topic receive high marks. The implications of this research show that using AR-based learning media can be an innovative solution to improve the quality of education in vocational schools. AR technology makes learning more interesting and interactive and can increase students' understanding and engagement in learning complex material. Thus, implementing AR in learning media in vocational schools can contribute to increasing student competence to the demands of 21st-century education.

Keywords: *Innovative, Interactive, Communication, Creativity.*

1. INTRODUCTION

In this modern era, almost all aspects of our lives use technology, including education [1]. Today, education is expected to follow and apply existing technological developments. In 21st-century education, emphasis is needed on "The 4Cs" competencies - Communication, Collaboration, Critical Thinking, and Creativity [2]. Communication is a person's ability to convey and share thoughts, ideas, concepts, questions, and solutions [3]. Collaboration is the ability to work together, adapt, and synergize with other people to achieve common goals. Critical thinking is a thinking process that results in deep reflection to decide what to believe or do [4]. According to [1], critical thinking involves self-regulation in deciding something based on interpretation, analysis, evaluation, and inference using evidence, concepts, methodology, criteria, or considerations that form the basis of the decision [1]. Creativity is the ability to think and produce ideas, concepts, or solutions that are innovative, relevant, and out of the box to solve certain problems [5].

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In the 21st century, learning is oriented towards digital lifestyles, thinking tools, learning research, and how knowledge works. Three of the four 21st-century learning orientations are close to vocational education, namely digital lifestyle, thinking tools, and how knowledge works. Digital lifestyle is the ability to adapt to life in the digital era. Thinking tools are the ability to use technology, digital media, and their services. Knowledge works through the ability to collaborate in a group despite differences in location and media used [6].

Based on data from GoodStats.id, Indonesia is ranked 6th out of 10 countries with the most smartphone users in 2023, with 73 million users, and this number is expected to increase to 115 million in 2027. This high number of smartphone users is a challenge and an opportunity in educational aspects in Indonesia. Smartphones can be used as learning technology to deliver material to students according to their habits.

Based on the author's observations during first aid activities at SMK Negeri 6 Bandung, in the competency of Building Modelling and Information Design (DPIB) skills, especially in Building Construction & Utilities (KUG) subjects, there is a problem where the learning media used is less interactive and innovative. This causes a lack of student understanding of the material presented, so some students need help understanding the material, affecting their performance and final assignment results. The KUG teacher at SMK Negeri 6 Bandung stated that this problem must be resolved immediately by utilizing technology as a learning medium to achieve the desired targets.

Educational technology [7] is crucial in various learning activities, especially in learning media, because it plays a big role in learning outcomes [8]. The use of technology in learning can accelerate the dissemination of information widely and evenly to students. In educational institutions, especially at the vocational school level, problems are often found in the student learning process caused by less effective learning media.

Technology development in education produces various tools or media that are useful for increasing the effectiveness of achieving learning goals. One technology product that can be used in education is Augmented Reality (AR) [9]. In 1990, the concept of this technology was first developed by Thomas P. Caudell in the term 'Augmented Reality'. The Encyclopaedia Britannia explains, “Augmented reality, in computer programming, is the process of combining or 'augmenting' a video or photographic display with data generated by a computer”. AR has three main characteristics [6][11]: combining the real and virtual worlds, being interactive in real-time, and being three-dimensional [10]. Augmented Reality is a technology that integrates the real world with the virtual world. In other words, Augmented Reality (AR) displays objects in is the three-dimensional form of videos or photos/images in the real world.

The Industrial Revolution 4.0 is a challenge, especially in terms of improving the quality of human resources, which must be improved with the quality of existing education. Education must follow the development of the 4.0 revolution to create quality human resources that can have a positive impact. Vocational Schools aim to prepare students with skill competencies according to their fields so they are ready to face the world of work and industry. One of the developments in the world of education is the increasingly diverse use of learning media due to technological developments, such as Augmented Reality (AR). AR can be a more interactive and user-friendly learning tool. AR, as part of multimedia learning media, can create different and interesting learning experiences for students. AR technology enables the projection of 2D or 3D virtual objects in real-time by combining virtual elements with the real environment. AR technology is developing rapidly, especially in image visualization. The use of AR in education is an innovation that adds a different learning experience for students, creating more interactive learning activities with animation and audio features.

Based on this background, researchers want to know how the application of Augmented Reality (AR) in learning media can increase students' understanding and involvement in Building Construction & Utilities (KUG) subjects at SMK Negeri 6 Bandung.

