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Development of Augmented Reality Applications as Learning media for Machine Assembly and Installation

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Abstract: There are several courses at the State University of Malang, Faculty of Engineering, Mechanical Engineering Department, one of which is Machine Assembly and Installation which studies knowledge related to management, procedures and materials used to assemble and install machines. The learning process is not optimal because there is no demonstration of the use of lifting aircraft due to limited availability. Therefore, learning media innovations are needed that aim to contain comprehensive material and visualizations lifting aircraft in 3D. Digital AR learning media that is easy to operate by students flexibly. Developing augmented reality-based learning media on lifting aircraft for engine assembly and installation courses and testing its feasibility are the objectives of this study. This development uses the ADDIE model. The results of this study are as follows: (1) material validation obtained a percentage value of 94.31%, which is classified as very feasible; (2) media expert validation showed the feasibility level with a percentage of 93.75%; and (3) the results of small group trials showed a very feasible level with a percentage of 90.12%. The implication of this research is to increase learning effectiveness, increase student learning motivation and facilitate teaching lecturers in the knowledge transfer process.

Kata Kunci:
Media Pembelajaran; Perakitan dan Instalasi Mesin; Pesawat Angkat; Realitas Tambahan

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Abstrak*: Ada beberapa mata kuliah di Universitas Negeri Malang Fakultas Teknik Jurusan Teknik Mesin, salah satunya adalah Perakitan dan Instalasi Mesin yang mempelajari pengetahuan terkait manajemen, prosedur dan material yang digunakan untuk merakit dan menginstalasi mesin. Proses pembelajaran kurang maksimal karena tidak adanya demonstrasi penggunaan pesawat angkat karena ketersediaan yang terbatas. Oleh karena itu, diperlukan inovasi media pembelajaran yang bertujuan untuk memuat materi yang komprehensif dan visualisasi pesawat angkat secara 3D. Media pembelajaran AR digital yang mudah dioperasikan oleh siswa secara fleksibel Mengembangkan media pembelajaran berbasis augmented reality pada pesawat angkat untuk mata kuliah perakitan dan instalasi mesin dan menguji kelayakannya merupakan tujuan dari penelitian ini. Pengembangan ini menggunakan model ADDIE. Hasil dari penelitian ini adalah sebagai berikut: (1) validasi materi memperoleh nilai presentase sebesar 94,31% yang tergolong sangat layak, (2) validasi ahli media menunjukkan tingkat kelayakan dengan persentase 93,75%, dan (3) hasil uji coba oleh kelompok kecil menunjukkan tingkat sangat layak dengan persentase 90,12%. Implikasi penelitian ini adalah meningkatkan efektifitas pembelajaran, meningkatkan motivasi belajar mahasiswa dan memudahkan dosen pengajar dalam proses transfer ilmu.*

INTRODUCTION

The development of learning patterns can be viewed from various aspects, including the quantity of educational institutions and the quality of their human resources. For the Indonesian nation, education has a strategic value in advancing the development of human civilization (Xiang, 2024). A sound education system will produce students who become human resources with expertise, knowledge, experience, productivity, professionalism, and independence so that they can compete at the global level (Janjuriana et al., 2024; Kilag et al., 2023). Currently, scientists are considering the role of the quantity of education in improving productivity, but in the last decade, the focus has shifted to the role of the quality of education in improving the quality of people because too much focus on the distribution of the quantity of educated people will slow down progress, especially in terms of the quality of education (Goldin, 2016; Timotheou et al., 2023).

To improve the quality of people, current learning patterns have transformed from traditional learning to electronic learning through the development of e-learning systems (Maqbool et al., 2024). In electronic learning, humans must have adaptive characters in the era of science and technology changing every day (Gligorea et al., 2023; Liu et al., 2024). Implementing learning using digital resources is proven to support the quality of education. The learning process is more interactive, flexible, and oriented towards improving students' practical skills through electronic simulations to achieve educational goals (Habib, 2023).

