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Augmented reality-based application design with rapid prototyping method to support practicum during the covid-19 pandemic

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A B S T R A C T

The COVID-19 pandemic that has occurred throughout the world has hampered the world of education in carrying out the learning process. It requires the world of education to make rapid changes to the concept of learning so that the results of the learning process remain following the curriculum. However, during a pandemic, students are forced to study from home. Of course, this limits the essence of the practicum, which has to be done in the laboratory because students need interaction activities with machines. Augmented reality (A.R.) is a technology that allows users to interact with virtual objects. In this study, the application design is carried out using the rapid prototyping method, which can quickly accommodate the application development process. This study proves that AR-based applications can increase the understanding of 58% of students about the use of lathe, milling and 3D printing machines.

1. INTRODUCTION

Covid-19 is an infectious disease that can interfere with a person's breathing, originating in the city of Wuhan and has spread throughout the continent [1]. On March 2, 2020, the first case of Covid-19 was detected in Indonesia. Until September 2020, COVID-19 cases continued to increase to 177,571 cases, and 7,505 people died.

COVID-19 containment measures in their respective regions are one of the most preferred ways to reduce the impact of the crisis due to the pandemic [2]. Lockdown is an emergency implemented by the government to prohibit residents from leaving their homes. It has resulted in the closure of schools and colleges for an undetermined time as a preventive measure against the increasing number of COVID-19 cases. In mid-March, up to 75 countries announced the closure of educational institutions [3]. The closure of the educational institution caused around 73.8% of registered students to be affected [4].

The closure of the University caused a shift in the teaching and learning process from offline to online. There needs to be a change in the Education system to adapt to conditions during an un-precedented pandemic. One of the teaching and learning activities that need to be redesigned is practicum activities, which require interaction between students and the tools available in the laboratory.

In pandemic conditions, students cannot carry out their regular practice. Therefore, it is feared that there will be a decrease in the quality of learning outcomes obtained by students. Technology is a solution that is expected to maintain the quality of the learning process. Although some adjustments are needed, the COVID-19 pandemic encourages educational innovations in a relatively short time. However, the COVID-19 pandemic motivates teachers to be able to integrate the learning process with technology [5].

Several technologies available can help the online learning process, such as learning management systems, sound recording, video recording and online video streaming. However, from all these technologies, students cannot interact with the tools presented in the video as an activity that must be present during the practicum. Manufacturing process practicum is one of the practicums that teaches students about making products using machines in the laboratory, such as lathes, milling machines, welding machines, and 3D printing machines. A pandemic causes students to be unable to carry out practical product manufacturing directly in the laboratory.

A.R. and V.R. are technologies that are widely used in emergencies for disaster management [6]. Like a simulation of handling dengue fever [7], hand washing simulation [8], and training in handling pandemic influenza to terrorism [9]. V.R. has a better ability to make training simulations to provide images such as injuries to disasters [10]. Meanwhile, AR can be used for training to help students make decisions or actions [11].

A.R. is a technology that can combine the real world with virtual objects. The ability of A.R. technology is a way to interact with the virtual world [12]. A.R. can make virtual objects appear to coexist in the same space as objects in the real world [13]. At this time, A.R. technology has become one of the most popular technologies in the world of education because this technology does not require expensive and sophisticated hardware such as head-mounted displays (HMD)

In the world of education, it is familiar with the use of technology to provide diverse motivation and learning to students. A.R. is a promising technology for building virtual laboratories [14]. Because AR has characteristics such as being interactive, it can generate 3D objects and animations and can combine physical and virtual objects [15]. In previous studies, it has also been proven that A.R. technology can increase students' learning motivation and understanding [16]–[18]. In addition, A.R. technology can also enrich the experience of Engineering students related to the science and experience they must have before entering the work activity to reduce the gap between campus and the work activity due to the rapid development of technology [19].

In the field of Engineering, the use of A.R. during the covid pandemic is in the field of physics [20] and Industrial engineering [21]. There is no research in industrial engineering for manufacturing process simulations and the use of rapid prototyping methods for its development, so in this study, we will design A.R. applications for manufacturing process practicums in laboratories using the rapid prototyping method during the COVID-19 pandemic.

