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Developing augmented reality on differential system, competency system, and power transfer in vocational education

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ABSTRACT

This study aimed to know: (1) Describe the development of augmented reality books in the differential system; and (2) Analyze the feasibility level of the application on the augmented reality book differential system. This study uses research and development (R&D) with the waterfall development design model, which includes four stages: analysis, design, coding or implementation, and testing. This study's sample was 11th-grade vocational high school students majoring in automotive light vehicle engineering. Application testing uses black-box testing by testing functionality without testing the internal structure or function of the application. The data collection used in this study included three media experts, three material experts, and 30 user responses (students) with data analysis techniques using descriptive analysis. The results of this study are (1) augmented reality books and applications on the android platform as learning media on the differential system, and (2) feasibility analysis by media expert validation with an average value of 80%, material experts with an average value of 84% and user responses with an average value of 90 % with a total value of 85% with the 'very eligible' category to be used as a learning medium in the differential system of chassis and power transfer competencies. Research products can be used as an attractive alternative learning media by utilizing digital technology that can display 3D objects in detail on the competence of the differential system.

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INTRODUCTION

Vocational high schools (SMK) are formal educational institutions that focus on preparing students for competencies in specific fields (Putra & Novelan, 2020). Vocational High School is devoted to preparing students to compete in the world of work and have competence and creativity following the needs of today's industry (Amin, 2017). Compared to schools in general, SMK has specific characteristics, including: (1) being Oriented to the competence of students in the world of work, (2) the need for equipment and logistics that are more realistic and expensive, (3) the curriculum focuses on cognitive, affective and psychomotor development, (4) sensitive to the development of society, technology, and the business world, and (5) closely related to society and the business world (Khurniawan, 2016). The existence of SMK is expected to be an institution that can print graduates into skilled and professional workers (Farman et al., 2018). This can happen if the learning process in schools can be synchronized with the needs of the industry, which is run on an ongoing basis.

Applying to learning with industrial standards in vocational schools prioritizes the achievement of students' competencies and hard skills, and soft skills. Soft skills are born from the practice of student experience, including individual and social communication, while hard skills are students' abilities in a particular field (Putri et al., 2019). Improving students' hard and soft skills can be achieved through a planned learning process concerning industry standards. Planned learning creates a practical and interactive atmosphere (Junaedi, 2019). The application of learning media is packaged attractively as a supporting medium in transferring knowledge from educators to students.

For learning activities to attract students' interest so that the learning atmosphere is more conducive and fun, it can be influenced by various factors, one of which is the selection of the learning media used (Hakim, 2018). Learning media is an intermediary that facilitates the communication process between educators and students. Currently, learning media continues to develop, especially in the industrial era 4.0, where the development of information technology is increasingly rapid through the use of the internet, causing learning media to be more diverse and innovative.

The development of digital technology in education is increasingly directing learning documents in digital learning materials (Ramdani et al., 2021; A. K. Sari et al., 2020). Learning media are grouped into four types, namely (1) visual media involving the sense of sight, (2) audio media involving the sense of hearing, (3) audiovisual media involving the senses of sight and hearing, (4) multimedia involving several types of media and integrated equipment in the learning process (Asyhar, 2011). The development of information technology is required educators to mix technology and learning into learning media that is fun, creative, innovative, and effective. One of the developments of learning media now is using Augmented Reality technology.

Augmented reality is a technology that unites the natural and virtual worlds by entering graphic, audio, sensory, touch, smell, and taste information from the real-world environment into the virtual world so that users can interact with virtual images (Papanastasiou et al., 2019). Augmented reality was discovered around 1957-1962 by Norton Heilig. Then in 1966, it developed into Head Mounted Display (HMD). Then in the 2000 era, to be precise, 2009-2010, Augmented Reality (AR) continued to be developed from FLARToolkit to become the current augmented reality (Hakim, 2018). The existence of augmented reality presents many advantages compared to other technologies, namely: (1) interactive, (2) effective, (3) easy to use in various media, (4) simple depiction of objects, (5) does not cost a lot, and (6) easy to use (Hakim, 2018). These advantages have made augmented reality the best choice for developing interactive learning media.