A course that also applies to learning using digital resources in the Mechanical Engineering Department is Machine Assembly and Installation. This course aims to transfer knowledge related to management, procedures and materials used to assemble and install machines by the applied disciplines. The learning process that is carried out without a work demonstration reduces the effectiveness of student understanding, so it inhibits the direct discussion process (Miguel-Alonso et al., 2024; Mohzana, 2024). This impacts the reduced interaction between lecturers and students on the Machine Assembly and Installation material, making the learning process less optimal.

The role of learning media with the help of technology is vital in the current digital learning period, both in the classroom and outside the classroom; teaching materials in the Machine Assembly and Installation course are pretty good, but not all of them are up to date (Berlian et al., 2024). As textbooks or e-books are less attractive, students need help understanding the textbook's contents (Masuudi et al., 2024; Yuniarni & Putri, 2024). Unattractive learning media can make students bored with textbooks that are still classified as monotonous (Febrina & Setiawan, 2024; Zakaria et al., 2023). The process of moving machines in the work area is an aspect that students must understand. This refers to the tools used to move machines: lifting aircraft in hand pallets, conveyors, forklifts, and hoist cranes.

To know the physical form and know how each lift aircraft works. Students are limited by learning the lift aircraft infrastructure's limitations, this makes students unable to watch the aircraft lift directly. The lift aircraft used to move the engine is also unavailable in the UM machining engineering workshop. Based on the above problems, students need a learning media that can visualization the shape of the lift plane and contain information about the specifications and uses of the lift plane. One of the technological innovations that can support cognitive development and offer an exciting and unique learning experience is AR (Augmented Reality) technology (Alkhasawneh & Khasawneh, 2024; Baxter & Hainey, 2024).

Augmented reality is a three-dimensional visual with a fusion of real life and digital achieved by displaying digital assets, sound, and responses from other sensor devices through hologram technology innovation and displayed live (Żydowicz et al., 2024). Various applications today aim to simplify a job, whether web-based, desktop or even mobile phone-based, so many Augmented Reality (AR) genre applications run on mobile phones whose operation is easier and more efficient (Rahmat et al., 2024). Applications that are based on several aspects are devices for tracking information to objects of interest in the real world, hardware and software for processing information. Software in the form of a smartphone is used to display digital

information integrated into the natural environment to users (Pan & Isnaeni, 2024; Putra, 2024; Rakha, 2024).

Combining the digital and natural worlds will create a more effective learning process. This AR approach is an achievement of the educational vision in Human Resource Development (Familoni & Onyebuchi, 2024; Koumpouros, 2024; Lase et al., 2024). This concept utilizing the built-in camera on learners' mobile devices to capture real-world views. The captured images are then processed using computer-vision algorithms, which analysis and recognize objects detected by the camera. The advantage of this approach is its ability to display virtual objects simultaneously with real-world objects in accurate and appropriate positions. In addition, it also supports the detection of both two-dimensional and three-dimensional markers.

Previous studies on the application of AR in engineering education show promising results in improving students' understanding of learning materials (Abdillah & Widodo, 2024; Kamaludin et al., 2024; Wahyuanto et al., 2024). However, there still needs to be a gap in the development of AR applications tailored to the specific needs of machine assembly and installation, especially at higher education institutions such as universities in Indonesia. Most research still focuses on the visualization aspect of components without paying attention to procedural details or more comprehensive interactive aspects.

There are several studies related to the development of augmented reality learning media such as interior building design at vocational high schools in building engineering, but there is a research gap of the evidence gap type. Researchers evaluate the development of AR media that supports learning with images, text, audio, video, and 3D shapes. However, the results of the AR media developed have no audio explanation of the material and no 3D animation. This is also reinforced by the results of the trial which states that the 3D display is not perfect so that improvements are needed (Sahria et al., 2024). This research also aims to perfect AR learning media from previous research and strengthen the novelty of AR learning media development. The novelty of this research is that the material compiled based on the curriculum and learning outcomes of the machine assembly and installation course includes understanding, how to use, and parts of each lifting aircraft (hand pallet, conveyor, hoist craine and fork lift). This learning media not only focuses on 3D object visualization but also features zoom in, zoom out and object rotation in four directions (up, down, right and left). In the lift aircraft section feature, the name of the section and the location of the object will be displayed. The material for using the lift plane has an audio explanation that supports student understanding in the process of assembling and installing the engine using the lift plane.