2. RESEARCH METHODS

The unexpected case of the COVID-19 pandemic resulted in educational institutions needing to make changes quickly to maintain the quality of learning. The rapid adoption of technology is one solution to survive during a pandemic. Technology always gives hope to increasing student involvement in understanding learning content [17].

Some digital product design methods, such as waterfall, take quite a while to develop digital products because the process is long and must be sequential. The waterfall method consists of 4 stages: requirements of the project, design, implementation, and verification. The multimedia development life cycle method is also very well used for developing educational or learning applications such as educational games [22], [23].

One method that can be used to develop products quickly is the rapid prototyping (R.P.) method. R.P. was developed to support product development by providing the possibility to create physical models to validate new designs quickly and at a low cost [24] so that it can speed up the product development process. In essence, R.P. consists of 3 stages, namely create, test and refine, where each process is connected and forms a repeating cycle (Fig. 1).

Create is the stage where the developer makes a prototype in visual form and user interface according to the chosen solution based on the problems faced. Making prototypes using 3D Max for 3D modelling. AR-based applications are made using Unity 3D and AR-Core software implemented on Android phones. Using mobile phones to display 3D virtual objects can facilitate the adoption of A.R. technology, especially for

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users who have never had A.R. technology before [25]. Tests are carried out to determine user perceptions of the prototype that has been developed. In addition, at this stage, an evaluation is also carried out according to the trials carried out. The final step is to improve the prototype according to the evaluation obtained in the previous stage. Refining is carried out in the testing phase of the prototype that has been made. At this stage, all involved try the prototype made.

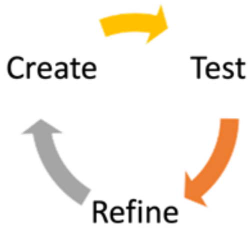

Fig. 1. Rapid prototyping process

3. RESULTS AND DISCUSSION

3.1. Create

Several alternative learning media used during the pandemic include virtual meetings, e-learning, simulated-based training, and virtual and augmented reality [26]. The following is a comparison between these media when viewed based on learning methods that can be applied (Table 1). Learning activities in the laboratory are identical to activities that require kinesthetic learning, where students are required to touch something, which can then provide certain information so that students can remember it. Table 1 shows that virtual and A.R. technologies allow students to perform kinesthetic learning activities [27].

Table 1. Alternative learning media used during the pandemic

	Virtual meeting	E-learning	Simulate based training	V.R. and A.R.
Visual	Yes	Yes	Yes	Yes
Auditory	Yes	Yes	Yes	Yes
Kinaesthetic	No	No	No	Yes

A.R. can display virtual objects using smartphones, which almost all students have. Meanwhile, V.R. must use an HMD to interact with virtual objects or environments, which not all students have, so this study focuses on developing AR-based applications.

In addition, A.R. can also allow students to carry out the learning process visually and through auditory. It is because A.R. can register 2D objects, videos, and even 3D, allowing students to see learning content from a 3D perspective. This 3D visualization can allow students to see learning objects from various perspectives and angles so that the understanding obtained can be more comprehensive [28].

The practicum design of the manufacturing process before the pandemic focused on the use of tools in the laboratory, where students took turns in groups and learned how to use lathe, milling, 3D printing, hacksaw, drill machines. The following is a practicum flow before the pandemic (Fig. 2).

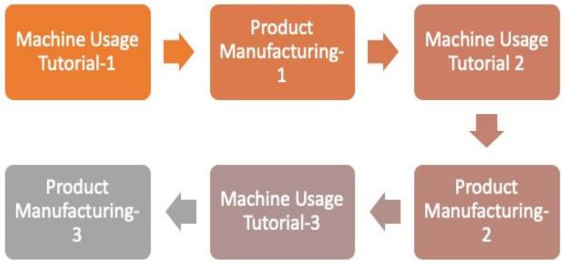

Fig. 2. Practicum flow before the pandemic

It can be seen in Figure 2 that students can interact intensely with the machines in the laboratory, where students constantly study the machines and then proceed with making products using the machines that were learned in the previous meeting. However, during a pandemic, students cannot carry out activities like before, where students cannot interact with machines. So the practice flow needs to be changed while maintaining the learning quality. The flow is made with the concept that students continue to learn the functions and uses of the machines in the laboratory and then carry out the production process. The following is a practical flow during a pandemic (Fig. 3).

