Design and Evaluation of Maliki V-Lab: A Metaverse-Based Virtual Laboratory for Computer Assembly Learning in Higher Education

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***Abstract*—Some schools keep using online learning media even after the new normal of COVID-19 to provide broader reach for students and teachers. Online learning in practicum class requiring physical practice equipment remains a challenge. This research proposes Maliki V-Lab, a metaverse-based VR laboratory that provides practicum class for computer assembly as an online learning media platform. The developed system then evaluated for the usefulnes and sense of virtual presence. System usability was measured using the System Usability Scale (SUS) questionnaire, and virtual presence was measured using the Igroup Presence Questionnaire (IPQ) that consist four categories. The system usability test result is marginally acceptable, while virtual presence test result is acceptable for general presence, spatial presence, and expected realism category, and marginally acceptable for involvement category. Based on these results, this system can used for practical learning specifically according to the criteria that have been tested. Maliki V-Labs needs to improve the level of usability and virtual presence before it can be expanded with another practicum class and another type of respondent.**

***Keywords*—online learning, usability, metaverse, virtual presence, virtual reality**

I. Introduction

Significant development of information technology influences the development of learning media models used in the knowledge transfer process. Common form of Technology-based learning media used in education is text, images, audio, video, and their combinations [1–3]. On the other hand, infrastructure technology developments such as internet networks, notebooks, smartphones, and other portable devices make technology-based learning media easily accessible anywhere. In addition, the learning process during the COVID-19 pandemic that occurred recently provides evidence that learning media can be accessed easily without physical classes [4–7]. Commonly used platforms for learning media during the pandemic are WhatsApp, Moodle, email, YouTube, Telegram, Zoom, Google Workspace, and Edmodo [8]. All of these learning media platforms are available on various devices, making them easier to access.

In the new normal era, the schools are gradually reinstating offline learning as cases subside and the handling of COVID-19 is improving [9–11]. However, some schools keep using online or hybrid learning [12] just like in the pandemic era. Maintaining this learning aims to provide a broader range of students and educators in carrying out the learning process. Video conferencing is a powerful learning media for online theory class activities, such as providing presentation material, conducting questions and answers, and discussion. This learning media can also be used in online practicum classes by showing practical steps as long as each student has sufficient equipment to practice them in their respective places, such as drawing, programming on a computer, and so on.

However, practicum class becomes difficult if students do not have the necessary practical tools to learn the subject [13], especially physical practical tools that are usually available in laboratories, such as measuring tools for measuring objects, body models in operating process simulations, and components in computer assembly. In addition, collaborative and cooperative learning in practicum classes cannot be carried out online with the current learning media platforms because the involvement can only happen via voice and picture without being in the same environment for working together physically.

Practicum classes with cooperative learning methods usually provide students with a deeper understanding after receiving the material in the theory class. This cooperative learning practicum process is carried out by working on a project together [14], usually in a small group of students. Some examples of cooperative learning practicum for the health sector are carrying out operations [15] and nursing [16], assembly, maintenance, and repair [7] in engineering fields, and safety simulations [17] in industrial fields. Therefore, a realistic virtual learning media platform that supports online cooperative practicum class at the university is needed. Realistic virtual learning media will make it easier for students to understand practical subject matter individually and in groups at online class practicum, just like physical class practicum.

Metaverse is a combination of two words: meta, which means beyond, and verse, an abbreviation of universe, which means universe. In one definition, the metaverse is a universe transcending the real world [18]. The sentence beyond the real world is interpreted as a technology that allows users to be in the virtual world but can interact like in the real world [18]. Users can feel like they are in the virtual world and do the same things in the real world, such as talking with family, working with office colleagues, and playing games with friends. Reality in the metaverse can be in the form of virtual reality or augmented reality [19]. VR is a technology that brings reality to a virtual world. Meanwhile, AR technology brings the virtual world into a real environment [20]. Apart from VR or AR technology, metaverse also requires an internet connection and a PC or mobile computer device to be able to connect with other

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users [21].