Based on a preliminary study in the form of distributing questionnaires to students in SMK, percentage data on the level of interest in learning media that use augmented reality technology can be seen in Figure 1.

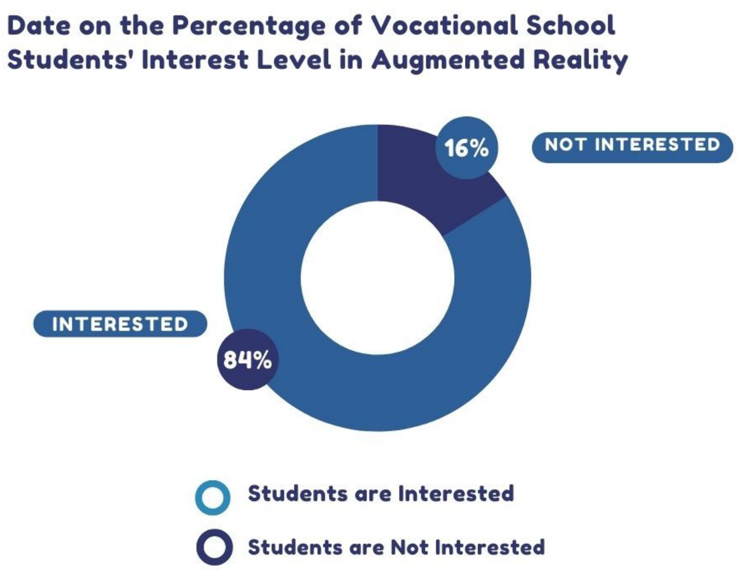

Figure 1. Data on the Percentage Level of Interest of SMK Students in AR

In the picture above, based on the distribution of questionnaires to 11th-grade students of the light vehicle engineering department, as many as 84% of students agreed with the existence of learning media using augmented reality technology as an innovation. As many as 16% stated that students disagreed. This shows that student interest in learning media using augmented reality technology is enormous.

According to Kiryakova et al. (2018), the role of technology and information, such as augmented reality, in education is critical because it can create conditions and accessibility. The augmented reality application is suitable for use at every level of education with various learning materials (R. M. M. Sari & Priatna, 2020). Augmented reality can help students learn, especially in Vocational High Schools (SMK) (Sulistyoko & Armanto, 2020). Augmented reality in vocational high schools, especially in the Automotive Light Vehicle Engineering (TKRO) department, requires tools to achieve successful learning. This technology will be very profitable and efficient because institutions do not need to present fundamental tools that can be cost-effective. At the same time, students can still perform realistic interactive learning (Kurniawan & Masugino, 2020). However, it is miserable that augmented reality in the TKRO department still needs to be used more. This is influenced by several factors, one of which is the lack of understanding of educators on augmented reality (Ismail & Nasrulloh, 2020).

Automotive Light Vehicle Engineering (TKRO) is an automotive engineering expertise program focusing on technology and engineering (Utomo, 2020). Through this program, students are expected to be able to repair and maintain vehicles independently. A differential system is one of the essential competencies in Automotive Light Vehicle Engineering (TKRO). A differential is a tool that is devoted to the transfer of car power. The goal is to compensate for the difference in speed at the rear wheels while passing through a cornering field (Utomo, 2020). Based on the results of interviews with teachers majoring in Automotive Light Vehicle Engineering (TKRO) at SMK Negeri 4 Serang City, the differential system is one of the essential competencies that can be a priority in applying augmented reality technology to learning media.