2. LITERATURE REVIEW

2.1. Learning Media

Media in the world of education has a very important role, especially in determining the success of the learning process. This is due to the media's ability to provide unique learning experiences for students [12]. Interactive media plays a very important role in learning activities. The term “instructional media” comes from the Latin “medius,” which means “middle,” intermediary, or introduction. In Arabic, media means an intermediary or messenger from the sender to the message's recipient [13]. Gerlach and Ely’s model states that media, broadly, are people, materials, or events that create conditions that enable students to acquire information, skills, or attitudes [14][15]. Based on this definition, teachers, books, and the school environment are also included in the media [16]. Specifically, media in the learning process is defined as graphic, photographic, or electronic tools used to capture, process, and reconstruct visual and verbal information [17].

The Association for Education and Communication Technology (AECT) defines media as a form used to distribute information [18]. Meanwhile, the National Education Association (NEA) defines media as objects

that can be manipulated, seen, heard, read, or talked about, along with instruments used in teaching and learning activities to increase the effectiveness of instructional programs [19]. Learning media are tools, methods, and techniques used to make communication and interaction between teachers and students more effective in the education and learning process [20].

Literature regarding learning media shows how important the role of media is in supporting and increasing the effectiveness of the learning process. Using appropriate media in learning can increase students' understanding and retention of material [21]. A cognitive theory of multimedia was developed that emphasizes the importance of combining visual and verbal elements to facilitate better understanding [22].

In addition, interactive media, such as simulations and animation, can provide a deeper learning experience and increase student engagement [21]. It was found that interactive media made learning more interesting and allowed students to explore complex concepts more meaningfully and structured.

The literature review also highlights the importance of selecting media that suits the characteristics and needs of students. According to [23], not all media are suitable for every learning situation. Media selection must be based on learning objectives, material characteristics, and student characteristics. They developed the ASSURE model, a guide for designing and effectively using learning media.

In modern education, digital technology has opened up new opportunities for developing more interactive and adaptive learning media. Using digital technology in learning, such as e-learning and web-based learning platforms, can increase the accessibility and flexibility of learning [24]. This is especially important in the context of distance learning and lifelong learning.

Furthermore, integrating digital technology into learning influences learning outcomes and students' motivation and attitudes toward learning [25]. They found that students who learn using digital media tend to be more motivated and have a positive attitude toward learning compared to students who learn using traditional methods.

Thus, the literature shows that learning media has a very important role in supporting and increasing the effectiveness of the learning process. The selection and use of appropriate media can provide a more meaningful learning experience, improve understanding and retention of material, and increase student motivation and engagement [26]. Therefore, educators need to understand the characteristics and potential of learning media and integrate them effectively into the learning process.

2.2. Augmented Reality

Augmented reality is a technology that integrates three-dimensional (3D) virtual objects into a three-dimensional real environment. As part of the Virtual Environment (VE) or what is known as Virtual Reality (VR), augmented reality gives users an overview of the combination of the real world and the virtual world from the same perspective [27]. Augmented Reality (AR) technology allows the combining of two-dimensional and three-dimensional virtual objects into a three-dimensional real environment, and then projecting these virtual objects into the real environment.

Augmented reality [28] is a technology that integrates two-dimensional or three-dimensional virtual objects into a three-dimensional real environment and then projects these virtual objects into the real world [29]. With the help of augmented reality technology, the physical environment around us can be interacted with in digital (virtual) form [30]. Information about objects and the environment around us can be added to an augmented reality system and displayed on top of the real-world layer in real time so that it appears as if the information is real [31]. AR technology is used to enrich the user's perception of reality, not to replace it [32].

AR devices have cameras, sensors, and screens [33]. This includes smartphones and tablets that provide mobile AR experiences and 'wearable devices' such as smart glasses and headsets. These devices record the real world and combine digital content (such as 3D models, images, or videos), thereby creating a fusion of the physical and virtual worlds. AR can be used via smartphone, as in Figure 1.

Figure 1 Application of AR in the Elizabeth Statue Building, USA [4]

Based on Figure 1. Augmented Reality (AR) can make it easier to visualize abstract concepts, thereby helping to increase understanding of the structure of an object.

Previous research regarding the use of Augmented Reality in Senior High Schools shows that this media has advantages in learning, especially in terms of interactivity. AR displays three-dimensional objects with an attractive interface that is close to its original form, so it can increase students' reasoning and imagination.

Therefore, the use of Augmented Reality in learning at the Senior High School and Vocational School level is considered diverse and suitable, for example as in Figure 2.

