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Designing learning media using augmented reality for engineering mechanics course

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Abstract: The development of digital technology for education is continuously conducted to successfully integrate digital technology with people's lives. This study aimed to develop an Augmented Reality learning media application for the Engineering Mechanics course, which is considered challenging by some students. Engineering mechanics, a discipline that analyzes structural analysis in compensating for the loads that work on a particular machine in scalar quantities, motion forces, vectors, and moments that require physical structural forms to analyze them, is considered challenging by some students. The Augmented Reality application was created using the prototyping method, which consists of three steps: 1) listening to the customer, 2) building/ revising mock-up, and 3) customer test-drivers mock-up. The AR-based learning media application includes usage instructions, developer info, learning videos, 3D AR object animation simulations, and exercise and discussion menus, which were tested as expected. The results of the black box testing indicate that the Augmented Reality-based engineering mechanics learning media application ran successfully as expected. However, users suggested improving the navigation speed by streamlining page transitions. The application provides an accessible solution for students as an alternative to traditional distance education, offering anytime, anywhere access to learning materials with longer duration.

Keywords: Design; Application; Engineering mechanics; Augmented reality

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1. Introduction

The development of digital science and technology that is growing faster and faster is an opportunity for the development of the education sector in increasing human resources, creativity, innovation, and skills that focus on combining technology and humanity in the society 5.0 system (Fukuda, 2020). Moreover, the growth of technology in the rapidly developing education system in developed countries such as Japan, Finland, and America is the foundation and opportunity for Indonesia to become a leading country in a very progressive education system and encouragement (Kang et al., 2019; Xie et al., 2019; Yada et al., 2019). This condition leads to the need for an education system that can prepare human resources who are ready to face challenges and compete globally.

In the aspect of education in universities in Indonesia, the implementation of face-to-face learning has changed to online and mixed learning which has resulted in access to distance learning at Universitas Negeri Padang. Additionally, some students find it challenging to learn engineering mechanics online because it is a science that examines structural analysis in compensating with loads working on specialized machines on scalar magnitude materials, motion forces, vectors, and moments that need the shape of physical structures to be studied. Technological advances provide opportunities for better utilization of infrastructure based on

learning technology that is interactive, clear, and easy to understand (Lee et al., 2022; Miranda et al., 2021). Moreover, the use of technology such as Augmented Reality has the opportunity to be used in learning media by providing interactive experiences by connecting the real world by combining 2D and 3D objects in learning content generated in real-time in the real world (Prasetya et al., 2023; Ronaghi & Ronaghi, 2022).

Learning technology has three basic principles that must be used as a reference in its development and use, namely a systematic, student-centred approach and the use of learning resources optimally and variedly (Almaiah et al., 2020; Rashid & Yadav, 2020). According to an earlier study, college facilities that require students to come directly can only employ the development model of computer simulation and animation-based engineering mechanics courses (Tajvidi & Fang, 2015). Thus, the application of learning media serves as a support for learning facilities, and educational aids in conveying the essence of the material used completely in the learning process. This article aims to design a prototype application that is used as an alternative and interactive media. This research is expected to be a reference for developers and educators in learning engineering mechanics that have the implementation of science both in education and industry.

2. Methods

This research uses the Software Development Life Cycle (SDLC) prototyping method by looking at the rapid development cycle of information collection and testing on the working model of the application that has been built with a process of repeated interaction. The stages carried out in the prototyping method (Pressman, 2010) say there are three stages in building a learning media application seen in the presentation of Figure 1.