This is due to several factors, namely: (1) Many small components on the inside of the differential make it difficult for educators to explain the meaning and function of these components so that augmented reality can be a solution by projecting 3D objects with complex concepts, especially when combined with audio and animation, educators need to explain repeatedly in class (Yuliono et al., 2018); (2) The use of learning media is still conventional and only relies on power points and learning modules, so if augmented reality is applied, it will attract the interest of students and make the learning atmosphere in the classroom more interactive; and (3) The availability of trainer tools that are not up to standard can be solved by augmented reality because institutions do not need to present fundamental tools so that they can be cost-effective. At the same time, students can still carry out practical, interactive learning.

Problems in vocational high schools include the availability of practical tools and the use of conventional learning media. Augmented reality as a learning medium born of advances in information technology today will greatly assist educators in transferring knowledge to students so that it can be the right solution. Based on the description above, it is necessary to conduct a study regarding the development of augmented reality books on differential system competence chassis and power transfer for vocational high schools with the research objectives, namely; (1) describes the development of the augmented reality book on the differential system, and (2) analyzes the feasibility level of the application on the augmented reality book differential system. This research develops augmented reality technology into learning media in the form of AR Books and applications on the Android platform to support the differential system's competence.

RESEARCH METHOD

This study uses a Research and Development (R&D) approach with a Waterfall development design model, which consists of 4 stages: needs analysis, design, coding, and testing (Yuliono et al., 2018).

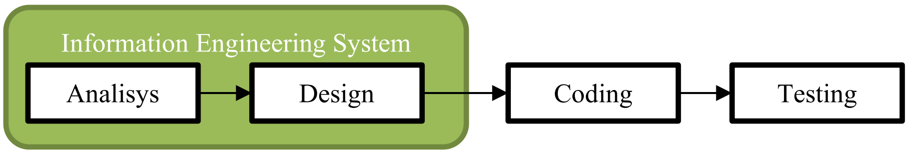

Figure 2. Waterfall Model

Needs Analysis

The needs analysis stage is a way to find the information needed to support application development. At this stage, interviews and observations were carried out with teaching teachers at SMKN 4 Serang City as well as distributing questionnaires and simulating the use of applications to 11th grade students majoring in automotive light vehicle engineering to find out the students' interest in augmented reality. The research population was 90 people who came from classes A, B and C. After that, they prepared all the supporting software and hardware needs to make augmented reality books and develop applications.

Design

The design stage is the step of designing what needs are contained in the Augmented Reality application that will be developed. Several design processes are carried out at this stage, namely, system architecture design, 3D object design, and user interface design.

Coding

The design that has been made is then applied, or coding is carried out into the application that will be developed in the form of a differential system learning media. The software used in this coding is Unity 3D with the programming language C sharp.

Testing

The stages of designing and coding differential system learning media with Augmented Reality have been completed. Furthermore, testing with black box testing and feasibility tests by material and media experts.

Research Subject

The subjects of this research are media experts consisting of 1 lecturer of Informatics Engineering, Universitas Serang Raya and 2 senior programmers who work at the Pension Fund of Bank Negara Indonesia (BNI) and PT Karios Utama Indonesia, material experts consisting of 2 instructors in the automotive field, the Training Center Vocational and Productivity (BBPVP) Bandung and 1 teacher at SMKN 4 Serang City. The user response involved 30 students of grade 11 majoring in TKR at SMKN 4 Serang City. The time of research was carried out from March - December 2021.

Data Collection Technique

Data collection techniques are steps to obtain data during observation so that research results can be used as new theories or discoveries (Sidiq & Choiri, 2019). To obtain information and data in this study using data collection techniques such as observation, interviews, and literature studies to get the necessary information to analyze the developed media needs. The questionnaire aims to determine the assessment of media experts, materials, and users on the products made.

Research Instruments

Aspects and indicators of the research instrument are based on three instruments aimed at media experts, material experts, and users (Wahono, 2006).

