

The Design of Prototyping Model Virtual Laboratory-Based Computer Numerical Control Course

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ABSTRACT

With the advent of the *Merdeka Belajar Kampus Merdeka* policy, universities are obligated to implement technology-based learning to guide students to have 21st-century skills, one of which is digital media innovation, as a result of the growth of information technology in the form of building opportunities. The use of Virtual Laboratory, a technology that enables users to carry out real learning with user models in the form of avatars that can interact through the virtual world in real-time, is one solution to the issue of the implementation of practicum learning, especially in lectures at universities as an alternative to learning in designing learning media. The goal of the computer numerical control course offered by the Department of Mechanical Engineering at the Universitas Negeri Padang is to provide students with hands-on experience operating CNC machines in a simulated but realistic learning environment. This research aims to design Virtual Reality-based learning media as a Computer Numerical Control course used in virtual laboratory simulations. Virtual Laboratory media is designed using a research method with a prototyping model approach: 1) listening to customers, 2) building/revising mock-ups, and 3) customer test driver mock-ups that are reviewed as needed in fulfilling all the criteria of a comprehensive learning media system. The results of black box testing and verification of the Virtual Laboratory CNC application design show that the CNC programming practicum learning process can run as expected, reduce the cost of cutting tools, and increase student motivation in the Virtual Laboratory design learning process.

Keywords: *Prototyping Model, Virtual Laboratory, Computer Numerical Control.*

1. INTRODUCTION

The *Merdeka Belajar Kampus Merdeka* policy introduced in 2019 is one educational paradigm shift focusing on educators and students. This policy encourages Indonesian students to be more creative, innovative, and independent [1]–[3]. Providing choices and freedom of thought in designing education itself is expected to spur motivation and critical thinking skills ready to face real challenges. The gap between university education and the world of work needs to be improved to make it more relevant according to current needs [4], [5].

Universities must be able to apply technology-based learning in building human resources that are following 21st-century skills [6]–[8]. The development of technology and information changes learning patterns,

including opening information and interacting with others [9]. Therefore, universities are expected to adopt and integrate technology into learning. The following are significant benefits that technology provides for universities: a) Broad accessibility provides opportunities to access educational resources online flexibly and independently; b) Flexibility of time and place of technology-based learning; c) Interaction and collaboration between lecturers and students in broadening insights on the development of collaborative projects, d) enrichment of learning with technology such as animation, simulation, and other interactive materials, e) development of 21st-century digital skills in the use of software, data analysis, an online collaboration that fosters creative and critical thinking.

One way of utilizing information technology that is currently developing is the use of Augmented Reality (AR) technology and Virtual Reality (VR) technology which offers users a lifelike picture of the merging of the real world with the virtual world seen from the same place [10]–[13]. In recent years the development of Virtual Reality technology has provided benefits and potential in various fields, especially in the field of education, which is used in creating an immersive and interactive learning environment through applications with 3D visualization in exploring concepts and theories that require image reconstruction analysis [14], [15]. This technology allows professionals to train in a safe and controlled virtual environment that mimics real situations without physical risks or high costs.

Vocational higher education plays an important role in producing quality graduates whose qualifications meet the criteria to answer the challenges faced by the Indonesian nation when courses are more practical than theoretical [16]–[18]. Basic competencies in a practicum course are not achieved, which is focused on technology and engineering study programs, where the basic knowledge to be obtained is the use and operation of tools or machines that are quite complex and complicated. Usually, these tools are rarely found in the community and can be found in certain laboratories. The Laboratory is one of the student lecture facilities that has not been maximally implemented because the post-Covid-19 pandemic has changed learning patterns from active to passive, so there is a need for alternatives and further application of the use of virtual technology as a distance learning facility for practicum [19]–[21].

So the need for learning media as a means of practicum in remote conditions by utilizing Virtual Reality technology that allows users to interact with a virtual world environment simulated by digital devices so that users can feel directly in the virtual environment. Virtual Reality begins with the user seeing the virtual world, which is a dynamic image derived from computer simulations [22], [23]. Then, using tools such as virtual reality glasses, users can interact with the virtual world and receive real, physical and imaginary feedback [24]–[26]. Courses conducted virtually using virtual reality technology are run in interactive computer simulations, especially three-dimensional ones [27]. Therefore, researchers are interested in designing an application in a virtual laboratory as an alternative source of CNC programming materials. The CNC Programming course is a material that explores the use of manufacturing machines such as lathes and milling machines using the software.