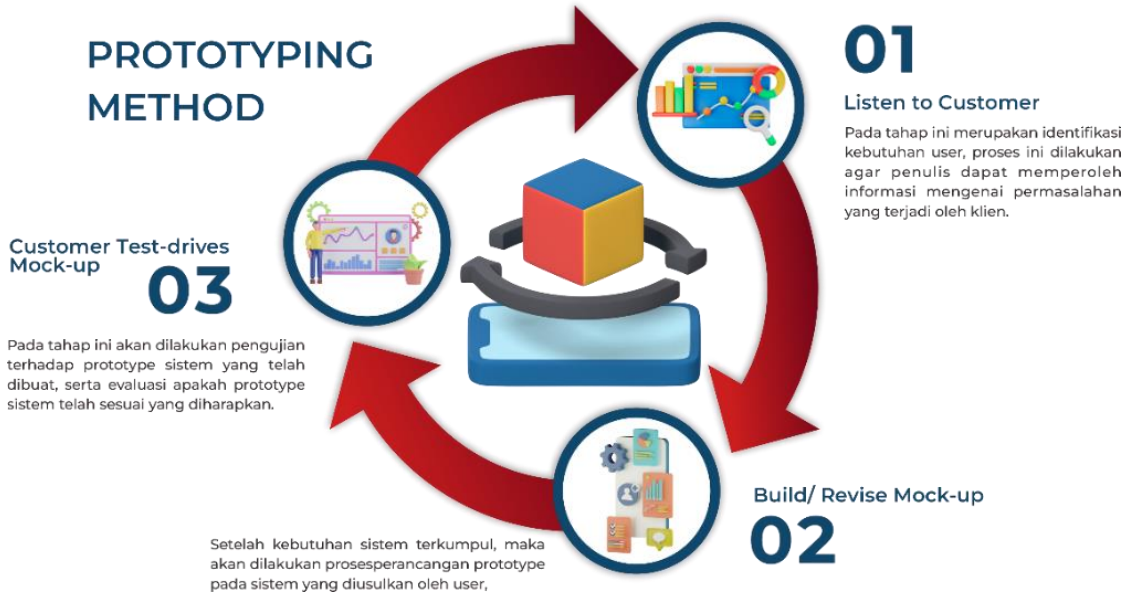


Figure 1. Prototyping method

The first stage listens to customer developers meet with target users in preparing goals and collecting data and materials from several references such as review literature, books, scientific arithmetic, journals, and other sources that are still related to the learning media developed. At this stage, needs analysis is needed, especially in the development of media, to determine material aspects of engineering mechanics that suit user needs.

The second stage, building/revising a mock-up of the prototype design process, is actively carried out on the software based on user needs, with the initial stage of building 3D objects

first with the help of the blender application. After the creation of 3D assets has been successfully created, they export to Unity, android studio, and Vuforia SDK, which are compiled into *Augmented Reality* applications that suit the system's needs.

The third stage, customer test-drives mock-up, evaluates the prototype that has been successfully developed to find out whether the application is to user needs. The testing process on learning media applications with black box testing techniques, if not according to needs, developers will re-evaluate the shortcomings in the application according to the stages of the method used.

3. Results and discussion

3.1. Listen to customer

Needs analysis starts from field observation and data collection, the next step of the findings is used in formulating problem formulations in research with functional needs, namely: a) Application of learning media engineering mechanics consisting of users as educators and students. b) The user interface in the application is designed based on user needs. c) The system on the application requires the user to log in as an identification process to obtain access rights. d) The application provides visualization of material that has physical structure analysis that embodies 3D objects learning engineering mechanics. e) User ease in navigating the designed application consists of an Augmented Reality menu, marker menu, learning video menu, and question menu and discussion of questions that make students learn independently.