Table 1. Media Expert Instruments

Aspect	Indicator	Question
Visual Communication	Media suitability with Basic Competencies and Objectives	1,2
	Audiovisual	3,4,6,7,10
	Text	5,8,9
	Layout Interactive	11,12,15,16
Software engineering	Smooth operation and media compatibility	13,17
	Usability	14,18

Table 2. Material Expert Instruments

Aspect	Indicator	Question
Learning design	Goal relevance learning with basic competencies	1,2,3
	Audiovisual compatibility	4,5,6
	Grammar	7,8
Material Depth	Material Actuality	9,10,11,12
	The accuracy of the evaluation tool	13,14
Benefit	Overcoming the limitations of practical tools	15,16
	Benefit for teachers and students	17,18

Table 3. User Instruments

Aspect	Indicator	Question
Learning design	Interactivity	1,2
	Flexibility	3,4
	Grammar	5,6
Visual	Display (Audiovisual)	8,10,11,12,13
Communication	Text	7,14
Software	Ease of operation	15,16,17
	Usability	9,18,19
Material Depth	Material actuality	9,18,19
	Evaluation Accuracy	20,21
	Giving motivation to learn	22,23
Benefit	Overcoming the limitations of practical tools	24,25
	Increase spirit	26,27

Data Analysis Technique

The data analysis technique uses descriptive qualitative data analysis generated from interviews, observations, and comments or suggestions of validators to be used as a reference for improving learning media and quantitative descriptive data analysis generated from the distribution of validator and user questionnaires to determine the feasibility of the learning media developed.

Table 4. Categories of Likert Scale

Score	Interpretation
4	Very Appropriate
3	Appropriate
2	Less appropriate
1	Not appropriate

The average percentage of student responses for each component is calculated using the Formula 1 (Sugiyono, 2013).

$$P = \frac{\sum x}{N} \text{x } 100\% \quad (1)$$

Information:
P = Gained percentage of respondents of experts and users
$\sum x$ = Total score for each criterion selected by the respondent
N = Total ideal score

The validation criteria or level of attainment used in the development of instructional media can be seen in Table 5. Based on the Table 5, the eligibility criteria accepted in this study are at least included in the "Appropriate " criteria with an achievement level in the 62.50 - 81.24% range.

Table 5. Achievement Level of Media Development

Achievement Level	Criteria
81,25 - 100%	Very Appropriate
62,50 – 81,24%	Appropriate
43,75 – 61,40%	Less appropriate
25% - 43,74%	Not appropriate

RESULT AND DISCUSSION

The results of learning media development are the augmented reality application of differential system competencies on the android platform and AR Book as supporting applications.

Figure 3. Application Name and Logo

The name of the augmented reality application for differential system competence is called “Ruang Otomotif AR”.

Figure 4. Splash Screen

The splash screen page is an application name branding that appears a few seconds before entering the main menu page. This page displays the application logo in the form of a ring gear as a characteristic of the differential system with the application name "Ruang Otomotif." The bottom of the page displays the Unity 3D logo as a software developer.

Figure 5. Main Menu

The main menu page is the main page that displays several buttons that are linked to other pages. The main page display has the application logo as well as several menus presented by the application that can be accessed by users, including; the augmented reality scan menu to scan the camera on markers, developer profile menu, Competency Standards & Basic Competence (SK&KD) menu, namely the differential system, manual user menu as a user guide in running applications, differential system material menu, practice questions menu, marker download menu, and application exit menu.

