

Lab work activities of computer network using virtual reality application

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ABSTRACT

Lab work activities are one of the hearts of science learning, but several students have limited use and time to explore computer network tools. This study proposes a virtual reality (VR) application used to support lab work activities of a computer network so that students may conduct lab work activities by themselves at any time. The method used in this study is a multimedia development life cycle (MDLC) that consists of five stages, they are concept, design, material collecting, assembly, and testing & evaluation. A formative evaluation carried out by involving two experts, namely software expert and material expert, to measure the feasibility of application before conducting user testing. Meanwhile, a summative evaluation used to evaluate the VR application by involving 25 students who were taking the course of computer networking. Statistical analysis shows that the score of Cronbach's alpha test is higher than 0.6 for aspects of material subject and experience. Hence, the VR application can be used to support the lab work activities of a computer network.

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1. INTRODUCTION

Computer networking is a subject matter that should be taught in grade X (ten) of SMK Muhammadiyah 1 Gondangrejo, Karanganyar, Indonesia. Based on the curriculum documents and the reference book used, this subject discusses about concepts of computer network technology, network topology, network medium, network protocol, addressing protocol, network hardware, network operating system, and developing a simple network [1]. Furthermore, the network hardware section is talking about various network tools such as router, unshielded twisted pair (UTP) cable, modem, repeater, switch, bridge, hub, and network interface card (NIC). These are essential since provides a necessary foundation for students so that they can learn the advanced concept of computer networks [2].

This vocational middle school implemented the subject since one of the learning outcomes (LO) is enabling students to capable of problem-solving in computer networks. Whereas, the intended learning goals can be determined by the effectiveness of learning approach that will lead to the certain LO [3]. The LO can be found in the curriculum document of the school and stated that the subject is a basic grounded to the next level. One approach to achieve the LO is by implementing lab work activities [4], such as cutting network cables, crimping to RJ-45 connectors, connecting network cable to the computers, switch, hub, repeater, modem, and router, as well as testing its network connections. Various learning media can be used to achieve

the goals, such as reference books, tutorial videos, articles on the internet, or through lectures delivered by teachers at school. Moreover, using real devices or embodied interactive video lectures (EIVL) may be performed better in understanding and memory of studying content [5].

Based on the observations however, several students show that they have limited time to use and explore the devices more details due to the study activities are bounded to other subjects. Besides, the tools of network devices are also have limited number due to the spent cost for buying in a large quantity is quite expensive. Additionally, another prominent problem is several devices are not reusable so that the tools will be discarded due to they cannot be used anymore.

Due to the stated problems, it is needed a media that support students to do lab work activities and reusable for any time, because the lab work experiences are the heart of science learning [6]. One technology that possible to resolve the problems is virtual reality (VR), which is the environment and its objects can be synthesized by computer [7]. The VR technology allows users to simulate three dimensional (3D) virtual objects [8] or users' physical presence that similar to the real devices [9]. VR also offers replication of real-life environments that enables users to thrive within [10] and intercommunicate with it while using a head-mounted display (HMD) [7, 11]. By utilizes its features, VR can be used for many researches such as the development of fire safety behavioral skills [12], fostering oral presentation [13], resolve stress disorder of post-traumatic [14], wheelchair simulator [15, 16], until earthquake safety training [17, 18]. In case of educational purposes, [19] stated that VR can be used in three different types, namely: 1) to present a state of knowledge in a particular field of science, theoretical knowledge, terminology, facts, rules or scientific theories; 2) to teach practical skills according to previously acquired knowledge; and 3) to teach how to use acquired knowledge when faced with problems. This research adopted that by developing a VR application to support lab work activities as the VR has effect to LO [20] and may engage students in learning [21].

Prior study about electronic laboratory related to computer networks has been conducted, but in the form of web application [22], so that the presented device objects are not in the 3D shape. This study proposes a virtual reality (VR) application to support lab work activities of computer networking that allows users to reuse and explore devices in a 3D virtual form. The application may also simulate computer networking and put users to the virtual environment (VE) that seem to perceive similar to the real world. The VE is designed identical to the real lab that consists of many network devices. Therefore, the users may carry out activities like practicum in the real world.