Figure 2 AR applied to Engineering Design (left) and Interior atmosphere of the meeting room (right) [4]

The research was conducted using the Marker Augmented Reality method to implement Augmented Reality as an interactive learning media for early childhood development applications [25]. The marker design chosen is the Magic Book, which is a collection of several markers stored in one textbook for teachers and parents [34]. Apart from being used as a marker for AR applications, Magic Book can also be used as a coloring medium for students because the design includes special images to color. It is hoped that, apart from recognizing objects, teachers or parents can also direct students to practice creatively coloring these objects [35].

2.3. AR System Development Toolkit

To build AR applications, 7 software are used, including;

a. Autodesk 3Ds Max (a 3D-based program for modeling, rendering, and animation)
b. Unity 3D (a cross-platform-based game engine program used as an integrated tool for creating games, building architecture, and animation).
c. Vuforia SDK/Software Development Kit (this software is AR-based, which uses the mobile device screen as a lens/glass to see into an augmented world where the real and virtual worlds appear side by side)
d. Sublime Text (as an editor application for code and text that can run on various operating system platforms using Python API technology.
e. Android SDK/Software Development Kit (as an API/Application Programming Interface tool used to develop applications on the Android platform based on the Java programming language.
f. JDK/Java Development Kit (a tool used to build software based on the Java programming language.
g. C# / C Sharp (tools from Microsoft based on the Borland Turbo C++ and Borland Delphi programming languages.

3. RESEARCH METHODS

The research method that will be used in this research is the R&D (Research and Development) method. This method is a scientific method in development for researching, designing, producing, and validating products that have been produced [36]. The product to be developed must be tested for its effectiveness so that it can be used and is beneficial for those who will use it; in this research, the students are the users. The research model that will be used is the 4D R&D Model developed by Thiagarajan [36]. This 4D development model consists of several stages, namely Define, Design, Develop, and Disseminate as in Figure 3.

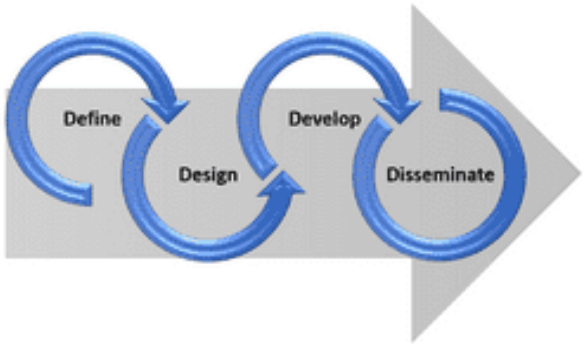

Figure 3 Thiagarajan's 4D R&D model

This research was carried out in the even semester of 2023-2024 at SMKN 6 Bandung in the Interior and Building Modelling Design (DPIB) class in Building Construction and Utilities subjects, with a total of 200 students as respondents, with details as in Table 1.

Table 1. Research sample

No	Respondent	Amount
1	DPIB Class 1	40
2	DPIB Class 2	40
3	DPIB Class 3	40
4	DPIB Class 4	40
5	DPIB Class 5	40
	Total	200

4. RESULTS AND DISCUSSION

4.1. AR Application Development Process

The process of creating and developing Augmented Reality (AR) applications for Building Construction and Utilities subjects involves a comprehensive series of stages. The initial step in developing this application is an in-depth study of teaching material, including an introduction to building structures and construction, such as substructures, column structures, beam structures, and roof construction structures. Researchers conducted research and analysis to understand in depth the basic principles of each type of structure. This includes the characteristics of the materials used, construction techniques commonly applied, as well as other technical

considerations such as the load that must be borne by each part of the structure.

Next, the researchers developed detailed and accurate 3D models for each type of structure. These models include every detail, such as dimensions, relationships between parts, and materials used. The development of this 3D model is very important because it will be the basis for the visualization that will be presented to users through AR technology. Next, these 3D models are integrated into the AR environment using object recognition and environment mapping technology. The goal is for users to view and manipulate models of these structures in real-time in their physical space. Thus, they can learn these structures in an interactive and easier-to-understand way, as seen in Figure 4.

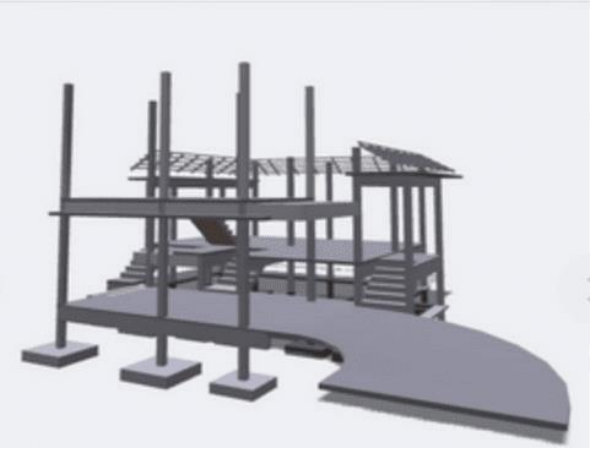

Figure 4 Structural modelling and building construction

Implementing AR technology also involves developing an intuitive user interface so that users can easily navigate and interact with the 3D models presented. This includes features such as zoom, rotation, and additional relevant information about each part of the structure. After the AR application has been developed, in-depth testing and evaluation are carried out to ensure the accuracy, readability, and effectiveness of the learning experience provided to users. Feedback from teachers and students is important at this stage to make improvements and adjustments to the application to suit learning needs in the Building Construction and Utilities class, as in the example in Figure 5.