Figure 6. Instructions for Use

Figure 7. Developer Profile

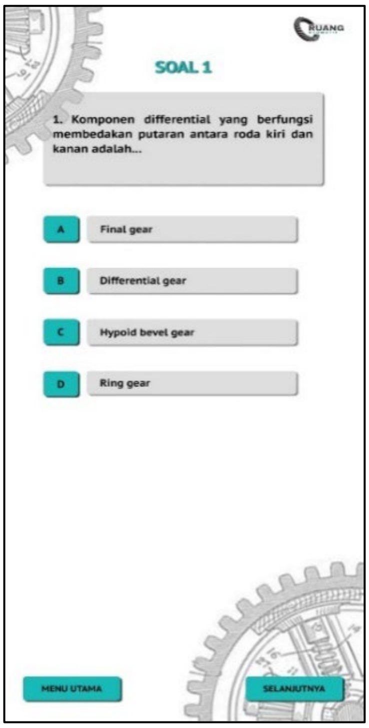

Figure 8. Learning Materials

Figure 8 shows the learning material page that summarizes the material and references the differential system. The material presented in 5 slides includes understanding differential, differential function, final drive parts, differential parts, how the differential works when going straight and turning, and inspection before and after being unloaded. This page is an initial introduction and theoretical guide for users to understand differential systems before projecting 3D objects on the AR scan menu.

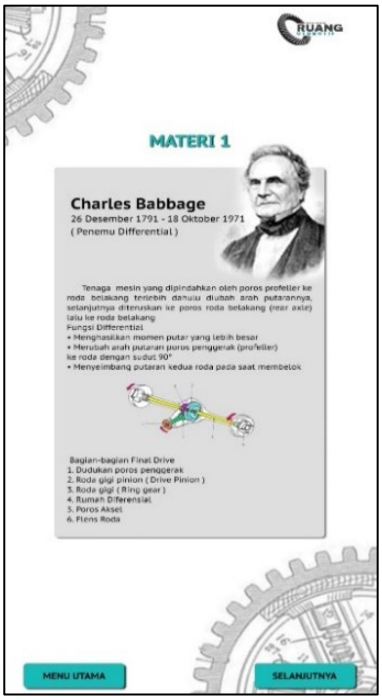

Figure 9. Practice Questions

Figure 9 shows 10 practice questions that cover the material on differential systems. The practice questions consist of multiple choice, where the user can choose one answer to determine whether it is correct. The purpose of this page is to become a benchmark in knowing the extent of user understanding after studying the material. In addition to the application, there is also an AR Book that functions as a support for the application. The AR Book contains instructions for use, and a summary of materials and markers for performing AR scans can be seen in Figure 10, Figure 11, and Figure 12.

Figure 10. AR Book Cover

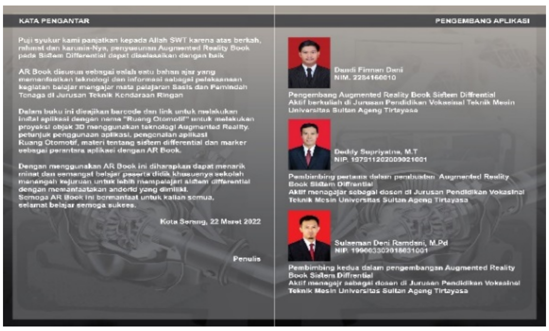

Figure 11. Foreword and Developer Profile

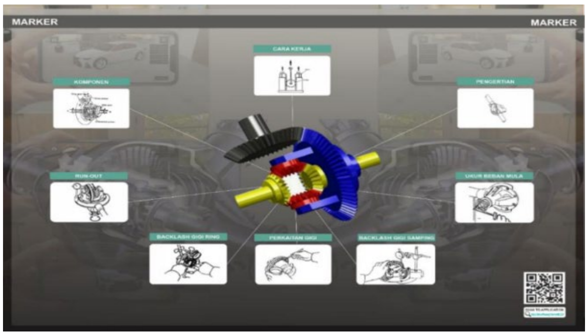

Figure 12. Main Marker in AR Book

The augmented reality scan page is a page for scanning markers by clicking the scan button. Users can directly pair the marker with the camera and wait a few seconds. The application will project a 3D differential object.