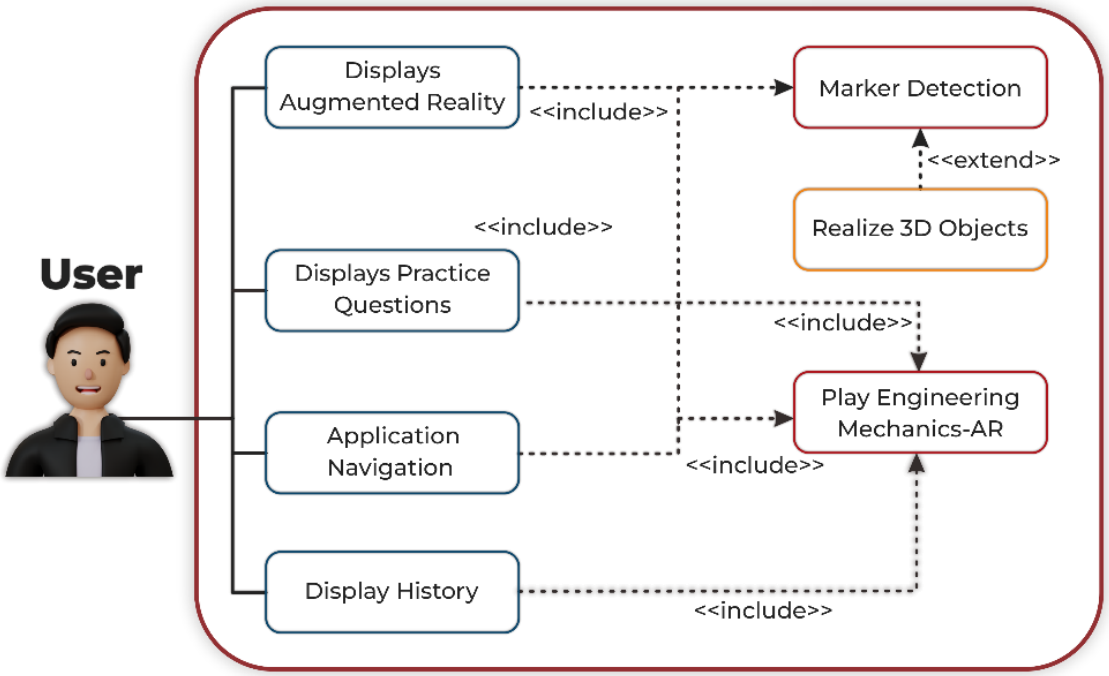


Figure 2. Use case diagram

The non-functional needs in Augmented Reality learning media applications on hardware and software that are needed in building application systems are: android studio, blender, Vuforia SDK, and mobile camera in building a system using the concept of use case diagrams and activity diagrams after the application design is built, a testing process will be carried out on users in seeing the validity of the running of the application based on the formulation of needs analysis by users (Ahmad et al., 2019; Vachharajani & Pareek, 2019). The next process of

Augmented Reality is used by interpreting the interaction between the application system and the user, which is illustrated to students in the form of a use case diagram shown in Figure 2.

In running Augmented Reality, the need for display devices, cameras, and special devices as intermediaries in interacting with virtual objects, when running the application, the camera will automatically realize objects from markers that have been marked, thus displaying 3D modelling of objects and their description panels. Seen in figure 2 that has been compiled shows user activities in running the Augmented Reality application, which displays engineering mechanics learning materials.

An activity diagram is a process that shows the flow or activity of using an application that will be designed in the form of a blueprint view with workflow modelling with grouping views of the system built by dissemination. The activity diagram shows the activities that occur in the application system designed with the event model that occurs in the use case diagram, and the following activity diagram process is shown in Figure 3.