We propose Maliki V-Lab, a Metaverse-based VR laboratory that provides practicum class for computer assembly as an online learning media platform. As a realistic digital world-based learning media and multiplayer [22], the metaverse characteristic in our system can be used for cooperative learning practicum for students from their own place. On the other hand, virtual reality technology will provide an experience of being in the digital world physically [23, 24] to provide a practicum learning experience that resembles an offline cooperative practicum learning.

II. Literature Review

Computer assembly practicum is a computer systems science, computer science, and informatics program course. Computer assembly practicum learning intends to allow students to install the components needed to produce a computer. Several studies on computer assembly learning utilize AR and VR with different goals, such as increasing student capabilities, practical tool limitations, and cost efficiency.

A study by Westerfield *et al.* [25] related to assembling the motherboard, which is part of a computer, using augmented reality learning media. This study aims to compare traditional AR learning and intelligence-AR. The results showed that learning motherboard assembly using intelligence-AR improved two aspects compared to traditional AR learning: an increase in test scores by 20% and an increase in processing speed by 30%.

Research of computer assembly using non-immersive VR has been conducted by Tong *et al.* [26]. The study describes the development of learning media for vocational high school students called the Virtual Training System for Computer Hardware Assembly (VTSCHA). The development of this system intends to overcome the limitations of practicum tools and equipment in schools. This learning media is designed according to what actual learning needs for users to interact easily. Although the system still uses non-immersive VR, it successfully replaces traditional computer assembly.

Another development of computer assembly using non-immersive VR conducted by Cai and Yang [27]. The development intends to increase user interaction, reduce the cost of purchasing practicum tools, and can be accessed anywhere. Not only developing the learning media, this research included usability test using Theory Acceptance Model (TAM) in 3 categories, namely Perceived Ease of Use (PEOU), Perceived Usefulness (PU), and Perceived Interest (PP). The results of the test show that all the median scores of questions in the PEOU, PU, and PP categories are above 4.

Another study by Rodrigues *et al.* [28] describes the development of computer assembly learning media using fully immersive VR. This system is intended to train the employee. Learning media evaluated with four instrument, namely Simulator Sickness Questionnaire (SSQ), System Usability Score (SUS), After-Scenario Questionnaire (ASQ), and self-developed virtual presence questionnaire. The results of the questionnaire show that all tests get good results with details of 93.4% (the higher, the better) for the virtual presence, 26.53% for SSQ (the lower, the better), 90% for SUS (the higher, the better), and 17.6% for ASQ (the lower, the better).

The use of metaverse in learning has also begun to be developed a lot [29, 30]. Its designation is not only for educational learning, such as universities and high schools. Instead, it is also used in the industry as a training learning medium following the needs of each industry. The main benefit of using Metaverse was the multi-user ability.

Research conducted by Lee *et al.* [17] describes the development of a serious game of evacuation training simulation during a fire disaster using fully immersive VR. The users of this metaverse based game are divided into two roles: trainees and supervisors. System testing was carried out by comparing the results of the trainees in the first experiment with the second experiment. The test results show that the scores of most trainees have increased after trying two times, especially for participants with a low level of understanding of fire evacuation.

Another research conducted by Lee *et al.* [7] describes development of metaverse based educational materials for aircraft maintenance procedures, equipment, and terminology using semi immersive VR. This research simulates the maintenance process of the aircraft KT-100 type carried out by multiple users. This research evaluated the system's usability using the System Usability Scale (SUS) and virtual presence using the Igroup Presence Questionnaire (IPQ). The SUS result of this research is 77.6. The IPQ score also showed good results. All criteria of the IPQ average score are more than 3, the average score of the Likert scale 0 to 6. Detailed score is General presence with 4.9, Spatial Presence with 5.08, Involvement with 4.25, and Expected Realism with 4.11.