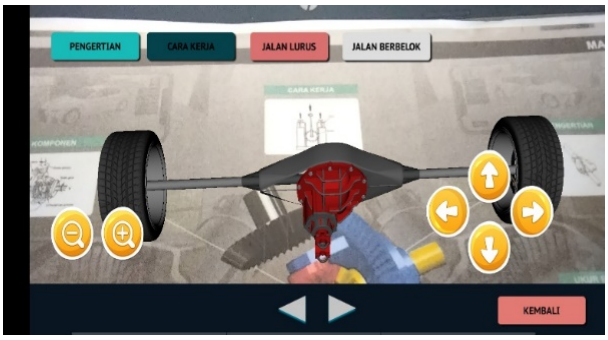

Figure 13. AR Scan Understanding Differential

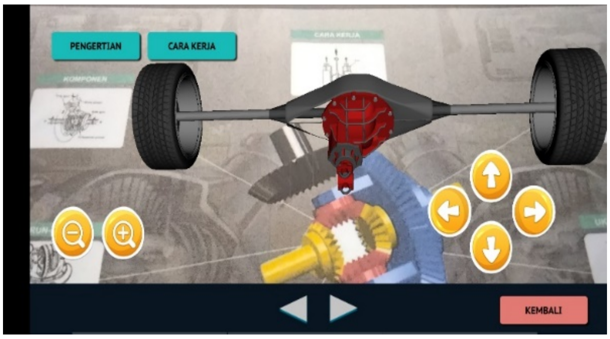

Figure 14. AR Scan How Differential Works

Figures 15 and Figure 16 are the first scenes that display 3D objects on the understanding and workings of differential materials. In addition, users can use zoom-in and zoom-out buttons to further clarify the observation of 3D objects, additional audio to explain the material, and motion animation on 3D objects to make the application more interactive.

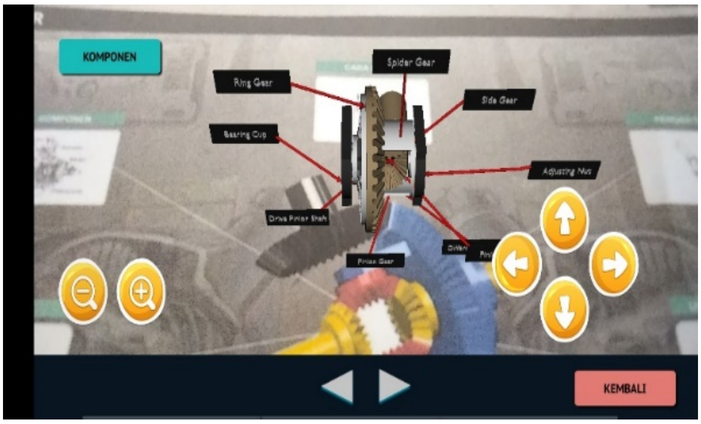

Figure 15. AR Scan Component Introduction

Figure 17 is the second scene displaying differential 3D objects in component recognition material. There are arrows and component name signs on this page that make it easier for users to identify all differential components. In addition, there are zoom-in and zoom-out buttons that users can use to further clarify the observation of 3D objects, additional audio explaining the function of each component, and motion animation on 3D objects to make the application more interactive.

Figure 18 is the third scene, a periodic differential inspection by displaying 3D objects with additional audio to explain the details and inspection procedures. In addition, users can use zoom-in and zoom-out buttons to further clarify the observation of 3D objects to make the application more interactive. Differentials' inspections include side gear inspection, run out, initial load, ring gear, and gear linkage.