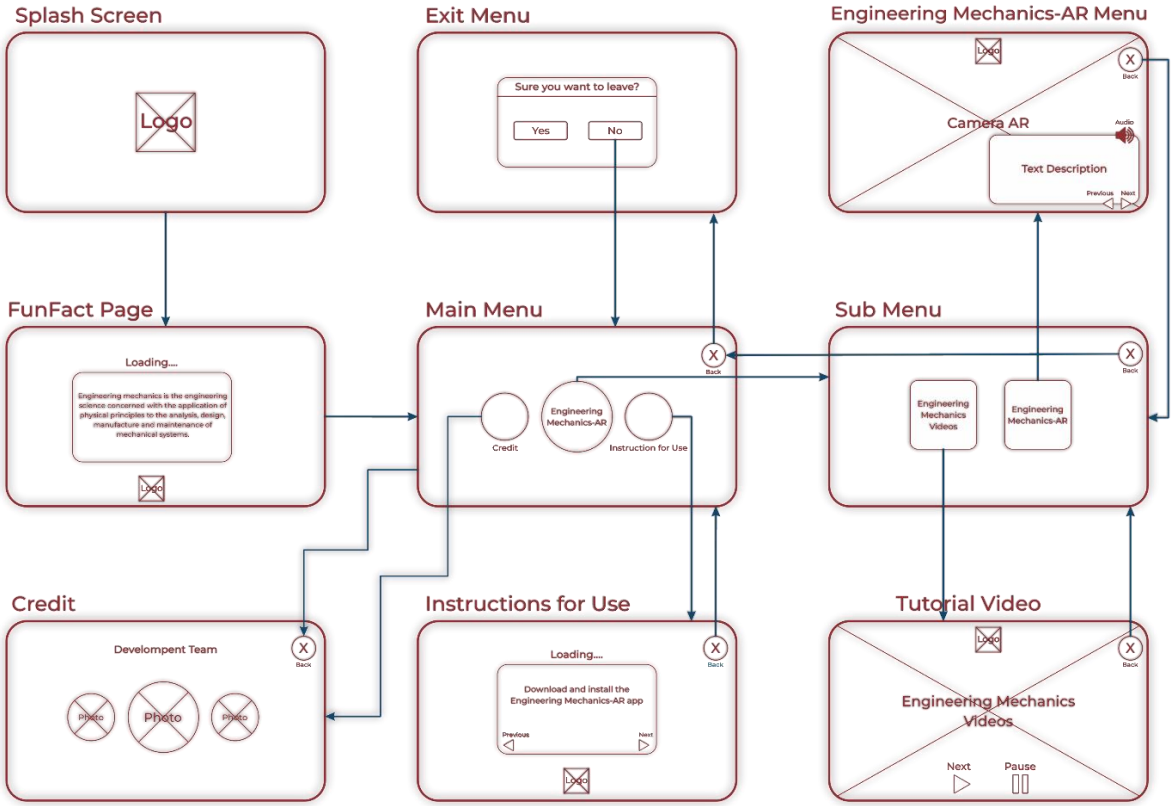


Figure 3. Activity diagrams

The activity in Figure 3 navigation on the application display consists of 9 user interfaces that vary from: splash screen, fun fact page, main menu, sub-menu, engineering mechanics-AR menu, credit, instructions for use, video tutorial, and exit menu. After the user passes the splash screen, it will enter the application menu display, which later users can carry out learning independently on the Augmented Reality menu, learning videos, questions, and discussions, so that learning is more interactive with a 360º animated reality experience.

3.2. Build/ revise Mock-up

At this stage, the developer will design a user interface that has a visual display of the system depicted in real form from the application developed so that the application to be used by users

can be tested by measuring the success rate of learning media processing functionality, then evaluate and improve based on system errors and shortcomings submitted by users.

3.2.1 3D Asset design

Assets used in Augmented Reality applications are created in blender software in the form of 3D objects seen in Figure 4 in building objects on vector materials, force moments, and machine frame structures. In a work project blender, work projects can be operated in almost all types of commercial 3D software, have a display that can be modified and arranged in such a way as to the wishes of the user, and there are physics simulations and use UV with better ease than other software. In addition, this blender also has the advantage of being able to make games because the blender has a *Game Engine* (Guevarra, 2019).