Based on these problems, in order to improve students' understanding and skills in the Engine Assembly and Installation course, especially for lifting aircraft by using learning innovations in the form of AR technology-based android application media which aims to visualization the lifting aircraft used in the Engine Assembly and Installation course.

METHOD

This research is a research and development (R&D) using the ADDIE model as the development approach. The ADDIE model is applied to evaluate the effectiveness of augmented reality (AR)-based learning media by considering the relevance of the product as a learning medium (Sugiyono, 2015). The ADDIE model consists of five main stages, namely Analysis, Design, Development, Implementation, and Evaluation. The ADDIE flow process is shown in Figure 1.

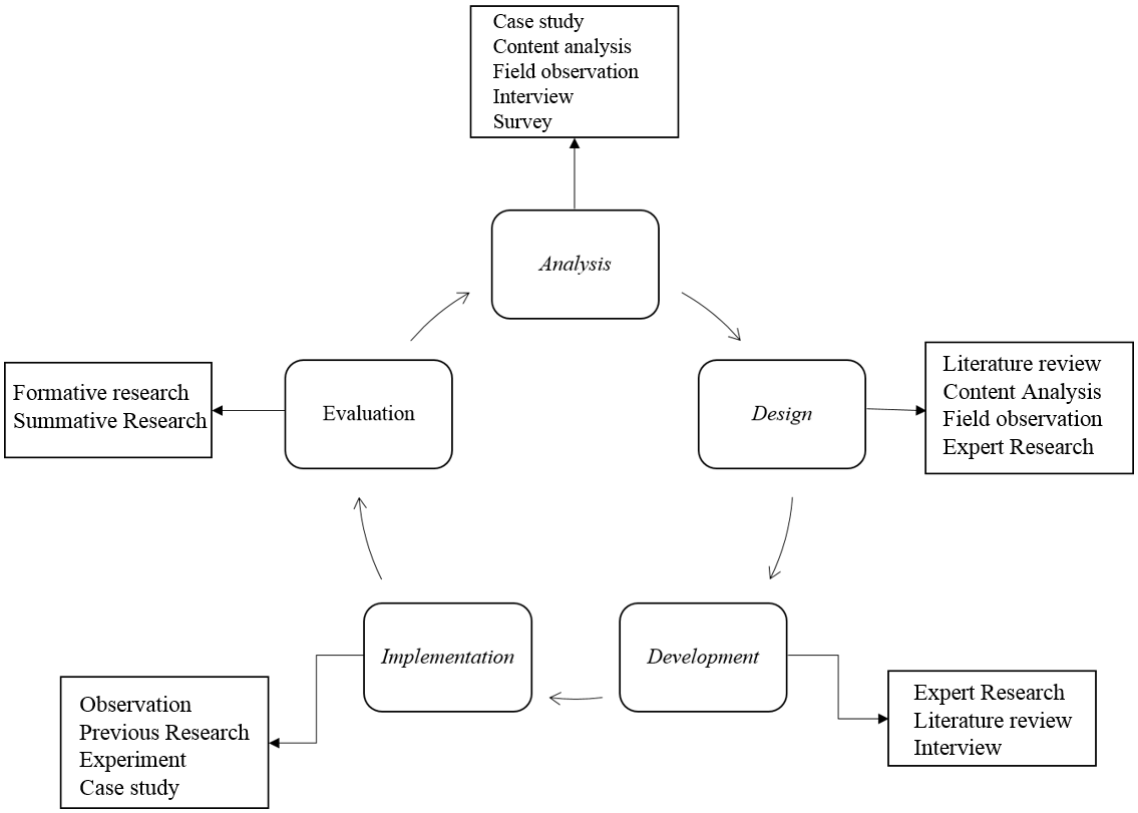

Figure 1. ADDIE research flow

The initial stage of the ADDIE model is Analysis. Activities in this stage include analysing problems in the learning process, identifying learning objectives, and evaluating the media or devices to be developed. The data obtained from this analysis is then compared with theoretical studies through literature studies to produce the right solution to the problems at hand. In the design stage, application assets, namely buttons or icons that are made customarily, the initial appearance or storyboard of the application that is adjusted to the flow of application use, and learning material designs are made.