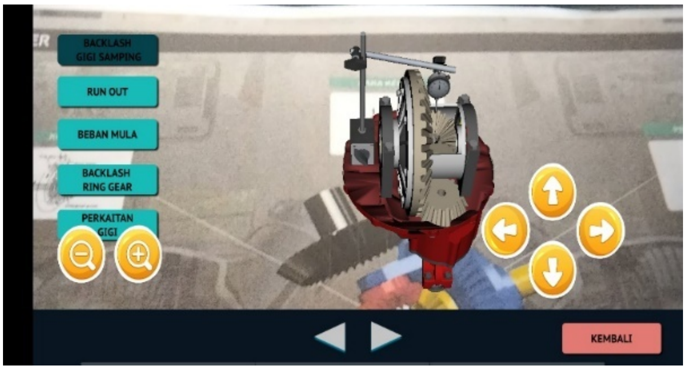

Figure 16. Side Dental Examination

Figure 17. Run Out Check

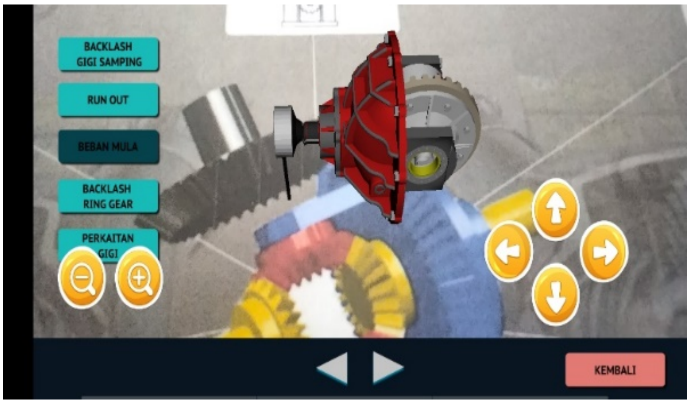

Figure 18. Starting Load Check

Figure 19. Ring Dental Examination

Black Box Testing Results

The way to determine the application's performance is to test the functionality without understanding the program code by testing black box testing. Testing is done by installing the application using an Android version of the device with different device specifications. The following table shows the results of the black box testing of the augmented reality system differential application with 5 other devices with the symbol (P), as can be seen in Table 6.

Table 6. Device Specifications for Testing

Statement	P1		P2		P3		P4		P5	
	Works (F)				Not Working (TF)					
	F	TF	F	TF	F	TF	F	TF	F	TF
Successfully Install Apk	√		√		√		√		√	
Functions of Each Button	√		√		√		√		√	
Rotation function (zoom in & zoom out 3D objects)	√		√		√		√		√	
Scan Camera function (Displaying 3D objects)	√		√		√		√		√	
Motion animation function	√		√		√		√		√	
Showing Correct Answer	√		√		√		√		√	
Audio Function	√		√		√		√		√	
Download Marker Function	√		√		√		√		√	

Validity Test Results

Media Expert

The feasibility of learning media for the augmented reality differential system application assessed by three media experts includes visual communication and software engineering, as seen in Table 7. Based on Table 7, the average value of the results of media expert validation in the visual communication aspect is 80%, with software engineering an average value of 81% and the overall average value of 80% in the "Appropriate " category.

Table 7. Results of the Media Expert Assessment Recapitulation

Aspect	Maximum Score	Total Score	Percentage	Category
Visual Communication	168	133	80%	Appropriate
Software engineering	46	39	81%	Very Appropriate
Average Amount	214	172	80%	Appropriate

Material Export

The feasibility of the augmented reality differential system application assessed by three material experts includes aspects of learning design, material depth, and benefits, as seen in Table 8. Based on Table 8, the average value of the results of material expert validation in the learning design aspect with an average value of 82%, the depth of material with an average value of 77%, benefits with an average value of 94%, and the overall average value of 84% in the "Very Appropriate" category.

Table 8. Results of the Material Expert Assessment Recapitulation

Aspect	Maximum Score	Total Score	Percentage	Category
Learning Design	96	79	82%	Very Appropriate
Material Depth	72	57	77%	Appropriate
Benefit	48	45	94%	Very Appropriate
Average Amount	26	181	84%	Very Appropriate

User Response

The augmented reality differential system application is rated by 30 users to determine how the user responds to the application. The aspects used are visual communication, software engineering, learning design, depth of material, and benefits, as seen in Table 9.