2. METHOD

This study uses the Software Development Life Cycle (SDLC) prototyping approach by examining the fast-paced cycle of data collection and testing on the

functioning application created through recurrent contact. The steps that constitute the prototype process [28] As shown in Figure 1 presentation, a learning media application is constructed in three steps.

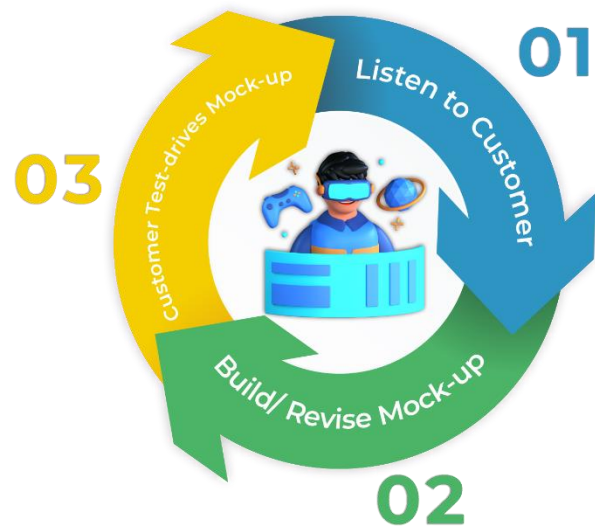


Figure 1. Prototyping Method

First, it starts with listening to the Customer. The developer (creating the 3D virtualization trainer) and the Customer (the Customer using the 3D virtualization trainer) meet to set up goals and needs and collect data [29]. Data collection steps are provided as primary and secondary data sources. Primary data sources are carried out through direct observation monitoring the use of conventional teaching aids in CNC programming material. Furthermore, secondary data sources use a literature review which aims as basic information in designing hologram media design prototypes. At this stage, it is discussed about the need to make learning media to determine and compile the desired learning material.

In the next stage, namely building/revising the mock-up (design), the design process is carried out actively, and the design is carried out repeatedly in the form of software that can later be following the wishes of the Customer [30]. Based on Customer needs in building or building 3D virtualization props appropriately, starting with modeling CNC TU 2A and 3A machine objects using the blender application, then designing an application or hologram program system. The design is done by designing 3D virtualization props that meet customer needs.

In the last stage, the Customer test-drives the mock-up (evaluation). Evaluate the prototype built on the software and clarify the customized requirements [31]. Evaluation of the final results of the design is then evaluated by various parties, such as customers, who aim to find out whether 3D virtualization props meet customer desires. Testing prototype applications or hologram program systems uses black-box testing

techniques. If it is not appropriate, the developer can repeat the first step.

3. RESULT AND DISCUSSION

This research produces learning media by utilizing Virtual Laboratory (VR Lab) digital technology for students of the Mechanical Engineering Department of Universitas Negeri Padang. Learning media in CNC (Computer Numerical Control) courses are used on this Virtual Reality headset device in the form of diving goggles with closed lenses such as diving goggles called VR box, where the smartphone is located, which functions to project virtual images in real time. [32]. Virtual Laboratory is designed as software developed using web access with files that can be installed on Virtual Reality headset devices and Windows.

3.1. Listen to the Customer

Virtual Laboratory CNC (Computer Numerical Control) is a solution that allows users to learn and practice in a near-reality simulation environment using CNC software [33]. In the needs analysis for the CNC Virtual Laboratory, some important factors to consider include:

3.1.1. Functions and Features

First, it is necessary to analyze the functions and features required in the CNC Virtual Laboratory. These include accurate CNC machine simulation capabilities, CNC programming capabilities, cutting process simulation, toolpath movement simulation, and so on [34]. Ensure that the CNC Virtual Laboratory can provide features relevant to the user's needs, both for beginners who want to learn the basics of CNC and for more experienced users who want to train learners' skills.

3.1.2. Simulated Environment

It is also necessary to analyze the simulation environment provided by the CNC Virtual Laboratory. Preferably, the simulation environment includes various commonly used CNC machines, including milling machines, lathes, and other cutting machines [35]. Ensure that the CNC Virtual Laboratory can simulate a real working environment by considering the type of materials, tools used, and different processing conditions.

3.1.3. Availability of Learning Materials

A good Virtual Laboratory CNC learning should provide comprehensive and interactive learning materials [36]. This can be in the form of CNC programming guides, step-by-step tutorials, demonstration videos, and sample programs that can be used to learn and practice. Ensure that the CNC Virtual Laboratory provides enough

resources to assist users in understanding important concepts and improving skills in using CNC machines.