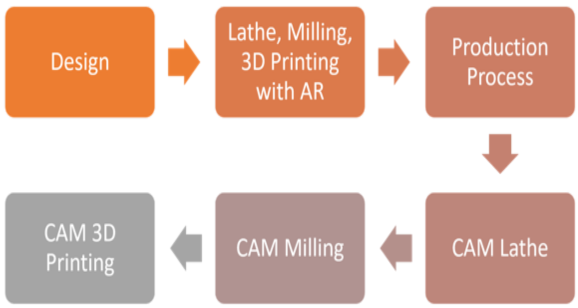

Fig. 3. Practicum flow during a pandemic

A.R. technology is used in the second meeting, where students learn how to use and work machines in the laboratory. The machines simulated in A.R. are lathe, milling and 3D printing machines. Fusion 360 software, which provides computer-aided manufacturing (CAM) features, can give students an understanding of how to turn materials into products using machines. However, the software has not provided features that allow students to interact directly with the machine because, in the software, students only make settings for replacing tools and see the simulation of the movement according to the settings made previously. Whereas in A.R., students can interact with machines that are displayed in 3D in their real-world via smart-phones. Interaction can be in the form of a touch on a certain part of the machine, and then the machine will respond directly.

A.R. technology is also the foundation of students' understanding of machines, where students then perform production simulations using other software. The initial design of the user interface can be seen in Fig. 4, wherein the initial design students select the machine on the initial menu. Students with devices that support the A.R. feature can continue to detect flat areas. Meanwhile, students with cell phones that do not support A.R. features cannot use AR-based practicum applications

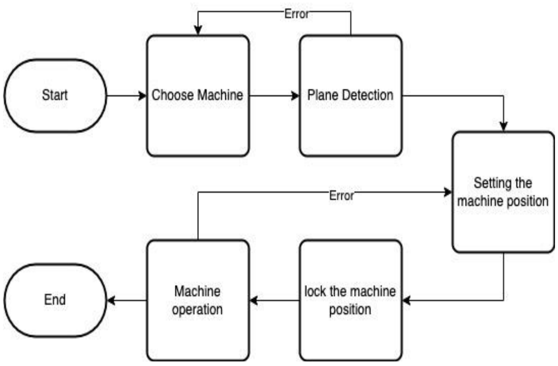

Fig. 4. Augmented reality application design for manufacturing process practicum

Planes are included in marker-less A.R. it can overcome the limitations of marker-based A.R. The marker must be positioned at a distance by the sensing system. The virtual object cannot be displayed when the marker is in a different location [29]. In the motion tracking section, the A.R. system will combine the visual data obtained from the RGB camera sensor with motion data obtained from the accelerometer and gyroscope sensor to be used as a basis for calculating the position of the feature. The calculation of the position of the feature uses the parallax formula. The system also uses a simultaneous localization and mapping (SLAM) process to ensure that the phone is in a position relative to the surrounding environment. The SLAM method allows the system to map a previously unknown environment to place virtual objects as if they blend into the surrounding environment.

In the next stage, the system will make the phone understand where the detected flat area is. So that virtual objects can be placed right on a plane. In the final stage, the system will detect the lighting in the surrounding environment to provide colour correction to certain objects so that the virtual object will adjust the light conditions in the surrounding environment.

After successful plane detection, the machine object will be displayed. However, if an error occurs, it is due to inadequate smartphone specifications. Because the object detection stage requires a compass and gyroscope feature, after the successful detection process, students can make settings such as machine position and size. When the settings are correct, the machine object can be locked. Students can interact with machines, such as moving machine parts, knowing machine parts, and seeing videos of machines in the laboratory. However, when operating the machine has problems, students can return to detecting objects and adjusting the position of the machine. Fig. 5 is the result of the initial prototype that has been made.