Another field that utilized metaverse for learning media is medical discipline that conducted by H. Koo [15]. The study described metaverse extended reality ability to create a virtual class in operation training called the smart operating room to accommodate a large number of participants. These things cannot be done in the real world, considering there is a limit to the number of people in the operating room. System testing was carried out during lung cancer surgery, where 200 participants could see the operation process as if they were in an operating room.

Research regarding the use of the metaverse in education field has been carried out by Arif and Nurhayati [31] using semi immersive VR. User role of this research were teachers and students. This research focuses on providing recommendations for mathematics material that suits students' abilities. The result of this study shows that MCRS-based LMS produces the highest accuracy of 92% for two to three input items and the lowest 90% for four input items.

The development of computer assembly learning media for the university student can be equipped with metaverse technology to enable cooperative learning at multiple locations with multi-user and multi role. Metaverse is proven to provide multi-location collaborative and cooperative learning both in the industry and education sectors. So, computer assembly learning media can be developed using metaverse technology, making it possible for students and teachers from various locations to be in the same room. A comparison between past research can be seen in Table 1.

Table 1. Comparisons and related research

Ref	Subject	Media	Meta Verse/ Multi Player	Evaluation Method	Targeted User
[25]	Mother board Computer Assembly	AR	No	Case Control	Not Defined
[26]	Computer Assembly	Non-immersive VR	No	Not Defined	Vocation-al High School Student
[27]	Computer Assembly	Non-immersive VR	No	System Usability	College & Uni-versity Student
[28]	Computer Assembly	Fully immersive VR	No	System Usability & Virtual Presence	Not Defined
[17]	Fire Disaster Evacuation	Fully immersive VR	Yes	Case Control	Not Defined
[15]	Surgery	Extended Reality	Yes	Not Defined	Medical Student
[7]	Aircraft Maintenance	Semi immersive VR	Yes	System Usability &Virtual Presence	Uni-versity Student
[31]	Mathematics	Semi immersive VR	Yes	System Accuracy	Elemen-tary School

III. Materials and Methods

A. System Design

The development of the system is divided into three stages: gathering and modeling the assets, creating media visualization, and programming the media. In the first stage, we gather the assets from multiple sources and model the character using Blender 3.3.1 Version. The next stage is creating the media visualization. In this stage, we build and design the virtual laboratory and put the assets in it. The virtual laboratory was built and designed using Unity Editor 2021.3.28f1 version. The last stage is programming the media. The media was programmed using the C# language with Visual Studio Community 2019 as the script editor. All of these stages of development use Acer Nitro notebook with Intel Core i7-9750H processor and Nvidia GTX 1660Ti graphic card specification, running on Windows 10 Operating System.

The proposed system uses metaverse so several users can be in the system simultaneously. Fig. 1 shows how this metaverse system consists of two parts: the virtual reality system and the virtual laboratory system. The virtual laboratory has a sub-system, namely evaluation. The function of the evaluation system is to determine the player's level of understanding regarding installing computer components.

When a user uses the VR headset and touch controller, the virtual reality system will recognize movements on the VR Headset and touch controller sensors. The reading results of the sensors are sent to the virtual laboratory system and visualized as the player's character movements, like walking, raising a hand, and grabbing a component. These visualizations happen in the virtual laboratory system. A virtual laboratory system is an environment for a virtual laboratory where players can use their characters to install the computer components, meet other user characters, and complete the objective together (Fig. 2).