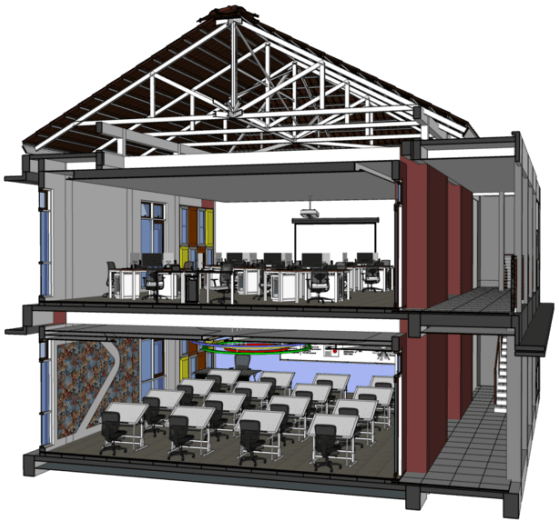

Figure 5 Principal cut of a school building showing the construction structure

4.2. Respondents' responses to the AR application being developed

Overall, students' opinions regarding the AR application being developed gave a positive response. This can be seen in the 9 aspects of the media that were developed that received good ratings by respondents as shown in Figure 6-14. Successively, we have achieved high to low average scores in the areas of layout, conformity, responsiveness, details, convenience, quality, clarity, speed, and control. So, what still needs to be developed are the aspects of Clarity, Speed, and Control.

Meanwhile, for the material aspects, good responses are aimed at 5 aspects of material assessment, as in Figure 15-19. The levels of relevance, interest, details, characteristics, and quality are seen from high to low.

4.2.1. Quality aspects of AR applications

Respondents' opinions regarding the quality aspect of AR applications as a whole are good (average = 3.104), as seen in Figure 6.

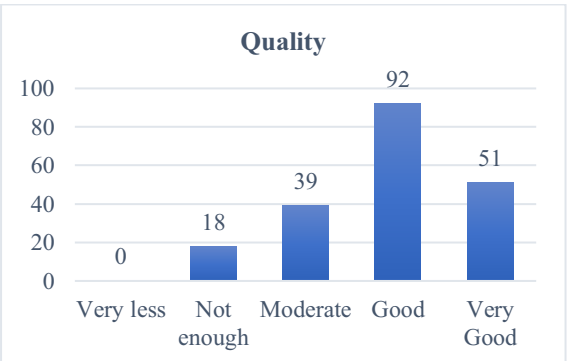

Figure 6 Respondent responses to Quality aspects

Based on the picture, 51 respondents rated it as very good, 92 said it was good, 39 said it was quite good, and 18 respondents said it was poor. So, even though this instrument is in good condition, it still needs to be improved in terms of appearance quality.

4.2.2. Clarity aspect of the AR application

Respondents' overall opinions regarding the clarity aspect of AR applications are quite good (average = 3.02), as seen in Figure 7.

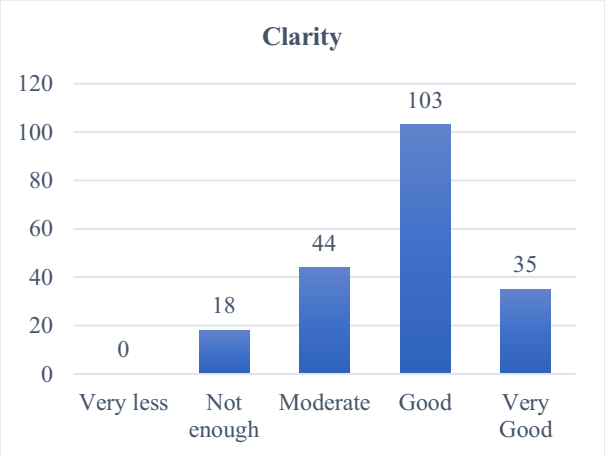

Figure 7 Respondent responses to the Clarity aspect

Based on the picture, 35 respondents rated it as very good, 103 said it was good, 44 said it was quite good, and 18 respondents said it was poor. So, even though this instrument is already at a fairly good level, it still needs to be improved in terms of the clarity of its appearance.