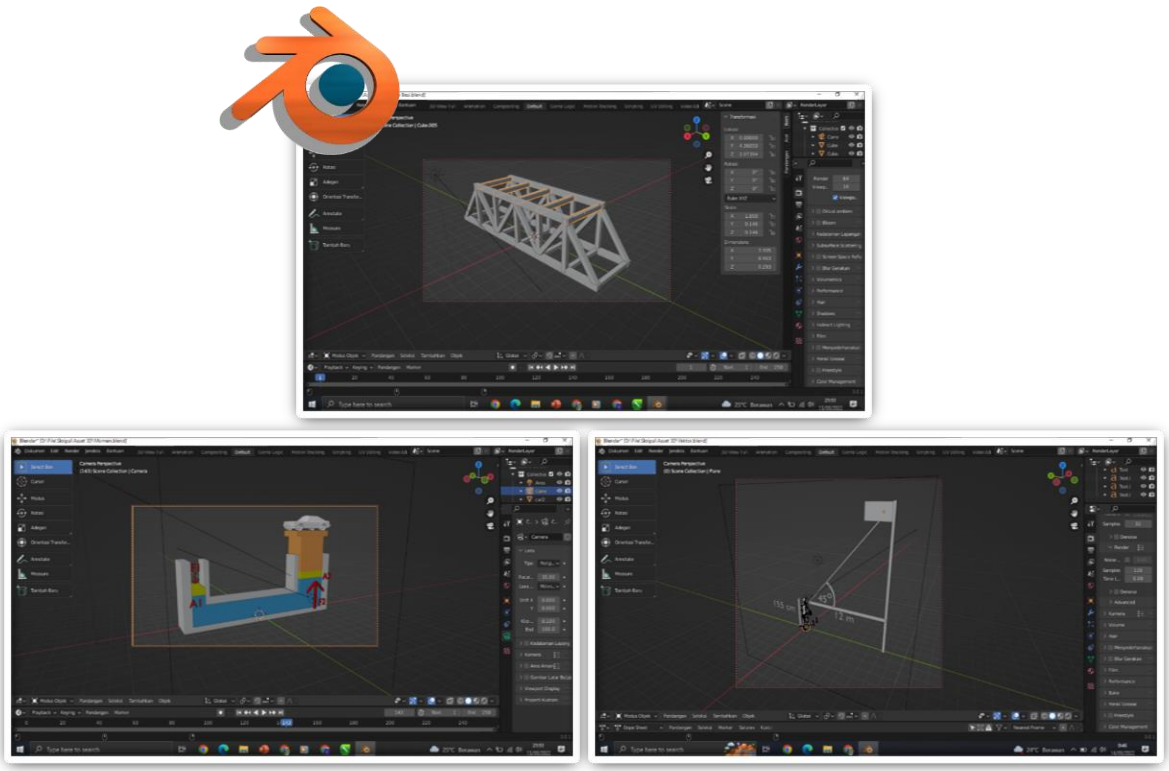


Figure 4. Asset 3D blender

3.2.2 Main menu page

The first-time display in the learning media application, especially the main menu as the main page that regulates the user's position in running the application according to the instructions for use instructions until exiting the application, on the main menu consisting of sub-menus such as: running Augmented Reality, learning videos, developer info, instructions for use, and exit menus from the application.

Figure 5. Main menu applications

Augmented Reality-based learning media that produces products in the form of Android applications developed using Unity applications provides a learning experience that creates a virtual environment that allows users to feel the surrounding nature becomes more real. The application of Augmented Reality technology as a supporting application of learning infrastructure in delivering learning engineering mechanics, especially on materials, namely: a moment of force, vector, and machine frame structure with interactive reality displays. If the camera reads the marked marker, the 3D object will realize an animated model of the material that has been developed so that it becomes an opportunity to be implemented directly in the learning process.

Figure 6. Augmented reality and engineering mechanics learning videos

The question menu page in the application serves as a measuring tool in seeing the level of understanding of students in learning technical mechanics material with questions consisting of 10 questions and ten discussion questions with a maximum score of 100 with a multiple-choice assessment model seen in figure 7.