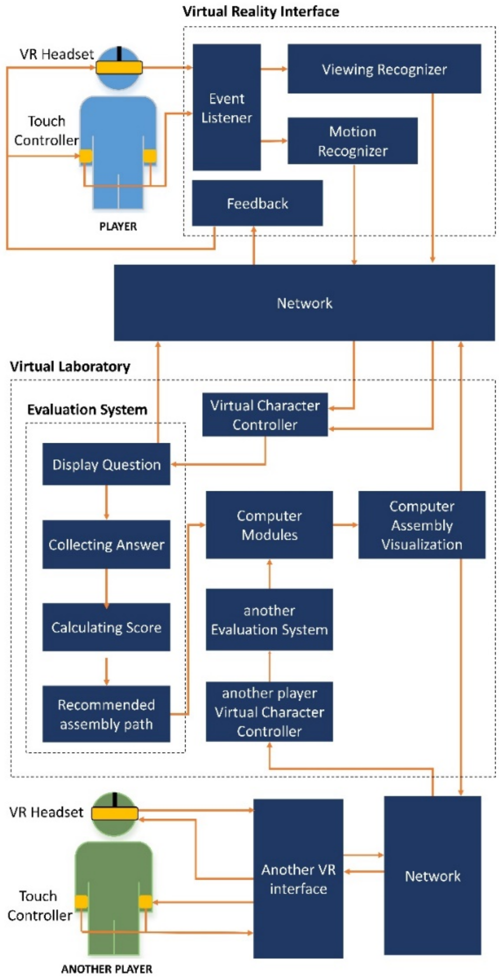

Fig. 1. Virtual reality system in this research.

Fig. 2. Players in front of computer components to be assembled.

B. Scenario Design

The experiment will use two VRs equipped with a touch controller and one computer. The network used by these three devices was the same, and users will be located in a separate location. The detailed tools used in the experiment are shown in Table 2.

Table 2. Tools used for this study

Item	1st Player	2nd Player	3rd Player
User	Student	Student	Teacher
Display	VR Head-Mounted Display	VR Head-Mounted Display	Notebook Screen
Device	Oculus Quest 2	Oculus Quest 2	MSI GL63
Motion Recognizer	Touch Controller	Touch Controller	None

Before entering the virtual world, all of the respondents will get an explanation of the course objective and how to use the VR headset and touch controller to complete the objective. The controller has a separate key for moving, rotating, and grabbing (Fig. 3).

Fig. 3. Controller function button.

When the students understand each key function, the VR headset will be used and fitted to the head, and the students will enter the virtual laboratory for the computer assembly practicum class. In the class, there is a teacher who supervises the computer assembly process. After completing the assembly, students are asked to remove the VR headset and touch controller.

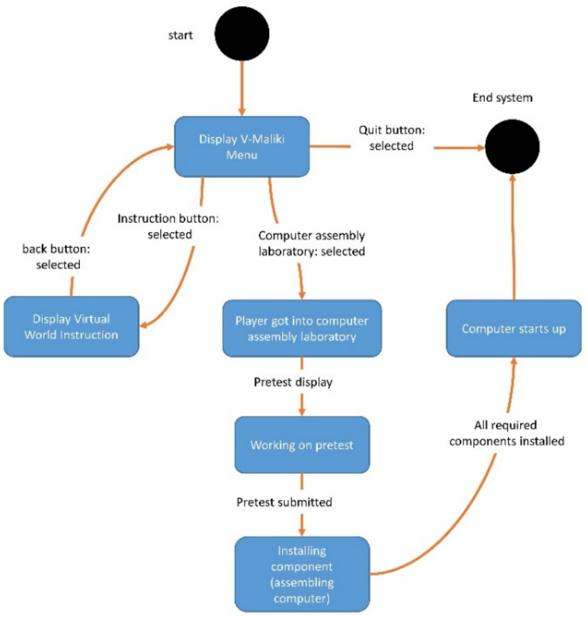

Fig. 4. Finite State Machine of the metaverse system proposed in this research.

All components that need to assembly are available on the lab table. Students can grab the component, bring it to the computer case, and install it. There are four sections in the computer assembly activity: Power Supply Unit (PSU) Installation, Motherboard and Cards Installation, Internal and External Drive Installation, and Internal and External Cable Installation. The PSU installation only consists of one part: installing the PSU into the computer casing. Motherboard and card installation starts with placing the motherboard in the casing, then installing the processor, heatsink and fan, Random Access Memory (RAM), graphics card, and other cards. Internal and external drive installation consists of installing Hard Disk Drive (HDD), Solid State Disk (SSD), and Optical Disk Drive (ODD). Internal and external cable installation includes the data and power cables on drives and computer peripherals, such as mouse, keyboards, and monitors. After completing the assembly, the player can exit the laboratory. The Finite State Machine for this metaverse system can be seen in Fig. 4.