Development is the process of realising the design that has been designed into reality. At this stage, everything needed or everything supporting the product preparation process must be prepared as a whole. The development stage consists of the process of making the appearance or user interface of the application and programming. If the storyboard has been compiled, then next, enter the application creation stage, which consists of several stages, namely designing the user interface or appearance of the application as a whole using Corel Draw X7. The application of augmented reality technology involves several software, namely Unity 3D 2019 version 4.13f1, Vuforia SDK 8.5.9, Microsoft Visual Studio 2019, and Blender 2.90.0. and Corel Draw X7.

Implementation is the stage where the system or programme that has been developed is applied. After the application has been designed and tested by the developer, validation is carried out through various stages, such as material expert validation, media expert validation, and small group trials. This process aims to get input in the form of criticism and suggestions that are used to improve the application. The research subjects consisted of Mechanical Engineering Lecturers who acted as material expert validators and media experts, as well as undergraduate students of Mechanical Engineering Education at State University of Malang as small group trial participants. Meanwhile, the object of research is augmented reality-based learning media designed for the Machine Assembly and Installation course with a focus on the topic of lifting aircraft.

The data collection instrument used is a Likert scale-based questionnaire. The purpose of using this questionnaire is to obtain quantitative data to ensure the perfection and feasibility of the developed application. Data was collected through material expert validation, media expert validation, and product trials. The research data analysis method uses descriptive methods. Descriptive statistical analysis is a type of statistical data that is used to analyse data by describing or describing the data that has been collected, without intending to make accepted conclusions or generalisations (Sugiyono, 2015). The purpose of this descriptive research is to make descriptions, describe or paint systematically, factually, and accurately about the facts, properties and relationships between the phenomena being investigated.

Data analysis using descriptive methods aims to describe data systematically, factually, and accurately without making generalisations. Descriptive statistics are used to describe the data that has been collected as it is. Measurement is carried out using a Likert scale, which makes it easy for respondents to assess their attitudes, opinions, or perceptions of certain social phenomena. Respondents are asked to provide an assessment of the application programme through a questionnaire that has been designed, by selecting the appropriate answer from the options provided. This data collection is done to evaluate the overall use of the application and improve its quality based on the feedback results. The validation results of media experts, material experts, and product trials will then produce comments and suggestions to improve this augmented reality learning application for lifting aircraft.

RESULTS AND DISCUSSION

Result

The results at the analysis stage are three aspects; the first is the analysis of problems while learning the assembly and installation of machines. Course students are less enthusiastic when participating in learning, and sometimes educators need to attract students' attention by asking questions. Second, learning outcomes or objectives should be analysed as the basis for developing learning media. Third, analysis of development tools, namely software and hardware used for the development of this application in the form of personal computers, smartphones and supporting software such as Unity 3D 2019 .4.13f1, Vuforia SDK 8.5.9, Java JDK, Microsoft Visual Studio Community 2019, Blender 2.90.0, Microsoft Word 2013.

The display design process begins with the creation of a design sketch that is used as a guide in media development. At this stage, several activities are carried out, such as designing media (storyboard), developing application assets, and determining learning materials. Based on the ADDIE development model procedure, the design stage aims to develop the initial design of the product being developed. This design includes learning outcomes that contain competencies in each learning activity. The result of this stage is a storyboard that becomes the main guideline in the application development process, as well as the creation of application assets, such as buttons or icons, which are specifically designed.