2. RESEARCH METHOD

The research method used in this study conducted through design and development research (DDR) inspired by [23] but in different model. The DDR is defined as the systematic study of design, development, and evaluation process with the aim of establishing an empirical basis for the creation of instructional and non-instructional products and tools and new or enhanced models that govern their development [24, 25]. This method divided into two main types, they are 1) research on products and tools, and 2) research on design and development models. The first type pertains to the studies of design and development of products and tools, while the second type focuses on the design and development model and process themselves, rather than demonstration. This present study applied the first type because requires to create a product of VR application that considered as a tool for learning like lab work activities situations.

The model used is the multimedia development life cycle (MDLC) adopted from Luther [26] that consists of six stages, but the last stage, namely "distribution" stage was omitted. The present study only uses five stages and modified the fifth stage by adding evaluation. The MDLC model chosen as an approach since the product contains multimedia artifacts to construct an application. The following sub-section explains more details the stages.

2.1. MDLC Stages

Figure 1 depicts the research design that used in this study, they are 1) concept, 2) design, 3) material collecting, 4) assembly, and 5) testing and evaluation. Detail explanation of each stage is described as follows:

2.1.1. Concept

Concept is an initial stage that aims to prepare the research. Reviewing literature includes into this stage since the concept development comes from here. Sources of literature review came from articles of journals, proceedings, and any sources related to the topics of study. Besides, curriculum documents related to the subject matter of computer networking are also reviewed to guide in developing the application contents. This is very helpful to formulate research problems so that it makes easier to propose a solution. Then, identify users and participants who can be involved in the research sample. The concept that emerged from this stage used as a basic grounded to continue to the next stage.

Another important thing in this stage is making a conceptual framework that helps to organize the research since it has a crucial role in developing academic and practical understanding [27]. The conceptual framework illustrates what expectation that will be found through the research related variables and its relationship. Figure 2 illustrates the conceptual framework of this study. Lab work activities of computer networking are constructed from two variables, they are material subject and new experience. The Material subject composed of information and simulation presented by the application related to network devices. Meanwhile, the new experience variable pertains to users' perception while using the application, namely pleasure, and attractiveness. Hence, two hypotheses are constructed for this study, first hypothesis (H1): The material subject that consists of information and simulation has significant impact to support lab work activities of computer networking; while second hypothesis (H2): New experience obtained from the feeling of pleasure and interesting in using VR application has significant impact to the lab work activities of computer networking.

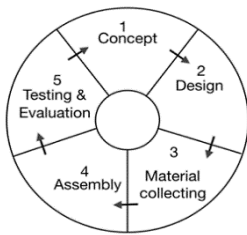


Figure 1. Research design

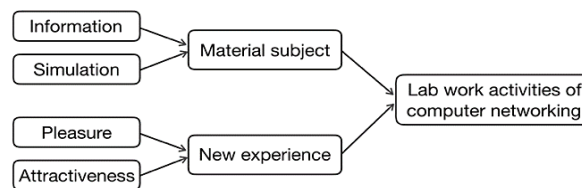


Figure 2. Conceptual framework of the study

2.1.2. Design

Design is the second stage to model out the specification of the VR application that will be created like scene menu structures and activity diagrams. Based on the previous stage, the developed application contains two notable scenes, namely educational zone scene, and the simulation zone scene, completed with about scene. All the scenes displayed at the main menu scene, so that the users may choose the provided scene includes an exit option. To aid users while using the application and makes user friendly, information is also provided in both notable scenes, so that the users feel comfortable to operate and minimizing confusion.

Figure 3 describes the design structure of the navigation menu to mapping the scenes that should be developed in the next stage. The educational zone scene presents an explanation about basic computer networking and its function, while the simulation zone scene allows users to interact and construct a simulation of a computer network. The about menu describes information about how to use the application.

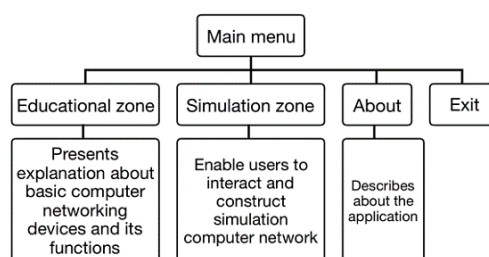


Figure 3. Design structure of navigation menu

2.1.3. Material collecting

Material collecting is a stage to gather material objects or artifacts that will be used to develop the application such as images to represent network devices, images for icon and background to construct a user interface, and sounds for back sound or sound effect to make the application perceived more real. The materials are collected from the internet provided by any free of charge sources.