4.2.3. Detailed aspects of the AR application

Respondents' overall opinions regarding the detailed aspects of AR applications are quite good (average = 3.132), as shown in Figure 8.

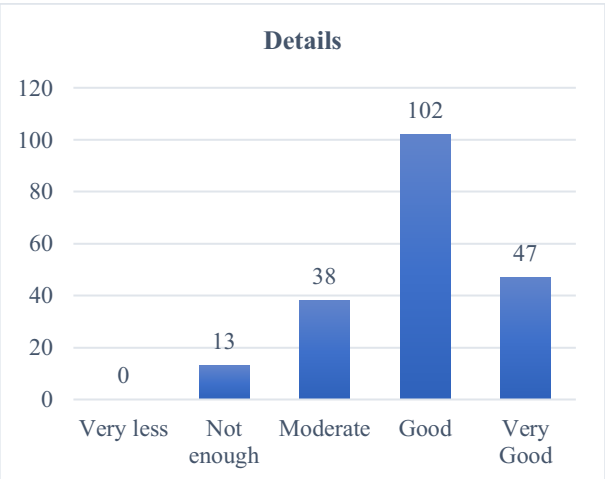

Figure 8 Respondent responses to the Details aspect

Based on the picture, 47 respondents rated it as very good, 102 said it was good, 38 said it was quite good, and 13 said it was poor. So, even though this instrument is already at a fairly good level, it still needs to be improved to provide more detail in its appearance.

4.2.4. Convenience aspects of AR applications

Respondents' overall opinions regarding the clarity aspect of AR applications are quite good (average = 3.12), as seen in Figure 9.

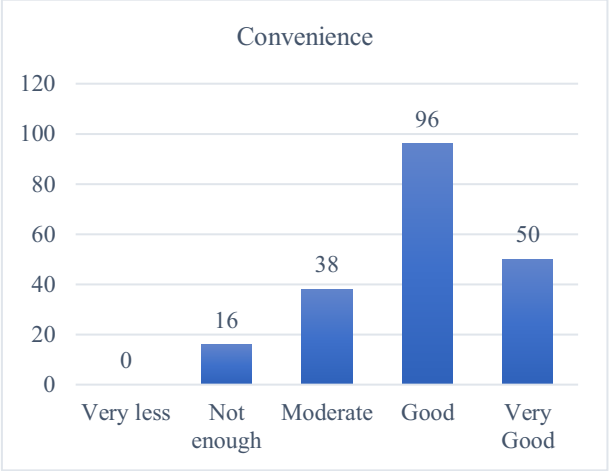

Figure 9 Respondent responses to the Convenience aspect

Based on the picture, 50 respondents rated it as very good, 96 said it was good, 38 said it was quite good, and 16 said it was poor. So, even though this instrument is fairly good, it still needs to be improved regarding respondents' comfort in using it.

4.2.5. Layout aspects of the AR application

Respondents' overall opinions regarding the clarity aspect of AR applications are quite good (average = 3.304), as seen in Figure 10.

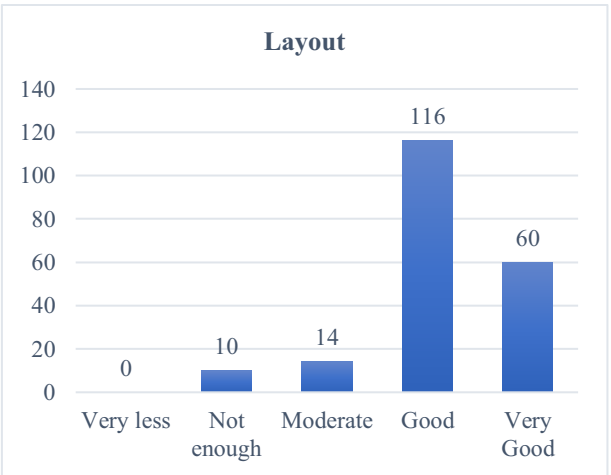

Figure 10 Respondent responses to Layout aspects

Based on the picture, 60 respondents rated it as very good, 116 said it was good, 14 said it was quite good, and there were 10 who said it was poor. So, even though this instrument is at a fairly good level, it still needs to be improved in terms of layout.

4.2.6. Conformity aspects of AR applications

Respondents' overall opinions regarding the conformity aspect of AR applications are quite good (average = 3.304), as seen in Figure 11.