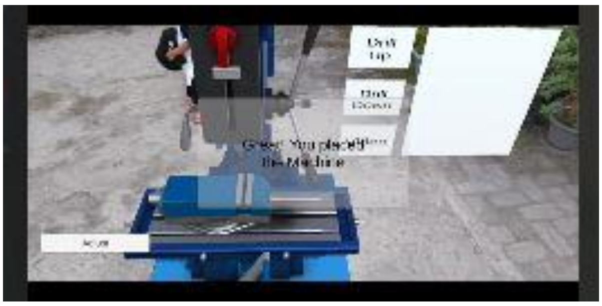

Fig. 5. Augmented reality application prototype

3.2. Test

Application testing uses the black box testing method that focuses on functionality to find out the shortcomings of the developed application so that by using this test, the user does not need to understand the internal performance of the application [30].

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From the results of the initial design, then testing was carried out on several stakeholders, namely students, laboratory assistants and lecturers, with details 35 students participated in the manufacturing process practicum, 14 laboratory assistants and two manufacturing process lecturers. The respondents were chosen because they understand the manufacturing process practicum. The test aims to obtain feedback on user perceptions from the development stage. The questions focus on the function of the A.R. application, so from the test, it can be seen which parts need to be improved. The score calculation is done using a Likert scale ranging from 1-5, where 1 means the application function is very bad, and five means the application function is perfect. Each student will give a score according to the question, and then the average score is calculated.

Table 2. User perception

	Average score
The application can already be used to simulate the use of machines	3.875
The application can give the impression of trying the machine like trying the real machine	3.125
The application can already help understanding in using the machine	3.625
Easy-to-use app	4.250
The application interface is not confusing	4.625
The layout of buttons and text is not confusing/easy to use	3.875
The letters on the buttons and application pages can be seen clearly	4.125
The location and size of the machine can be positioned properly	3.750
The application already describes the use of the original machine	4.250

From the test results in Table 2, it can be seen that the lowest value is in the user's impression when trying the A.R. application. It is like trying the original machine with a score of 3.125. This section is the most important part of the use of A.R. technology, where immersive can show the extent to which a computer screen can give the illusion of inclusive, wide, and alive reality.

It can be seen that the user does not feel the virtual machine in the AR-based practicum application. It is displayed on the mobile application that can fully replace the real machine, even though the user can interact with the machine by touching the parts so that the machine responds with specific movements. In open-ended questions, it can be identified that the low level of immersiveness can be caused by unrealistic engine movement where the engine movement is still too fast. For example, when shifting the table on a lathe machine or milling machine. So in this case, it is necessary to make improvements so that users feel more that virtual machines can replace real machines. The highest score is on the user interface, which is not confusing for the user. So that the flow that can be seen in Fig. 4 is already considered suitable by the user. Regarding the understanding of using machines, a test will be carried out on students at the implementation stage to see how much influence the use of AR-based practicum applications will have on students' understanding, especially on using machines.

3.3. Refine

Improvements were made by adding several features, such as engine movement, closer to the original engine. Improving the detection process, which was still too difficult to display the model, fixing buttons to move engine parts and adding several functions to the video such as stop, pause and continue (Fig. 6).

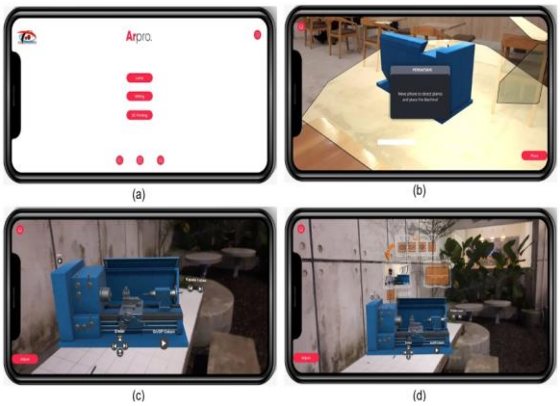

Fig. 6. Augmented reality application after repair. (a) main menu, (b) plane detection, (c) position object, (d) operate a virtual machine

3.4. Implementation

Table 2 shows that the prototype developed is still in the sufficient category in improving student understanding. Therefore, to find out how much influence the use of A.R. applications has after going through the repair process on understanding the use of machines in the manufacturing process, practicum, pretest and post-test are carried out before and after using the A.R. application. The questions given are related to understanding the use of machines. The questions cover the name of the part on the machine and how to start and stop it. The score calculation is based on the rubric that has been made; for example, a student can name 5 parts on the machine and then get a value of 100, while students who cannot mention the names of the parts on the machine get a score of 0.