2.1.4. Assembly

Assembly, is stage to start developing the application. Programming skills are demonstrated here to make a program by coding from scratch. The programming language used for the coding is C#. Several codes

are provided by Google VR plugin, but programmers are allowed to add or modify source code based on the need of the application, such as play sounds, pick up and moving the objects, as well as control the menu actions. Besides coding, material objects that collected in the previous stage are assembled based on the software application requirements, like compose user interface, insert subject matters for learning, debugging the program, and running preview to ensure that the program is running well.

This stage is the most severe one due to the necessary energy for coding and time spent on thinking and develops the application. Additionally, debugging and preview are conducted iteratively to test and obtain the expected result of the application. Then, the application is exported to the Android package file and installed on the smartphone. In this smartphone, all functions are tested include the controller function. If the application required to repair, for instance, one function is not running as expected, thus it should be revised. This process should be conducted to ensure that the application is appropriate well.

2.1.5. Testing and evaluation

Stage of testing and evaluation is the last phase of this research. This stage conducted to find out the usability of the application whether the application is quite usable or vice versa. The testing carried out to the users, they are students of SMK Muhammadiyah 1 Gondangrejo as participants at once. However, before tested to the users, several experts are involved to review and try the final VR application, so that obtaining feedback. The feedback and comments gathered from the experts are very useful to improve the quality, but not all suggestions are realized due to the available LO at the school. Therefore, two evaluation types are used in this stage, namely formative evaluation and summative evaluation. The formative evaluation used to obtain preliminary tests before users testing, while summative evaluation used to asses the usability of the application. In the formative evaluation, a beta version of the application is used, while the final version of the application used in the summative evaluation.

2.2. Participants

Participants who involved in this study are experts and students. Two experts were involved to judge the application. One expert assesses all the functional systems of application, while other assesses presented materials whether appropriate to the LO or vice versa. One expert has had experience in software engineering for more than five years, while the other one has taught computer networking for more than five years as well. Therefore, all of the experts are competence and qualified to judge the application before used for users testing. On the other hand, the students who involved in this testing are grade X at SMK Muhammadiyah 1 Gondangrejo, Karanganyar, Indonesia, and take basic networking classes at the time. They are chosen since they have just taken the course so that they may give an appropriate feedbacks whether the application is suitable to use or not. Those who participated in the testing are 25 persons (44% male and 56% female) with the average age are between 15 and 16, where only one person has the experience to use VR application.

2.3. Instruments

Instruments used to collect data are questionnaires, both in formative and summative evaluation. The questionnaires consist of three different types, they are questionnaire for software expert, materials expert, and the students. Table 1 shows question lists that used to assess the VR application to support lab work activities of computer networking. The questions are grouped into three categories, namely user interface, visualization, and audio. Table 2 describes the question lists to asses the material subjects presented in the application related to computer network devices including material contents and learning objectives provided in the VR environment. These questions used to make sure that the overall presented materials are appropriate to the basic competencies of computer network devices that taught in the school.

Table 1. Questionnaire for software expert

No.	Questions
A. User Interface	
1.	Display menus are interesting
2.	All buttons and its functional system are running well
3.	The overall system of the application is running well
B. Visualization	
4.	All 3D objects (network devices, tables, and chairs) are displayed well
5.	Presented text information is seen clearly
6.	Color combinations of 3D objects of network devices and their environment are interesting
7.	3D objects model are almost similar to the real devices
C. Audio	
8.	The back sound used is appropriate
9.	Presented voice explanations are sound clearly

Table 2. Questionnaire for material expert

No.	Questions
A. Material content	
1.	Presented materials are appropriate to basic competencies
2.	Presented materials are easy to understand
B. Learning objectives	
3.	Learning objectives are presented clearly
4.	Presented visualization examples of network devices are appropriate to the material subjects of network devices
5.	Overall presented simulation can be used to help lab work activities of students

To do an assessment, the experts should be trying and use the application first, then giving the feedback by providing a check sign to the printed questionnaires. Likert scale ranging from score 1 to 4 is used to judge every question lists, where score 1 refers to very disagree while 4 asserts very agree. In the last section of questionnaires are also provided space for experts to write the comments. However, oral comments and feedbacks are also noted to anticipate if the comments are not written by experts. If the feedback scores are not as expected, the application will be revised based on the comments and suggestions, then come back to the experts to show the revisions. If the feedback scores have been as expected, it means that the application is ready to be tested to the students and collect the data from users. Table 3 shows the instrument to collect users' responses that use the Likert scale as well which is adopted from user experience questionnaire [28].