In this stage, researchers create AR-based learning media; to run the AR, researchers must create applications. The researcher's application is named "ARPA", short for Augmented Reality Aircraft Lift. Researchers assemble and arrange assets prepared using Unity 3D 2019 .4.13f1 software with the script programming language in Unity. Researchers make applications using a personal computer with Intel Core i3-9100F CPU specifications 3.60GHz (4CPUs), ~3.6GHz, 8 GB RAM, and Windows 10. on application development is also required for a programming or coding process. Script or coding is the brain of a program or application because the coding or script contains a programming language made by researchers in such a way manually. Researchers make scripts or code with the help of various sources, both from books and the internet; in preparing programming languages, researchers use script software already available in Unity 3D software.

The development stage involves the preparation of the software used, the implementation of the application based on the design that has been designed, and the process of editing the product to add or update elements such as material, appearance, or other components. The results

of this stage are in the form of several application displays that reflect the learning media that has been developed such as splash screen, main menu, AR lift aircraft menu, learning material menu, user manual menu and profile menu, each menu has its own function such as: (1) The AR menu of lift aircraft has a function to scan markers from the number of four available lift aircraft, namely hand pallet, conveyor, forklift, and hoist crane, (2) The learning material menu serves to display lift aircraft material according to the user's choice, including understanding, parts and how to use lift aircraft, (3) The menu of instructions for use serves for an explanation of how to use the Augmented Reality Lift Plane application through the user's android smartphone, (4) The profile menu to load information about the parties who participated in developing this application.

Figure 2. AR application of lift aircraft

Figure 3. Application of AR in the application

The validation of augmented reality-based learning media on lifting aircraft was validated by material experts, namely Mrs Dr Widiyanti, M.Pd, and Mr Marsono, S.Pd, M.Pd. PhD, as a lecturer at the Department of Mechanical Engineering, State University of Malang. Table 1 presents Aspects that become observations about augmented reality-based learning media on lifting aircraft.

Table 1. Material expert validation instrument results

No.	Aspects assessed	R1	R2	Σ	$\bar{X}$
1	The material in the learning media is by the CPMK of the Machine Assembly and Installation course.	4	4	8	4
2	The material in the learning media is by the learning objectives	4	4	8	4
3	The delivery of material in the learning media is presented coherently	3	4	7	3,5
4	Presentation of material in the learning media is presented in full	4	4	8	4
5	The discussion of material content in the learning media is clear	4	3	7	3,5
6	The material in the learning media is scientific truth.	3	4	7	3,5
7	Images on learning media are by the material	4	3	7	3,5

8	Use of language that is communicative and easy to understand	4	4	8	4
9	The material presented can increase learning interest	4	3	7	3,5
10	The material presented encourages students to build their knowledge	4	4	8	4
11	Through this learning media, the delivery of lifting aircraft material becomes easier	4	4	8	4

Description: R1 = Dr Widiyanti, M.Pd. R2 = Marsono, S.Pd., M.Pd., Ph.D. Σ = Total Score $\bar{X}$ = Average

Based on Table 1, six validation items (numbers 1, 2, 4, 8, 10, 11) received a score of 4, which is categorized as excellent. Meanwhile, the other five validation items (numbers 3, 5, 6, 7, 9) scored 3.5, which is also categorized as excellent. The total score on all items obtained from the material expert validation results was 41.5 out of a maximum score of 44. The results of calculating the percentage of the feasibility of the material expert results are as follows.

$$X_1 = \frac{\Sigma s}{S_{max}} \; x \; 100\%$$

$$X_1 = \frac{41{,}5}{44} \; x \; 100\%$$

$$X_1 = \; 94{,}31\%$$

Based on the results of these calculations, the percentage value is 94.31%. According to Burhanudin (2017), the content of the learning material is AR-based lifting aircraft learning media classified as very feasible.

Media validation was carried out by media experts, namely Marsono, S.Pd., M.Pd., Ph.D., and Dr Widiyanti, M.Pd., lecturer in Mechanical Engineering at State University of Malang. The validated aspects are described in Table 2.