C. System Evaluation

The system was built for computer assembly practicum that can provide a learning experience that resembles an offline cooperative practicum learning, as previously mentioned. Therefore, evaluating system usability and virtual presence will involve students who have taken an offline computer assembly course as respondents.

System evaluation was carried out using a questionnaire instrument. The System Usability Scale (SUS) questionnaire is used for usability tests [32], and the Igroup Presence Questionnaire (IPQ) is used for virtual presence tests [33]. SUS consists of 10 questions with answer choices using a Likert scale from 1 to 5. IPQ has 14 questions consisting of one general presence question, five spatial presence questions, four involvement questions, and four expected realism questions. All questions on the IPQ questionnaire use a Likert scale from 0 to 6. SUS data calculations are carried out by finding the mean value for each question item, while IPQ calculations are carried out by finding the mean value for each category.

D. Experiment Flow

The experiment flow begins by running the system with two players as students and one as teachers. All three players are in 3 different locations. Students use a VR HMD with a touch controller while the teacher observes the student's activity with a notebook. Players enter the virtual laboratory simultaneously and perform computer assembly procedures.

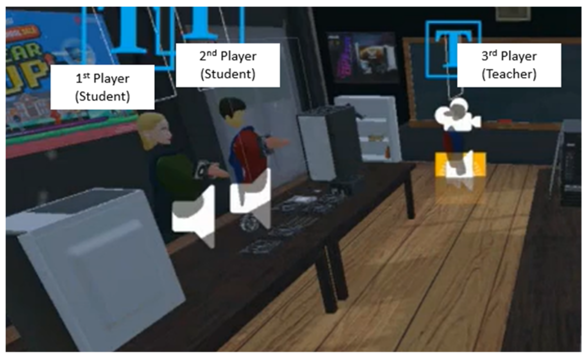

Fig. 5. 2 students and the teacher in the virtual c.

Fig. 6. Male and female students assembling computer in different place.

Fig. 5 shows all players with his character in the virtual environment. Fig. 6 shows two players in different locations running their respective characters in a virtual environment. After completing the experiment, these two players will fill out the usability and virtual presence questionnaire. The experiment continued with the next two players as students until the last pair of respondents.

IV. Result and Discussion

A. Respondent Demography

The total number of respondents involved is 40, consisting of 17 (42.5%) female and 23 (57.5%) people from them are male. When conducting the test, the respondents were between 19 to 22 years old. All respondent are students from the computer system course. Details of the respondents can be seen in Table 3.

B. Usability Result

Respondent data for the usability questionnaire was calculated using the formulation of the SUS score. For each item, the mean score is calculated, followed by calculating the contribution score of each item. The contribution score is calculated for odd item numbers by reducing the mean score by 1. Meanwhile, for even item numbers, the contribution score is calculated by subtracting 5 from the mean score of each item. The contribution score of each item is added up and then multiplied by 2.5 to get a scale of 0–100 [32]. The mean score and contribution value can be seen in Table 4.

Table 3. Detailed respondent demography

Demographic Characteristic	Item	No of Respondent	Percentage (%)
Gender	Female	17	42.5
	Male	23	57.5
Age	19	11	27.5
	20	16	40.0
	21	12	30.0
	22	1	2.5
Experience in VR Environment	Yes (Non-Interactive VR)	2	5.0
	Yes (Interactive VR)	10	25.0
	No Experience	28	70.0