Table 3. Questionnaire to obtain users' response

No.	Questions	Categories
1.	The presented information of materials in this VR based learning media is easy to understand	Information
2.	I perceive more understand while using this VR based learning media compare to previous tools	
3.	Presented simulation in this VR application give me more insight of computer networking	Simulation
4.	I like this learning media used to support learning computer networking	Pleasure
5.	This VR based learning media is playful	
6.	This VR based learning media give me new experience in learning computer network devices	Attractiveness
7.	Overall, this VR based learning media is very interesting	

Based on the conceptual framework in the Figure 2, the question lists of questionnaires to obtain students' responses are classified into four categories, they are information, simulation, pleasure, and attractiveness. These are independent variables that influence to dependent variables of the material subject and new experience which is influencing lab work activities of computer networking as well. The questionnaire used to find out the response related to these variables. In the last section, the students also have a chance to write comments or suggestions based on their experience while using the application. Besides this questionnaire, the students also were given another questionnaire to find out the comparison between using VR based media and Microsoft (Ms.) PowerPoint, since the materials also delivered through this software. The questionnaire is shown in Table 4. In this question type, the students only answer yes or not that state their perceptions subjectively, so that the answer can be different from each other based on their experience while using the application.

Table 4. Questionnaire to compare VR and Ms. PowerPoint

No.	Questions
1.	VR based learning media is more playful than Ms. PowerPoint
2.	I feel more understand the material presented in the VR based application than Ms. PowerPoint
3.	VR based learning media give me more new exciting experience than Ms. PowerPoint
4.	According to me, VR based media learning can more improve knowledge about computer networking than Ms. PowerPoint
5.	Presented information in the VR based learning media is easier to understand than Ms. PowerPoint
6.	VR based learning media is more playful than Ms. PowerPoint
7.	I feel get motion sickness while using VR based learning media

However, the last question is not to compare VR application and Ms. PowerPoint. The last question is more to find out how the feeling when using VR application bundled in HMD whether getting motion sickness or not, because the previous researches [17, 29], stated that several participants were potentially getting motion sickness and dizziness when switching viewpoints in using VR application. Therefore, this question used to evaluate whether the application is getting a similarity of negative effect with the previous study or not.

2.4. Data analysis techniques

Statistical analysis is used to analyze the collected data through SPSS software. Validity and reliability test are performed to test whether the developed questionnaires are valid and reliable. The results are used to examine the constructed hypotheses whether having a significant impact or vice versa. To test the validity, Pearson Product-Moment Correlation is used, while to measure the internal consistency or reliability, we use Cronbach's alpha test. Since the participants involved in this research are 25 persons so that the value of r table used is 0.381 with a significance level is 5%. If the value of r score is higher than r table ($r \text{ value} > r \text{ table}$) means that the questionnaire is valid. Otherwise, if the r score is smaller than r table means that the questionnaire is invalid. Meanwhile, the used value of Cronbach's alpha is 0.6 to examine whether acceptable or the opposite [30].

3. RESULTS AND DISCUSSION

3.1. VR Application features

The VR based learning media application on this study was developed with Unity software 2018.3.11f1 Personal version and Google VR plugin for Unity v1.190.0 version. The programming language used is C# with Visual Studio community version as the programming editor. To test the built version, the application is installed on an Android smartphone and inserted into the VR glasses as HMD, viz. VR Shinecon 6.0 G04E Stereo bundled with controller and headset. With these VR glasses, users can only see the views of the virtual environment (VE) generated by a smartphone in front of their eyes while worn. Since the VR glasses can set up the limited display that makes the users do not see the real world around them. The view displayed in the VR glasses is the first-person perspective, which is the users also allows to see surrounding VE by 360-degree views. The views perspective can be controlled with available gaze sensors by turn head to the right, left, up, or down. Meanwhile, to control the movement may use the controller that connected to the smartphone via bluetooth sensor, so that changing the coordinate positions of users. To control the movement of users, the controller can be connected to the smartphone via bluetooth. Therefore, the application is designed with two controllers, namely by the hardware controller and other is gaze cursor sensor provided by the VR plugin in default.

Based on the design Figure 3, the application consists of two notable scenes and other complements. The two notable scenes are the educational zone scene and the simulation zone scene. The main menu scene will be displayed at the first time when the application is opened, then users allowed to choose the scene or zone that will prefer to enter. At the first time, while entering both notable zones, a greeting voice played by the system. Besides, the system also gives information where the users located, whether in the educational zone or simulation zone. Then, the users will be guided what should they do by voice instructions as well, so that the users feel convenient and easy to use the application.