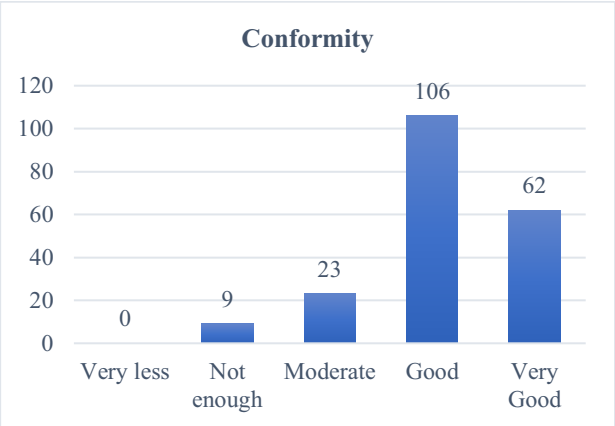

Figure 11 Respondent responses to aspects

Based on the picture, 62 respondents rated it as very good, 106 said it was good, 23 said it was quite good, and 9 said it was poor. So, even though this instrument is at a fairly good level, it still needs to be improved regarding the conformity aspect

4.2.7. Control aspects of AR applications

Respondents' overall opinions regarding the control aspects of AR applications are quite good (average = 2.844), as seen in Figure 12.

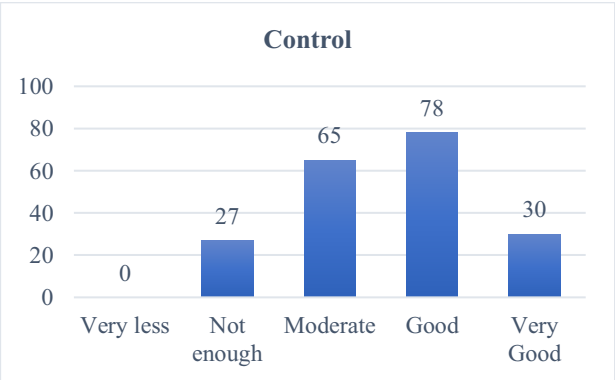

Figure 12 Respondent responses to the Control aspect

Based on the picture, 30 respondents rated it as very good, 78 said it was good, 65 said it was quite good, and 27 said it was poor. So, even though this instrument is at a fairly good level, it still needs to be improved in terms of control aspects

4.2.8. Speed aspect of the AR application

Respondents' overall opinions regarding the speed aspect of AR applications are quite good (average = 2.844), as seen in Figure 13.

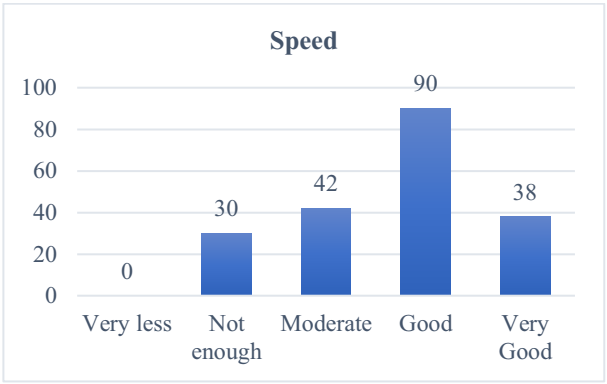

Figure 13 Respondent responses to the Speed aspect

Based on the picture, 38 respondents rated it as very good, 90 said it was good, 42 said it was quite good, and there were 30 who said it was poor. So, even though this instrument is already at a fairly good level, it still needs to be improved in speed.

4.2.9. Responsive aspects of AR applications

Respondents' overall opinions regarding the responsiveness aspect of AR applications are quite good (average = 3.212), as seen in Figure 14.

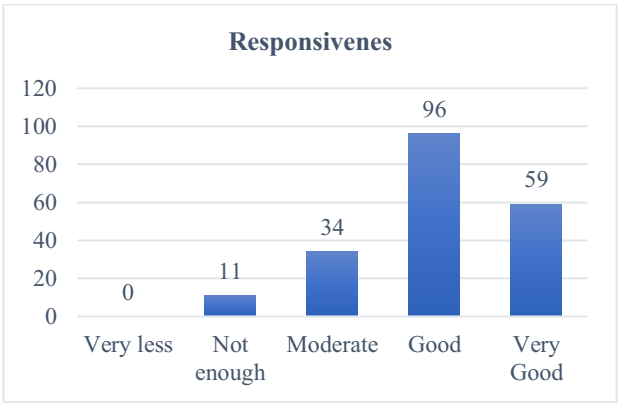

Figure 14 Respondent responses to the Responsiveness aspect

Based on the picture, 38 respondents rated it as very good, 90 said it was good, 42 said it was quite good, and there were 30 who said it was poor. So, even though this instrument is at a fairly good level, it still needs to be improved in terms of responsiveness.

