The Design of Mini CNC Assembly Simulator Based on Virtual Reality Toolkit (VRTK)

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Abstract. Information and communication technology development today has provided the latest innovation in didactic world. One of such innovation is the usage of virtual reality (VR) as learning media. The application of virtual reality in learning environment started to be adopted because VR is considered more capable to explain learning material when compared with other learning material. Moreover, learning with VR has the capability for student to learn independently anytime and anywhere. One of VR utilization in learning environment is to use it in a Mini CNC machine assembly simulator. The learning media is meant to be used to improve student skill in assembling a Mini CNC machine independently. This research uses Research and Development method with waterfall model which has several stages which are communication, planning, modelling, construction, and deployment. However, this research only aims up to construction stage, because this research focuses on media functionality test. The media black box research has shown that the media is capable to function as expected.

1. Introduction
Education in higher education currently experiencing a big challenge. This is because technology advancement in higher education cause education in higher education must be capable to prepares student in accordance to recent development. Technology advancement today has reached the 4\(^{th}\) era which known as 4.0 industrial era. 4.0 Industry era had been introduced for the first time in Germany during Hannover Fair in 2011 [1]. This Industry era aims to increase competitiveness between countries which utilized digital technology [2].

One of the uses of digital technology in didactic world is the use as learning media. The availability of learning media today is still limited in and tends to lack in development, especially for schools or higher education which situated in remote areas [3]. This limit of media usage causes the learning process to be less than optimal. This situation is getting worse with COVID-19 pandemic that makes learning must be done online and independently by student.

Due to that, learning media development must be done so that learning process can continue. One of the learning media which could accommodate that is learning media development with virtual technology like virtual reality which based on Virtual Reality Toolkit (VRTK). Learning media based on virtual technology has several benefits during online learning process nor independently. This is due to virtual technology is capable to introduce practical knowledge towards student without the need to be present in classroom [4] or in other words, media can be used anytime and anywhere by its user or student [11]. Moreover, virtual learning media can reduce the risk of work accident in practical learning and of course it also reduces expense [5], so that it is very appropriate to be used as student’s
independent learning media, especially for CNC Maintenance and Repairs Practice course. Virtual learning media application like simulator in aforesaid course, could give more experience towards student on maintenance practice up to build a CNC, so that the purpose of learning competence can be done even without the needs to be present in a classroom.

1.1. Virtual Reality Toolkit (VRTK)

Virtual Reality or abbreviated as VR is a term to describe virtual environment which can be manipulated by its user in real time, this virtual environment is the results of computer processing which projected in a device strapped in one head, a computer monitors or projection screen [6]. Whereas Virtual Reality Toolkit known as VRTK is a library that contains method and component that could work with Virtual Technology. VRTK library consists of numbers of solution or order, like movement in VR, interaction with object like touching and catching, and 2D and 3D control like button, lever, and another object [7]. VRTK can ease users in creating a game or simulator application because of built-in program in one library. One of program or feature in VRTK library is Snap Zone. Snap Zone has the principle to integrate an object with another object according to initial object placement setting. Because of that, VRTK is very compatible to be used to create an application or game with the type of simulation. Because of that, it can be concluded that virtual reality is a virtual environment produced by computer image which can be done by manipulating said image in accordance to user need. While VRTK itself is a library which contain methods and components to create virtual reality.

1.2. Mini CNC

CNC machine or the abbreviation of Computer Numerical Controlled is a machine that controlled by computer with numeric language in accordance to ISO standard [8], while a Mini CNC is a CNC machine that smaller in size. Today CNC machine has become manufacture tool which often used in industry. This is because CNC machine has higher accuracy in comparison with conventional machine in general [9]. Because of that, several schools and higher education today opened expertise program that has relation with CNC machine operation. However, as time goes by, not only CNC machine operating skill, but the skill to make and repair CNC machine is also opened in several schools or higher education even though it is only with a Mini CNC machine. Because of that, manufacture and maintenance simulation learning media of CNC machine must be developed in the future.