3.1.4. Platform Availability and Support

Ensure that the CNC Virtual Laboratory can be accessed using a platform like a personal computer, laptop, or mobile device [37]. Ease of accessibility will allow users to learn and practice anytime and anywhere. Additionally, technical support is also an important factor to consider. Ensure adequate support regarding queries, technical issues, and troubleshooting regarding the use of the Virtual Laboratory CNC.

3.1.5. Customization and Progress Monitoring

A good CNC Virtual Laboratory should allow users to customize their learning experience. For example, users should be able to set the difficulty level, select the type of exercise, or set specific challenges. In addition, the CNC Virtual Laboratory should also provide progress monitoring features, such as training statistics, performance evaluation, and feedback that help users track and improve learners' abilities [38].

3.2. Build/revise Mock-up

The Virtual Laboratory CNC learning media is designed using several supporting software such as Spoke by Mozilla to arrange the layout of 3D assets that have been built in the blender application for learning CNC programming, which is built using the C# programming language. Creating layouts and inserting 3D assets is done using Mozilla's Spoke to create a Virtual Laboratory Computer Numerical Control simulation model that can move virtually interactively and interact with virtual environments and theoretical spaces that have been available.

3.2.1. Designing a Story Board

Virtual Laboratory learning media is a single user accessed by one user and requires VR support devices, namely VR Box, as the main hardware in operating Virtual Laboratory [39]. The steps of developing a storyboard for Virtual Reality learning media: 1) prepare a VR Box device that works properly, 2) Install the application that has been designed in the form of a prototype, 3) Use the VR Box device on the user's head to get a virtual environment experience, 4) Register the user, whether as a lecturer or student, 5) After registering the user will be at the spawn point as an avatar that can access all features on the Virtual Laboratory CNC that has been successfully designed by the application developer.

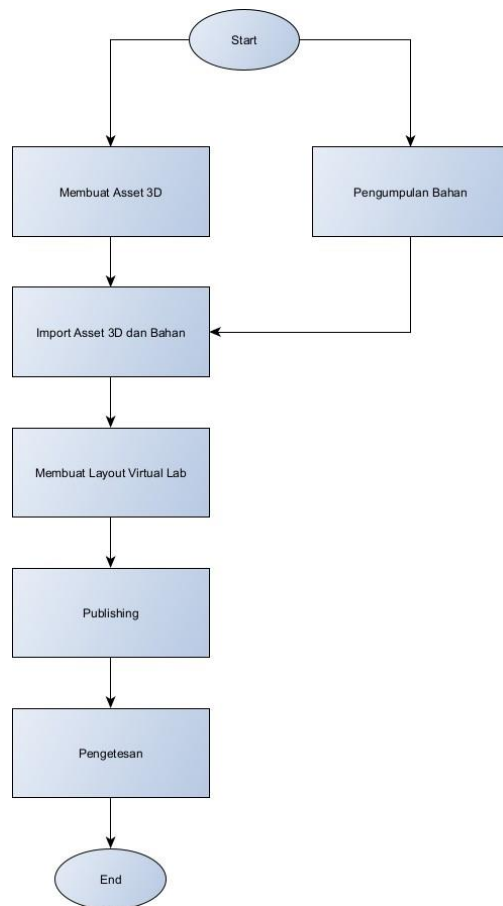


Figure 2. Flowchart Story Board

3.2.2. 3D Asset Design

3D object assets and texturing are made using the Blender application. Here are the 3D objects that have been made:

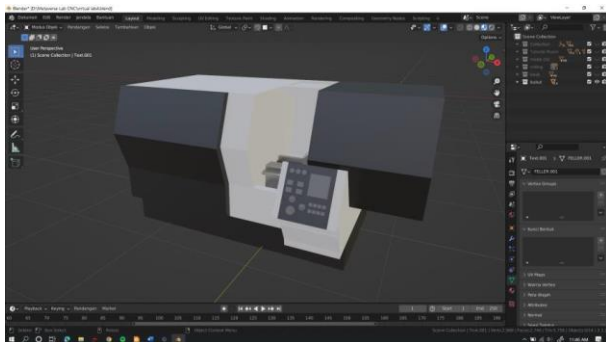


Figure 3. TU-2A CNC Machine

CNC Training Unit 2 Axis is a machine specifically designed to provide training in the operation and programming of CNC machines that have components, namely: workbench, spindle, X, and Y shafts, motor, and control system [40]. The type of programming used is G-code or M-code, executed using a computer system set to the X and Y axis points as needed.