Table 2. Media expert validation results

No.	**Aspects assessed**	**R1**	**R2**	**Σ**	$\bar{X}$
1	The file size of learning media in the form of AR applications is not large	4	4	8	4
2	The process of installing learning media in the form of AR applications is done easily	4	4	8	4
3	During operation, the app does not crash or stop	4	4	8	4
4	It does not cause the phone to freeze or stop during application operation.	4	4	8	4
5	During operation, the app does not lag or slow down.	4	4	8	4
6	Easy app operation process	4	4	8	4
7	Learning media in the form of AR applications can be run on various types of Android mobile phones today.	4	3	7	3,5
8	Information on instructions for using the application is presented clearly	4	4	8	4
9	This AR application is by the learning objectives	4	3	7	3,5
10	The design and appearance of the app are attractive	4	4	8	4
11	The selection of colors used in the application is appropriate	4	4	8	4
12	The layout of the components in the application is appropriate and neat, so it looks comfortable to look at	4	3	7	3,5
13	The text in the app is accessible to read	3	4	7	3,5
14	The selection of images in the application is correct	4	3	7	3,5
15	Images in the app are not blurry	3	4	7	3,5
16	Easy-to-access navigation buttons	3	4	7	3,5
17	The button display design is appropriate	3	4	7	3,5
18	The lovely and neat button layout	3	4	7	3,5

Description: R1 = Dr Widiyanti, M.Pd. R2 = Marsono, S.Pd., M.Pd., Ph.D. Σ = Total Score $\bar{X}$ = Average

Based on Table 2, nine validation items (numbers 1, 2, 3, 4, 5, 6, 8, 10, 11) scored 4, which is categorized as excellent. Meanwhile, the other nine items (numbers 7, 9, 12, 13, 14, 15, 16, 17, 18) scored 3.5, which is also categorized as excellent. The total score on all items obtained from the material expert validation results was 67.5 out of a maximum score of 72. The results of calculating the percentage of the feasibility of the results of the media expert are as follows.

$$X_1 = \frac{\Sigma s}{S_{max}} \; x \; 100\%$$

$$X_1 = \frac{67{,}5}{72} \; x \; 100\%$$

$$X_1 = \; 93{,}75\%$$

Based on the results of these calculations, a percentage value of 93.75% is obtained. According to Burhanudin (2017), AR-based lifting aircraft learning media is very feasible. The augmented reality application trial of lifting aircraft was conducted on 15 undergraduate students of Mechanical Engineering Education who had taken the Machine Assembly and Installation course. The quality aspects of the learning media observed are described in Table 3.

Table 3. Small Group Trial Results

Test Subject	Question												
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**
1.	3	4	3	3	3	3	4	4	3	3	3	4	3
2.	4	4	4	4	4	4	4	4	4	3	3	4	3
3.	3	3	3	3	3	4	4	4	3	3	3	4	3
4.	3	4	4	4	4	4	3	4	4	4	3	4	3
5.	4	4	4	4	4	4	3	4	4	4	4	4	4
6.	3	4	3	4	4	4	4	3	3	4	4	4	4
7.	4	4	3	4	3	4	3	3	4	3	3	4	4
8.	3	4	3	3	3	4	4	4	3	4	3	3	3
9.	4	4	4	4	4	3	3	4	4	4	4	4	4
10.	3	3	4	3	3	3	3	3	3	3	4	3	3
11.	4	3	4	3	4	4	4	3	4	4	3	4	4
12.	3	4	4	3	4	4	3	4	4	3	4	4	4
13.	4	3	4	3	3	3	4	4	4	4	4	4	4
14.	3	4	4	3	4	4	4	3	4	4	4	3	4
15.	4	4	3	4	4	3	4	4	3	3	4	4	4

Table 4. Question description for small group trial questionnaire

Question A	The file size of learning media in the form of AR applications is not significant.
Question B	The process of installing learning media in the form of AR applications is done quickly.
Question C	Information on instructions for using the application is presented clearly
Question D	During operation, the app did not crash or stop.
Question E	During operation, the app does not lag or slow down.
Question F	The process of operating the application is carried out easily
Question G	The discussion of material in the learning media is clear
Question H	The material presented can be understood easily
Question I	Use of language that is communicative and easy to understand
Question J	The design and appearance of the app are attractive
Question K	Learning media in the form of AR applications can increase student learning motivation.
Question L	Students can carry out independent learning easily
Question M	Learning objectives are more quickly achieved using this learning media