2. Research Method

This research uses the method of Research and Development with waterfall model developed by Pressman [10] which has several stages which are communication, planning, modelling, construction, and deployment. Waterfall model is started with communication stage which consist of observation and interview. Communication stage is useful to dig information that supports later development process. The next stage is planning done by planning time and flow of to be made learning media development process, so that media development can be controlled and does not need a long time to be done. Modeling stage is done by designing product in accordance to data which has been collected through the stages before, so that product that will be made will correspond with research needs. Construction stage is done by writing programming code, so that learning media can function in accordance to program code that has been made. Deployment stage is to find out the feedback of user toward learning media that has been made, so that the media is suitable with its user characteristic. However, deployment stage is not carried out in this research, because this research is only focuses on media functionality test only.
3. Research Results and Discussion

This research is started with communication stage which consists of observation and interview. Observation is done by doing needed competency identification related to Mini CNC machine assembly. Competency Identification is done by studying existing document like lesson plan and other supporting document, while interview is done by asking several questions towards lecturer that teach CNC Maintenance and Reparation course in Electrical Engineering Department to get data which will be used in media development process.

Planning stage is done by determining which application will be used in developing media, like 3D design application for virtual reality development. 3D design application which will be used is Unity 3D. Furthermore, in planning stage preparation time of manufacture is also done so the media development does not waste a lot of time.

Modeling stage is started by designing program flow diagram to ease development process (Figure 2), then it is proceeded with designing the content of media by using 3D design application up to designing the interface of learning media in game engine application. Moreover, instrument design of black box test is also carried out in this stage. Designing stage of the media is done by creating 3D design of Mini CNC machine by using Blender application then it is converted into .FBX or .OBJ file type so that it can be processed in game engine application (Figure 3). After designing the content of media is done, the next activity is the modelling stage which design user interface of the media in accordance to existing 3D design (Figure 4).
Construction stage is done by programming component content of the media which has been made in modelling stage to be integrated with each other until an artificial environment (virtual reality) is created which will be used during Mini CNC machine assembly practice. Media programming is done by using Unity 3D application by utilizing Virtual Reality Toolkit (VRTK) feature. Programming is started by inputting “InteractableSnapZone” towards work shape (Figure 5). InteractableSnapZone function as laying place of object which will be integrated with another object. After the process of inputting InteractableSnapZone succeed, the next step is to change the shape of InteractableSnapZone to becomes certain object so that the laying area is easier to be identified (Figure 6), after that apply the same towards every object which will be integrated (Figure 7).
Figure 5. Insert InteractableSnapZone

Figure 6. DefaultHighlightMesh Setting

Figure 7. Virtual Reality Toolkit Final Setting
Besides that, in modelling stage a black box test is also done to understand the functionality of media that has been made. Black box functionality test has shown that the system is capable to be working as expected as shown on Table 1. According to Table 1, it can be seen that the media main screen view is working properly. Moreover, user’s movement command and connectivity between media components can work properly.

Table 1. Black Box Test Result

| Number | Scenario                      | Expected Result                          | Result |
|--------|-------------------------------|------------------------------------------|--------|
| 1.     | Clicking RIG camera appearance | Media main screen is shown virtually     | ✓      |
| 2.     | Pressing W button on Keyboard  | VR user will move forward                | ✓      |
| 3.     | Pressing S button on Keyboard  | VR user will move backward               | ✓      |
| 4.     | Pressing D button on Keyboard  | VR user will move to the right           | ✓      |
| 5.     | Pressing A button on Keyboard  | VR user will move to the left            | ✓      |
| 6.     | Dragging the mouse to the right | VR user will turn right                  | ✓      |
| 7.     | Dragging the mouse to the left  | VR user will turn left                   | ✓      |
| 8.     | Dragging the mouse to the top   | VR user will look up                     | ✓      |
| 9.     | Dragging the mouse to the bottom | VR user will look down                  | ✓      |
| 10.    | Clicking scroll on mouse       | Activates teleport command               | ✓      |
| 11.    | Clicking Right button on mouse  | Activates picking object command         | ✓      |
| 12.    | Putting object according to its place | Object can interact with each other     | ✓      |

4. Conclusion
This research resulted in a learning media in the form of Mini CNC Assembly simulator. This media development is done by using waterfall model with four steps which are communication, planning, modelling, and construction. Media is developed by using Virtual Reality Toolkit or VRTK. VRTK is used to develop learning media, especially for movement command or connectivity between objects. Mini CNC Simulator learning media can be used in online learning or independent learning by student. This is proved by black box test towards media which has shown that every system that has been built could function appropriately. However, to find out feasibility and effectivity level of media, further research is needed to be done.

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