Table 9. Results of User Response Assessment Recapitulation

Aspect	Maximum Score	Total Score	Percentage	Category
Learning Design	720	618	86%	Very Appropriate
Visual Communication	840	765	92%	Very Appropriate
Software engineering	360	327	91%	Very Appropriate
Material Depth	840	771	92%	Very Appropriate
Benefit	480	424	89%	Very Appropriate
Average Amount	3240	2905	90%	Very Appropriate

Based on Table 9, the average value of the results of the assessment of user responses in the learning design aspect with an average value of 86%, visual communication with an average value of 92%, software engineering with an average value of 91%, depth of material with an average value of 92%, benefits with an average value 89% and the results of the overall average value of 90% with the "Very Appropriate " category.

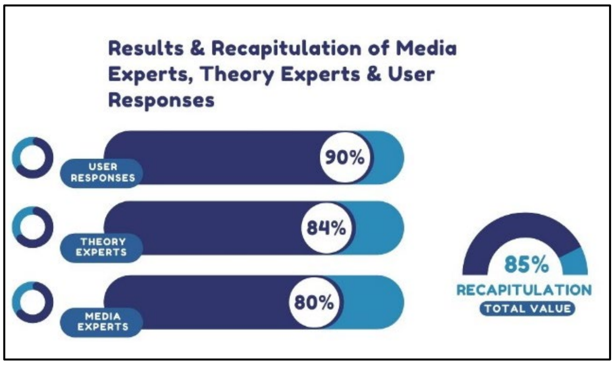

Figure 20. Results of Assessment Recapitulation

Based on the results of the recapitulation of expert judgments and user responses, the average value of media experts is 80% in the "Decent" category, material experts 84% in the "Very Eligible" category, and 90% user responses in the "Very Eligible" category. The average value of the three media experts, material experts, and users obtained a total score of 85% with the "Very Eligible" category.

Research conducted by Anugrah and Alfian (2020) regarding augmented reality on the main components of a car engine produces an augmented reality application that projects a 3D object of a car engine component with an additional application feature, namely rotate. Different research was also carried out by Kurniawan and Masugino (2020), who discussed augmented reality in differential for SMK students. The research resulted in a differential competency augmented reality application for class XI SMK that can be operated on Android. Tests are carried out directly on material experts and material experts without testing the performance or functionality of the application first so that it can minimize the occurrence of hangs, crashes, or buttons that are not according to orders when the application is used.

From the previous studies above, this research has several advantages, including the content presented in the application being more complex and interesting, such as motion animation on 3D objects. In addition to buttons to rotate, there are also buttons to zoom in and out to see more details of differential and additional objects. Audio that explains each scene that is displayed. In addition, this research also conducted black box testing to determine the application's functionality.

CONCLUSION

The conclusions obtained in this study are as follows. First, the resulting product is an augmented reality book and a differential system competency application on the android platform. This application has main components, namely (1) The main menu page, which contains buttons to other pages; (2) The developer profile page contains profiles of developers and mentors in making the application; (3) The user manual page, which contains steps for using the application; (4) The material page contains an introduction to the material Differential System and its references; (5) The exercise page contains materials for evaluating student understanding d) The marker download page contains the marker file and AR Book; and (6) The AR scan page is the most important page in projecting differential 3D objects which consists of three scenes, namely introduction and how it works, component recognition and differential examination. Second, the functionality test results using black box testing with testing on five different devices show that all functions in the application can run as ordered, so it is said to be feasible to use. The feasibility level was obtained from the validation of media experts, with an average of 80% in the "appropriate" category, material experts, with an average of 84% in the "very appropriate " category, and the validation of user responses on average 90% with the "very appropriate " category used. Based on the average results of the three validation tests, the augmented reality application on the differential system competence is said to be "very appropriate" for use in vocational high schools. The results of this study have yet to reach the stage of testing application performance efficiency and testing the effectiveness of learning media, so suggestions for further researchers can follow up on this in different competencies.

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