In the educational zone scene, users presented several network devices like UTP cable, LAN card, modem, bridge, access point, router, repeater, hub, and switch. In that devices conceive information about name, brief explanation, and its function. By default, the pieces of information are hidden and to show the information gaze cursor in the VR environment should be directed to the device. Figure 4 (a) displays an example of information that showed by gaze cursor in the educational zone. To hide back the information, gaze cursor should be directed back to the device that shows the information. In this scene, users can only see the devices that put on the table without the interaction of constructing computer network. To enable more interaction and construct a computer networking, users should enter the simulation zone.

Figure 4 (b) shows the simulation zone scene that allows users to do more interaction by constructing computer network devices, so that it may support lab work activities. When users entering to this scene, the users will be guided by voice instructions what should they do. For example, shown at the Figure 5 displays the 3D object of a free table with the word "switch", the voice guidance will instruct the users to find out the switch device around the virtual lab world and put it to the table. Once the step finished, the users will be instructed to find a cable that attached to a computer server and connect to the switch device. Then, the users will be given the next instruction, namely to find a cable that attached to the computer client, and then connect it to the switch device. After finished the tasks, the users are congratulated by the voice of the application system as a sign. This task is very challenging since the 3D virtual room is using a three-dimensional coordinate system that sometimes makes the depth and length among objects are unmeasured clearly. It can influence the outlook on how deep or how far the objects located, so that may be missing to connect a cable to other devices. Therefore, it is requiring a little bit of effort to accomplish the task, but this is one feature that makes the application is interesting.



(a)



(b)

Figure 4. (a) Educational zone scene displays network devices and its information, (b) Simulation zone scene to simulate computer networking activities

Figure 5 simulates a connection from the computer server, switch, and client. The connection created from the cable constructed by the user. The simulation of cable is still not really similar to the real. However, this lack does not reduce the feeling of users' playful to use the application since they get new experience from this learning media. Additionally, the virtual laboratory room designed on this application is also designed with the modern style, so that it makes users feel comfortable to exploring the area surrounding them.

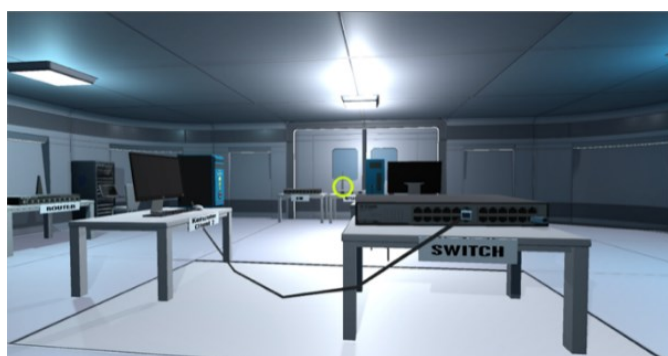


Figure 5. Simulation of network cable that connected to switch

3.2. Formative evaluation

Final version of the VR application obtained from the formative evaluation (FE) to identify potential and actual influences on the implementation process [31]. The FE conducted through testing the application by the experts, namely software expert and material expert, then they fill out the questionnaires that designed at the Table 1 and Table 2. Table 5 shows the final result recapitulation of FE from both software expert and material expert. The average percentage score of software facet like user interface, visualization, and audio is 69,16% that shows the application is feasible to use for testing. Meanwhile, the average percentage score of

learning content obtained from the material expert is 85,4% which means that includes a very feasible category. Overall, the application is quite feasible to be used in conducting user testing.

Previously, the experts give feedback and comments to improve the application, such as the software expert stated that the font used is so close to each other, so that it should be evaluated. Additionally, he also stated that instructions at each zone should be made per step, so that makes users convenience to follow the guidance. Meanwhile, the material expert has only slightly comments since the materials are taken from curriculum documents that appropriate to the LO.