4.3. Respondents' Responses to the Material Content of the AR application.

4.3.1. Quality aspect of the material presented in the AR application

Respondents' opinions regarding the quality aspect of the material presented in the AR application as a whole are quite good (average = 3.024), as seen in Figure 15.

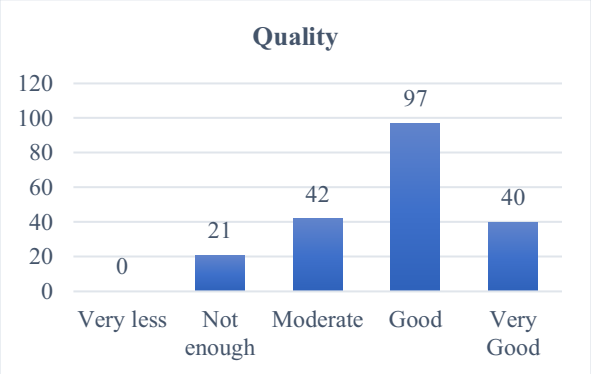

Figure 15 Respondent responses to Quality aspects

Based on the picture, 40 respondents rated it as very good, 97 said it was good, 42 said it was quite good, and 21 said it was poor. So, even though this instrument is at a fairly good level, it still needs to be improved to suit the aspects of the material presented in the AR application.

4.3.2. Complete material aspects are presented in the AR application

Respondents' opinions regarding the detailed material aspects of the AR application as a whole were quite good (average = 3.196), as seen in Figure 16.

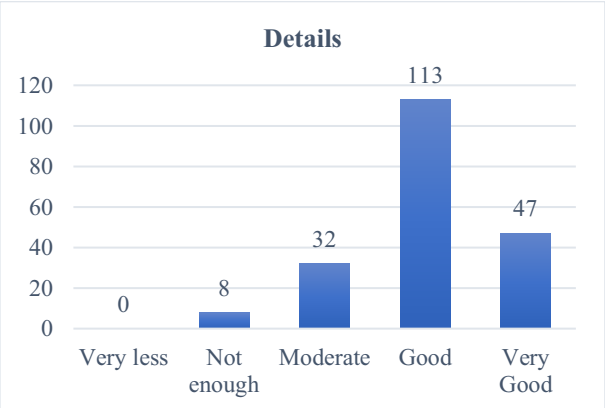

Figure 16 Respondent responses to the Details aspect

Based on the picture, 47 respondents rated it as very good, 113 said it was good, 32 said it was quite good, and there were 8 who said it was poor. So, even though this instrument is already at a fairly good level, it still needs to be improved to suit the complete material aspects presented in the AR application.

4.3.3. Characteristic aspects according to the topic of the teaching material presented in the AR application

Respondents' opinions regarding the characteristic aspects of the material presented on the topic of teaching material content in the AR application were overall good (average = 3.136), as seen in Figure 17.

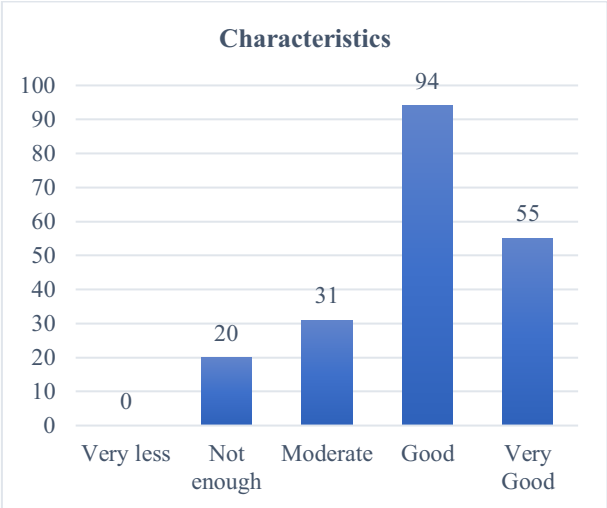

Figure 17 Respondents' responses to the Characteristics aspect

Based on the picture, 55 respondents rated it as very good, 94 said it was good, 31 said it was quite good, and 20 said it was poor. So, even though this instrument is at a good level, it still needs to be improved to suit the characteristic aspects according to the topic of the teaching material presented in the AR application.

4.3.4. Aspects of relevance to the topic and content of the teaching material presented in the AR application

Respondents' opinions regarding the level of relevance of the material presented by the topic of the content of the teaching material in the AR application were overall good (average = 3.136), as seen in Figure 18.