Based on Table 3, the application trial phase was sent to 15 undergraduate students of Mechanical Engineering Education who have completed the Machine Assembly and Installation course. The total score on all items obtained from the small group trial results was 703 out of a maximum score of 780. The results of calculating the percentage of the feasibility of the trial results are as follows.

$$X_1 = \frac{\Sigma s}{S_{max}} \; x \; 100\%$$

$$X_1 = \frac{703}{780} \; x \; 100\%$$

$$X_1 = \; 90{,}12\%$$

Based on the results of these calculations, a percentage value of 90.12% is obtained. According to Burhanudin (2017), this is considered very feasible. Based on material expert validation, media expert validation, and small group trials, data were obtained: material expert validation of 94.31%, media expert validation of 93.75%, and small group trials of 90.12%. This data shows that the learning media is classified as very suitable for use. The average results obtained are presented in Figure 4 below.

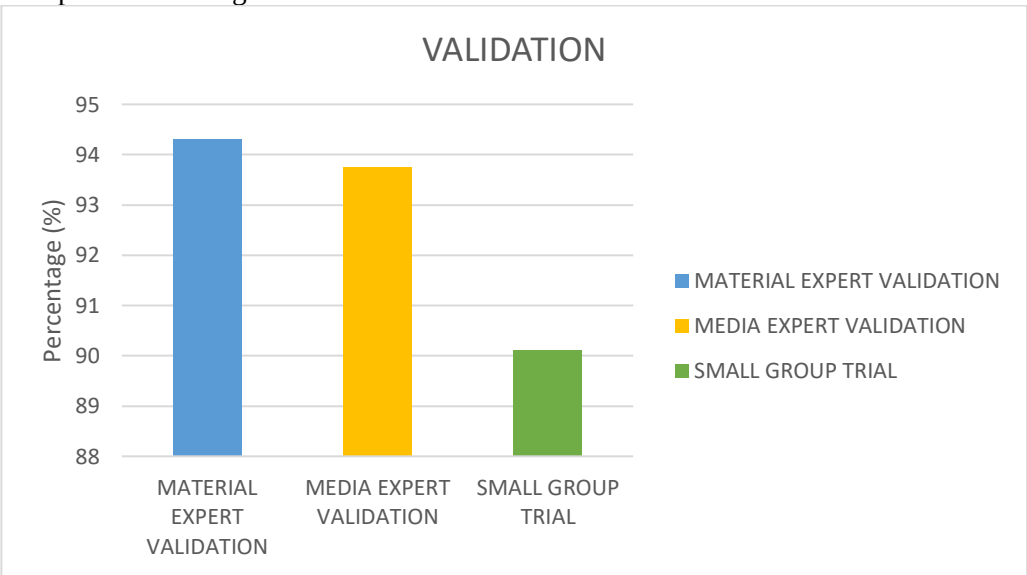

Figure 4. Average results of validation and trials

Based on data analysis and suggestions from material and media experts, the developer follows up by collecting data in the form of suggestions for improvement. Table 5 below lists the suggestions given by material and media experts.

Table 5. Suggestions from material experts and media experts

No.	Improvement Suggestions	Follow-up
Suggestions from Material Experts		
1	Images are adjusted to the material and should not be too small	Proportional adjustment of images to learning materials
2	Images of learning materials are given as a reference source.	Providing references to images in learning materials
3	Give practice questions as a complement to learning media	Giving practice questions on learning materials
No.	**Suggested Improvements**	**Follow-up**
Media Expert's Suggestions		
1	Add images, photos or video links to clarify the material	Providing images, photos and video links to learning materials

2	Add explanation sound when scanning app markers	Explanatory voiceover covering the definition, parts and usage of the lift aircraft being scanned

The final product of the development of augmented reality-based learning media on lifting aircraft for assembly and engine installation courses with the file type or .apk extension file that can be installed and used on all Android smartphones with the Android Kitkat operating system and above. The AR aircraft lift application, a finished product, has passed the revision stage. Revisions made to the application refer to material and media experts' suggestions.