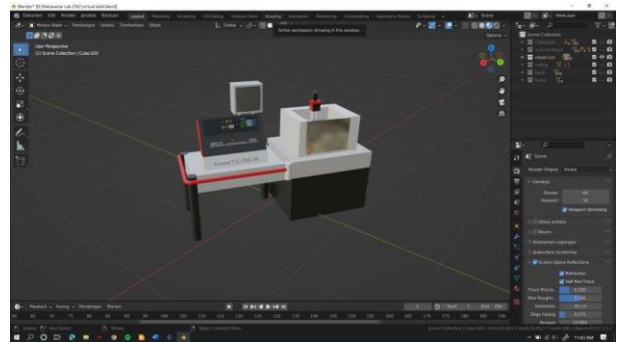


Figure 4. TU-3A CNC Machine

CNC Training Unit 3 Axis machine is a machine that can move cutting tools or tools in three axes: X (horizontal), Y (horizontal), and Z (vertical) [41]. Before operating, the 3 Axis CNC Training Unit machine needs to be calibrated and set to a defined starting position. This involves moving the three-axis X-Y-Z shaft per the specified coordinates at a preset reference position so the machine can run in the correct range.

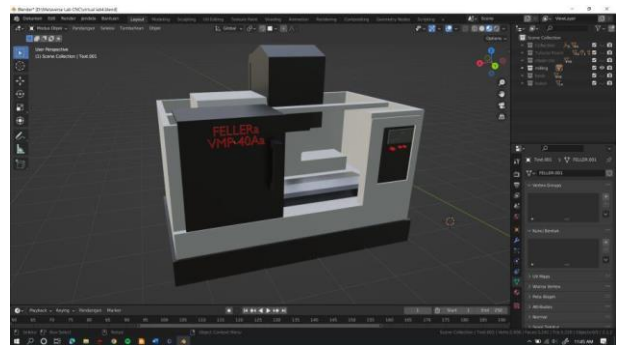


Figure 5. CNC Milling Machine Unit Production

The working principle of a CNC milling machine production unit has the main steps, namely: preparation in operating a CNC milling machine starts from determining the specifications of the workpiece, the selection of cutting tools, to the determination of the starting point position (zero point) of the X, Y, Z axis and inputting G-code and M-code [42]. Instructions are given to set the movement of the cutting tool, cutting, cutting speed, and other parameters. Once usage is complete, the unit's production CNC milling machine needs to be properly maintained and cared for. This involves cleaning, lubrication, regular checks, and maintenance according to the instructions provided by the manufacturer.

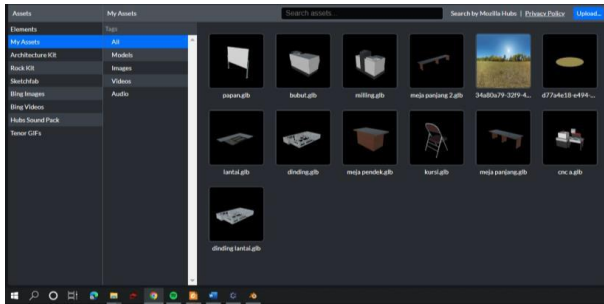


Figure 6. Supporting 3D Assets

The 3D assets designed in the Virtual Laboratory environment are whiteboards, long tables, short tables, chairs, and educational posters about work safety, all designed virtually. After all the assets were successfully designed, the assets were inputted into the Virtual Laboratory Environments layout.

3.2.3. Design of Prototype

Virtual Laboratory is made in the form of an application operated on an Android-based VR Box device with minimum specifications of v6.0 (Marshmallow). In the design of the system, first set the 3D environment in the form of lathes, milling machines, TU-3A CNC machines, long tables, short tables, chairs, blackboards, and Virtual Laboratory rooms that are adjusted to the coordinates of the position of other virtual objects. Virtual Laboratory is built based on the suitability of the CAD / CAM / CNC Laboratory of the Department of Mechanical Engineering, Universitas Negeri Padang.

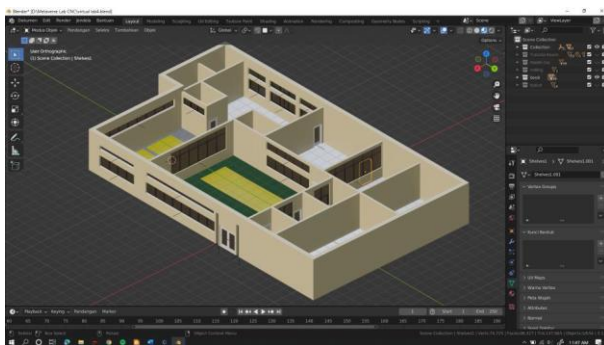


Figure 7. Virtual Laboratory Environments

The 3D assets and Virtual Laboratory CNC environment successfully built in the Blender application will be imported to Spoke by Mozilla: <https://hubs.mozilla.com/> to be arranged based on the needs using the operator account by clicking "New Project" and can choose the available rooms.