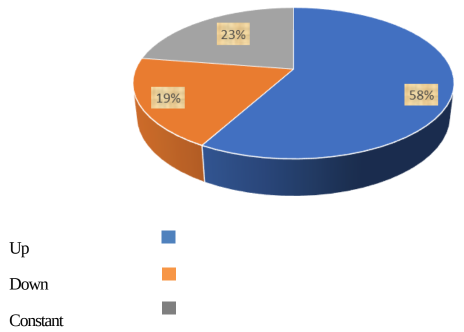

Fig. 7. Comprehension level test

The question asked to the user is about how to use the lathe, milling and 3D printing machines. From a total of 15 questions and a total of 156 students who took the manufacturing process course got results 19% of students experienced a decline in grades (down), 23% of students had unchanged grades (constant), and 58% of students experienced an increase in understanding related to the material taught using the A.R. application (up) (Fig. 7). The assessment results are based on the results of the pretest conducted previously. However, judging from the average value is still relatively low; before using the A.R. application, students got an average value of 43.1, and after using the A.R. application, the average value increased to 54.6. it happens because the functions provided in the A.R. application are not optimal; for example, in the section bringing up the names of machine parts that are not yet stable, some students can bring up the names of machine parts well. Still, some students have difficulty, so the machine part names cannot be displayed. Other things such as the movement of the machine which is less responsive because of the touch point area changes depend on the smartphone's condition. So the test proves that A.R. can improve students' understanding of using the lathe, milling and 3D printing machines in the manufacturing process practicum, even though the average value obtained in this study is still relatively low. Improvements can lead to the functions provided in A.R. applications that are not yet stable with a longer repair timeframe. So it is expected that students' understanding will increase significantly.

Application development using the rapid prototyping method starts from August to October 2020, lasting 8 weeks. This method is faster than the waterfall method, which takes more than 16 weeks [21]. Rapid prototyping is more appropriate for system or application development that requires fast time. In a pandemic condition, a method with a faster processor will be more appropriate so that the application developed can be implemented immediately. However, from the evaluation results, several things still need to be developed because this method cannot identify the needs of the user more deeply.

4. CONCLUSION

During a pandemic, several media have developed that can assist the learning process, such as virtual meetings, e-learning, simulated-based training, and virtual and augmented reality. However, because this research is used for practicum-based learning, A.R. technology is considered more relevant because it can accommodate learning using the kinesthetic method. The result improves 58% of students' understanding of increasing the use of lathe, milling and 3D printing machines. The average value is relatively low; the average pretest is 43.1, and the average post-test is 54.6. Researchers believe that A.R. technology can have a more significant impact with a higher level of immersion.

Some improvements can be made to increase the immersive level, such as adding a rotating speed feature of the drill so that the user can adjust the settings. In addition, several work piece processing schemes can be created to make certain products. The addition of these features is expected to increase the level of immersiveness. On the A.R. side, there is still unstable when detecting a flat plane, and this is because A.R. cannot detect textures such as ceramics. So that it can be improved so that A.R. can detect all types of flat areas.

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The rapid prototyping method is well applied to pandemic conditions where it requires a short time to develop digital products because it focuses on developing and evaluating prototypes and a relatively short development process. But to develop the application to be more specific according to user needs, it is recommended to use other user-centered methods. Marker-less mobile A.R. is considered good because it does not depend on markers. However, it is necessary to consider the use of marker-based A.R. (such as features in the Vuforia SDK), which requires lower phone specifications than AR-core, so it is hoped that more students can take advantage of this technology.

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