Disscussion

The development and application of Augmented Reality (AR) in vocational education, particularly in machine assembly and installation, presents an innovative pathway to enhance student engagement and understanding. This approach aligns with findings demonstrating the usefulness of AR in engineering mechanics courses by facilitating complex visualisation of mechanical components and structural analysis (Fortuna et al., 2023). The integration of AR in pedagogical strategies is not only in line with technological advances in educational strategies but also significantly contributes to students' digital literacy skills, a critical aspect in today's educational landscape (Jiwani et al., 2024).

The practicality and validity of AR learning media in the subject of electric motor installation, which is highly relevant to our study's focus on machine assembly and installation. They highlighted the ability of AR to simplify complex processes and provide interactive and real-time learning experiences, which can greatly enhance students' ability to understand and recall complex information (Muskhir et al., 2024). The ability to visualise and interact with machine components in a controlled virtual environment enables deeper understanding and potentially reduces the cognitive load on students.

Incorporating AR in vocational training tools also supports the idea of student-centred learning by providing a platform where students can learn at their own pace and repeat difficult concepts as needed. This is particularly important in vocational education where practical skills are highly prioritised. The customisable capabilities of AR applications allow educators to tailor the learning experience to the needs of each student, accommodating various learning styles and paces (Jiwani et al., 2024).

Furthermore, AR's interaction with real-world objects provides an immersive learning experience that traditional educational tools cannot offer. This method fosters a more engaging learning environment that can motivate students to actively participate and improve their learning outcomes. The use of AR in education can transform traditional passive learning into an active exploration process, where students can manipulate 3D models and gain a thorough understanding of the operational mechanics of machines (Fortuna et al., 2023).

CONCLUSION

Augmented reality learning media for the Machine Assembly and Installation course has several advantages, such as ease of use, flexibility, and support for independent learning. This media is equipped with components such as three-dimensional objects, images, and text, which are in accordance with the learning outcomes of the course. The results showed that: (1) The ADDIE model is used in the development of this learning media in the form of an android application, (2) The learning media that has been developed has been validated by material expert validators material expert validation resulted in a percentage of 94.31% with a very feasible classification with a note that there are few revisions, (3) The learning media that has been developed has been validated by media expert validators. Media expert validation obtained a percentage of 93.75% with a very decent classification with a note that there were minor revisions, (4) To test the use of applications in the field, a small group trial was conducted for 15 students. The small group trial showed a percentage of 90.12%, which is also included in the classification of very feasible to use.

This AR-based lifting aircraft learning media for engine assembly and installation courses is expected to be used as a medium to support the learning process for Engine Assembly and Installation Courses at the State University of Malang, Faculty of Engineering, Mechanical Engineering Department. Below are some suggestions that are used to maximise the use of this learning media: (1) Material about understanding, parts, and how to use several lifting aircraft, namely hand pallet, conveyor, forklift and hoist crane, can be used for learning references, especially in the Machine Assembly and Installation Course, (2) Using an android smartphone that has a camera resolution of at least 5 Mega Pixel so that the quality of 3D images looks good and it is recommended to use a smartphone with a minimum android 4.4 (Kitkat) and 2 GB RAM, (3) Information related to the ways and steps of using this learning application, before operating this android application, users are expected to read and understand how to use it properly and correctly. Access to usage instructions can be seen on the "Instructions for Use" menu. (4) It is necessary to add material and practice questions about lifting aircraft so that learning media with a broader range of material is produced, but still pay attention to the size of the application so that it is manageable. The application's size is manageable, making it easier to operate it in a variety of smartphone specifications owned by students. (5) It is necessary to add various lifting aircraft projected in augmented reality to cover much discussion of lifting aircraft and ways to move machines in the Machine Assembly and Installation course more varied. (6) It is necessary to add animated videos related to the operation of lifting aircraft in three dimensions accompanied by a reasonable explanation voice so that users understand how to use lifting aircraft.

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