3.3. Customer test-drives the mock-up

Before testing, the Spoke by Mozilla application must be published or general access so that Virtual Laboratory

CNC can be used on the server of the user who accesses it. The trick is to press the Publish to Hubs button in the image below, and you will receive a request to change the screen name and add your attribution, and finally, press the Allow Remixing button.

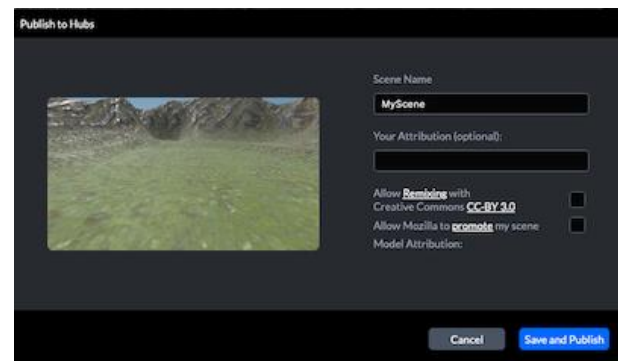


Figure 8. Publishing Virtual Laboratory

3.3.1. Blackbox Testing

Testing shows whether the application can work properly and according to the previous plan. The tests consisted of a) Displaying the application with the home screen and main menu on Hub, spoken by Mozilla. b) Testing the user's character control, especially at the spawn point, the avatar controller on the Oculus Rift can act according to the user's control. c) accuracy is improved by testing the contact between the character's finger and the shot and control panel; the better the touch. d) search test for each virtual object marked with a virtual object using the avatar's hand virtually.

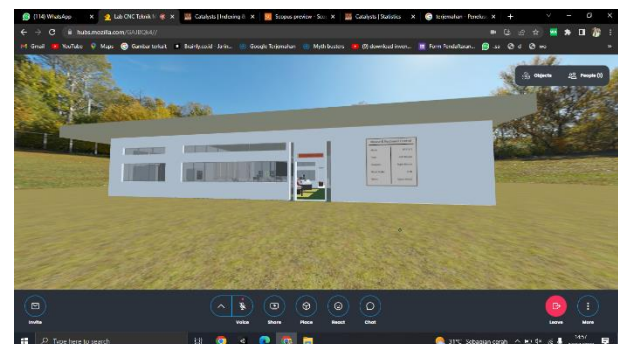


Figure 8. Spawn Point

The following is a display of spawn points that have been set up to be used by users to try the application simulation with black box testing to see the functionality of applications that have been successfully designed [43].

Table 1. Blackbox testing results

No	Indicator of Assessment	Result
1	The Virtual Laboratory main menu displays correctly, as expected.	√
2	The application usage instructions page runs as expected.	√
3	Runs successfully on Android and Windows devices.	√
4	Virtual Laboratory CNC app navigation works well.	√
5	Successfully display the 3D asset design.	√
6	The CNC machine simulation tutorial video was successfully displayed on the application.	√
7	The back sound in the Virtual Laboratory application has a clear sound.	√
8	Successfully display all descriptions of 3D assets that have been designed.	√
9	Display a virtual simulation of CNC machine axis points successfully.	√
10	Able to display clear information on educational posters about occupational safety and health.	√

4. CONCLUSION

Based on the results of the prototyping design, the Virtual Laboratory application model has been successfully designed on Blender software, spoken by Mozilla, and using the C# programming language. This research produces learning media as Virtual Laboratory technology-based learning tools in CNC programming courses based on analyzing the wholeness of listening to the Customer, building/revising mock-ups, and Customertest-drivings the mock-up. Obtained from black box testing with assessment indicators, as many as ten main points obtained the results that the Virtual Laboratory application successfully runs as expected.

AUTHORS' CONTRIBUTIONS

All the researchers contributed to the paper. F. Prasetya, Budi Syahri and A. Fortuna conducted the research and wrote the paper. B.R. Fajri and M. Iqbal Parezi analyzed the data and checked the whole one, and Y. Yufriзал reviewed and resolved the papers. All authors accepted this final version.

ACKNOWLEDGMENTS

We would like to extend our gratitude to the Department of Mechanical Engineering, Faculty of Engineering at the Universitas Negeri Padang for having already provided the necessary research permits.

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