Table 5. Result of Formative evaluation from experts

No.	Assesment	Score/Max	Percentage
Software Expert			
1.	User interface	9/12	75%
2.	Visualization	14/20	70%
3.	Audio	5/8	62.5%
	Average		69.16%
Material Expert			
4.	Material contents	7/8	87.5%
5.	Learning objectives	10/12	83.3%
	Average		85.4%

3.2. User testing

User testing conducted toward 25 students of SMK Muhammadiyah 1 Gondangrejo grade X who were taking basic computer network subjects. Beforehand, the students are explained the set of tools used such as VR glasses bundled headset, controller, smartphone, and the VR application that installed on it. They are told how to use and what functions of each device. To anticipate the worst thing, they were also informed of the potential of motion sickness while using the application. However, they are advised to no worry when using the devices since it is guaranteed to be safe and will not result in an accident. Hereinafter, the students are explained that they should fill out the questionnaires and encouraged to be honest in filling out, since their privacies are safe guaranteed and will not share to any party, merely for research purposes only.

Figure 6 shows the students who were using VR glasses and hold the analog controller. The VR glasses contain a smartphone which is installed VR application. The students move their head to see VE around them. They can use the controller to go forward or moving coordinate positions. Besides, the controller can also be used to select 3D objects in the VE room since the provided "Ok" button that has a function as "enter" in a computer keyboard. Hence, the 3D objects of network devices can be moved from one place to another. Noticeable that the students are quite enjoying their activities in the VE, it can be seen from the movements of their hands and limbs to the left and the right to control the application. Sometimes, their lips looked like reading guidance in that virtual room.



Figure 6. Students using VR glasses with the application and its controller

Every student tried the application for about 7-10 minutes on average. Once finished, the students are allowed to fill out the questionnaires provided. Table 6 shows the result of the validity and the reliabilty test obtained from the questionnaire outlined in Table 3. It can be seen that all of the questionnaire items are valid due to the score of correlation coefficient (r value) are higher than the r table (0.381). The smallest score is question item Q1 with the value 0.670, while the highest score is item Q3. This interprets that the presented

simulations in the VR application give students more insight into computer networking since the 3D objects simulated by VR are similar to the real devices.

Table 6. Validity and reliability test result

Aspects	Questions (Q)	Correlation coefficient	Cronbach's Alpha	Meaning
Material subject	Q1	.670	.683	Valid
	Q2	.785		Valid
	Q3	.879		Valid
New experience	Q4	.734	.728	Valid
	Q5	.744		Valid
	Q6	.683		Valid
	Q7	.809		Valid

Meanwhile, the Cronbach's alpha score is higher than 0.6, namely 0.683 for the material subject aspect and 0.728 for the aspect of new experience. Therefore, the first hypothesis (H1) and the second hypothesis (H2) are acceptable. It means that the aspect of the material subject which consists of information and simulation provided by the VR application can be used to support lab work activities of computer networking, mainly to introduce the computer network devices. Additionally, the aspect of new experience that obtained from the feeling of pleasure and attractiveness while using VR application may support lab work activities of the students.

Lastly, the participants are asked to fill out the questionnaire to find out the comparison of learning media between the VR application and Ms. PowerPoint. Table 7 shows the result of the questionnaire outlined in Table 4 after the participants using the application. The average percentage of comparisons between the VR application and Ms. PowerPoint is 78% versus 22%. It means that the VR application built for this research is more preferable than Ms. PowerPoint. Question 7 used to find out whether the participants getting motion sickness or not while using the set of VR applications. Evidently, 24% of participants were getting motion sickness, while 76% of others are feeling good. This motion sickness occurred due to the participants have never been using the application before. However, the feeling of motion sickness is just a moment. Then, they fine to continue using the set of VR applications.

Table 7. Comparison of VR application and Ms. PowerPoint

Questions (Qs)	Answers (%)	
	Yes	No
Qs1	88	12
Qs1	64	36
Qs3	88	12
Qs4	72	28
Qs5	72	28
Qs6	84	16
Average	78	22
Qs7	24	76

4. CONCLUSION

Based on the above testing results and discussions, it can be concluded that lab work activities of computer networking can be supported through a VR application due to its features allowing to simulate network devices similar to the real objects. It can be seen from the score of Cronbach's alpha test is 0.683 which means higher than 0.6. Aspects that may be embedded into the VR application to support the lab work activities are information on learning material related to the subjects and simulation of the real devices that support the subjects. Additionally, the application should be designed to have users feel pleasure and interest so that they gain new experience while using VR application. One challenging task in this VR application is to connect a virtual network cable from one device to another because the 3D virtual room of the VR environment applied three-dimensional coordinate system that makes the depth and distance among 3D objects are unmeasured clearly. Further, this study may contribute to the knowledge that VR technology can be used to support lab work activities of computer networking. However, feeling of motion sickness while using VR application should be anticipated if the users have never been using previously.

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