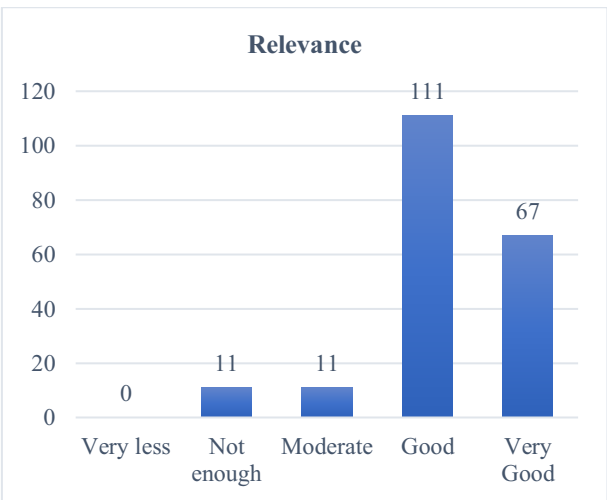

Figure 18 Respondent responses to the Relevance aspect

Based on the picture, 67 respondents rated it as very good, 111 said it was good, 11 said it was quite good, and there were 11 who said it was poor. So, even though this instrument is at a good level, it still needs to be improved in terms of the level of relevance according to the topic of the teaching material presented in the AR application.

4.3.5. Interest aspect of the content of the teaching material presented in the AR application

Respondents' opinions regarding the level of interest in the topic and content of the teaching material presented in the AR application were overall good (average = 3,200), as seen in Figure 19.

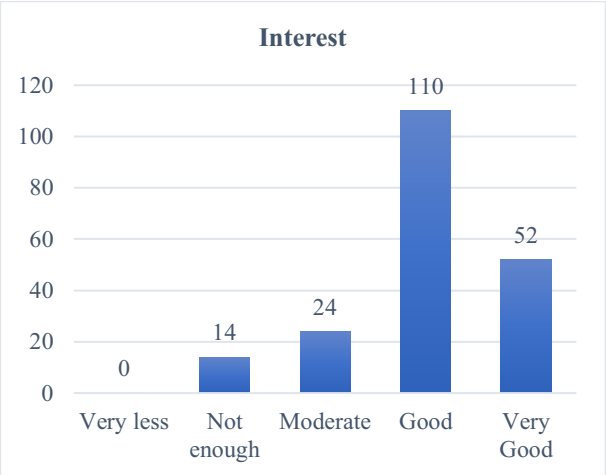

Figure 19 Respondent responses to the Interest aspect

Based on the picture, 52 respondents rated it as very good, 110 said it was good, 24 said it was quite good, and 14 said it was poor. So, even though this instrument is at a good level, it still needs to be improved so that interest in the topic and this teaching material will be good.

5. CONCLUSION

The AR application development process involves several stages, starting from the in-depth study of teaching materials, and development of accurate 3D models, to the integration of these models into the AR environment. The app is designed with an intuitive interface and interactive features such as zoom and rotation, allowing students to manipulate and study building structures in a more in-depth and practical way.

Application testing and evaluation were carried out involving 200 students from five DPIB classes at SMK Negeri 6 Bandung. The evaluation results show that this AR application received positive responses from students. The quality aspect of the application was assessed as good with an average score of 3,104, while the clarity and detail aspects also received a good assessment but still require further improvement. Responses to the material delivered via the AR application also showed positive results, with aspects of relevance and interest in the topic receiving high marks. Thus, the use of AR-based learning media has been proven to increase students' understanding and involvement in KUG learning at vocational schools. AR technology provides a more interactive and interesting learning experience, in line with the needs of 21st-century education, which emphasizes "The 4Cs" competencies-Communication, Collaboration, Critical Thinking, and Creativity. Thus, implementing AR in learning media can be an innovative solution to improve the quality of education in vocational high schools.

AUTHORS' CONTRIBUTIONS

Muhammad Rafly Favian Jiwani was responsible for **the concept and design of the research**, including the development of 3D models and the Augmented Reality (AR) application used in this study. He also played a role in data collection and analysis of research results.

Asep Yudi Permana provided **guidance and supervision throughout the research process**. He contributed to formulating the research methodology and offered critical input on the design and implementation of the AR application. Additionally, he acted as **the primary correspondent** and wrote and edited **the research article**.

Indah Susanti was involved in **data analysis and interpretation of research results**. She also assisted in preparing the literature review relevant to the research topic and contributed to writing the discussion section of the research findings.

Juang Akbardin was **responsible for field data collection and coordination with the school**. He also participated in testing the AR application. He contributed to preparing **the research report and writing the article**.

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