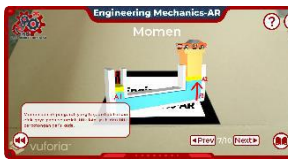
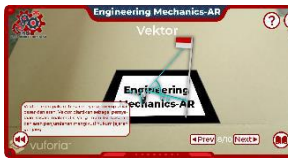
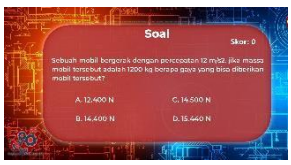
Figure 7. Questions and discussion of engineering mechanics material

3.3. Customer Test-drives Mock-up

The last stage is to conduct black box testing to prove the suitability of the function can run well according to the target and desired needs of application use trial cases that have been made with valid cases or not according to (Wallace et al., 2020) Seen in the Augmented Reality-based engineering mechanics learning media that have been presented in Table 1.

Table 1. Application black box testing

Testing	Test scenarios	Success parameters	Test results	Category
Main Menu Page	Choose play, additional, and settings menus	Move to the following page according to the selected menu		Succeed
Instructions for Use page	Press the manual instruction button	The manual instruction page is successfully displayed		Succeed
App Developer Page	Press the developer profile button	The developer profile page is displayed successfully		Succeed
Learning Video Page	Run the engineering mechanics learning video menu	The engineering mechanics learning video successfully displayed		Succeed

Testing	Test scenarios	Success parameters	Test results	Category
Moment of force simulation AR menu page	The camera focused on the moment marker of force	Augmented Reality moment style one successfully displayed		Succeed
Vector simulation AR menu page	The camera focused on vector marker	Augmented Reality vector successfully displayed		Succeed
Machine frame structure simulation AR menu page	The camera focused on the machine frame structure marker	Augmented Reality machine frame structure successfully displayed		Succeed
Two-vector simulation AR menu page	Camera focused onto two vector markers	Augmented Reality vector two successfully displayed		Succeed
Questions menu page	Pressing the menu button of an engineering mechanics problem	Perform engineering mechanics learning problems		Succeed
Question discussion menu page	Pressing the menu button discussing engineering mechanics	Discussion about learning engineering mechanics		Succeed
Level analysis results page Cognitive	Pressing the level analysis menu button Cognitive	Displays percentage data on the user's cognitive level		Succeed
Exit Menu Page	Select the exit button	Sign out of the app		Succeed

The results of the black box test show that the Augmented Reality-based engineering mechanics learning media application has been successfully run as expected with the advice given by users to speed up navigation time by moving pages from one another so that the presence of engineering mechanics learning media applications is a solution for students as an alternative to distance education that can be accessed anywhere and anytime with a longer duration. The platform used in the design of learning media in the form of applications that provide an easy-to-use page display interactively, especially in the use of Augmented Reality menus that display 3D objects from vector materials, moment forces, and machine frame structures accompanied by animated back sounds that can move 360º. This application is designed to be responsive, so it is not limited to Android devices, but can also be accessed on platforms: iOS, Windows, Unity Web, Mac, and others.

4. Conclusions

Based on the analysis of the application design, Augmented Reality-based learning media has been designed to have been completed with a prototyping method with the C # programming language with software in building applications are unity engine and Vuforia SDK that supports Augmented Reality technology. The results of the study produce functional and non-functional needs analysis in application design depicted in use case diagrams and activity diagrams. Testing on the application is carried out with a black box testing process so that the application starts from the main menu, instructions for use, developer info, learning videos, simulation of 3D Augmented Reality object animations, practice menus, and discussion of tested questions as expected. Testing is still carried out to limited users with the acquisition of information on user experience that is more complete with improvements based on evaluations provided by users at an early stage.

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Declarations

Author contribution

Aprilla Fortuna and Waskito developed a research concept, applied learning media, and wrote an article. Purwantono and Andre Kurniawan designed Augmented Reality-based learning media, collected and processed research data. Welli Andriani and Masnaini Alimin interpreted the data, improved grammar, and edited the article format.

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Complict of interest

The authors declare no conflict of interest.

Ethical clerance

There are no human subjects in this manuscript and informed consent is not applicable.

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