Table 4. Questionnaire statistics of SUS

No	Item	N	Mean	Std Deviation	Contribution Score
1	I think that I would like to use this system frequently	40	4.30	0.723	3.30
2	I found the system unnecessarily complex	40	1.98	0.862	3.03
3	I thought the system was easy to use	40	4.38	0.667	3.38
4	I think that I would need the support of a technical person to be able to use this system	40	3.13	1.223	1.88
5	I found the various functions in this system were well integrated	40	4.35	0.700	3.35
6	I thought there was too much inconsistency in this system	40	2.15	1.122	2.85
7	I would imagine that most people would learn to use this system very quickly	40	4.10	0.841	3.10
8	I found the system very cumbersome to use	40	1.98	1.000	3.03
9	I felt very confident using the system	40	3.88	0.883	2.88
10	I needed to learn a lot of things before I could get going with this system	40	3.83	1.059	1.18
	Total				**27.95**

The total SUS score for this system is 27.95, then multiplied by 2.5, so the numbers obtained for the range 0-100 are 69.88. Calculation continues by converting the SUS score into an acceptability range and an adjective rating [34]. The conversion results state that the system is marginally acceptable and has an OK adjective rating (Fig. 7).

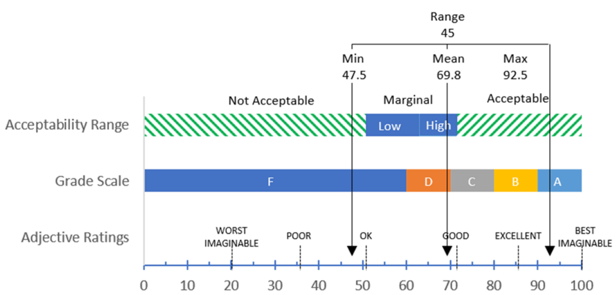

Fig. 7. Rating for usability of this research.

C. Virtual Presence Result

IPQ results are divided into 4 categories, namely General Presence (G), Spatial Presence (SP), Involvement (INV) and Experienced Realism (REAL). The calculation of respondent's data is to search the mean of every item according to the question. Before calculating the mean, the reversed items according to IPQ, namely SP2, INV3, and REAL1 [35], were reversed. The mean details for each item can be seen in Table 5.

Table 5. Questionnaire statistics of IPQ

No	Item	N	IPQ category	Mean	SD
1	In the computer-generated world I had a sense of "being there".	40	G1	4.73	1.062
2	Somehow, I felt that the virtual world surrounded me.	40	SP1	4.78	1.349
3	I felt like I was just perceiving pictures.	40	SP2	4.15	1.505
4	I did not feel present in the virtual space.	40	SP3	4.08	1.299
5	I had a sense of acting in the virtual space, rather than operating something from outside.	40	SP4	4.28	1.301
6	I felt present in the virtual space.	40	SP5	4.93	1.163
7	How aware were you of the real world surrounding while navigating in the virtual world? (i.e. sounds, room temperature, other people, etc.)?	40	INV1	3.43	1.010
8	I was not aware of my real environment.	40	INV2	3.53	1.450
9	I still paid attention to the real environment.	40	INV3	3.18	1.551
10	I was completely captivated by the virtual world.	40	INV4	3.93	1.328
11	How real did the virtual world seem to you?	40	REAL1	3.33	1.559
12	How much did your experience in the virtual environment seem consistent with your real-world experience?	40	REAL2	3.45	0.815
13	How real did the virtual world seem to you?	40	REAL3	3.58	1.083
14	The virtual world seemed more realistic than the real world.	40	REAL4	3.30	0.911

Fig. 8 shows the mean IPQ results for each category. The highest one is G with 4.73 points as a bow. Followed sequentially by SP (4.51 points), INV (3.51 points), and REAL (3.41 points) on three axes. These mean results are higher than the average of the Likert scale from 0 to 6. Each IPQ result is then interpreted into an acceptability range and adjective rating, then translated into a grade [36].

G category is rated as acceptable, has an excellent adjective rating, and A grade. Grade A means the system has outstanding performance; users like the system and may suggest it [36]. Detailed results of the G category can be seen in Fig. 9.

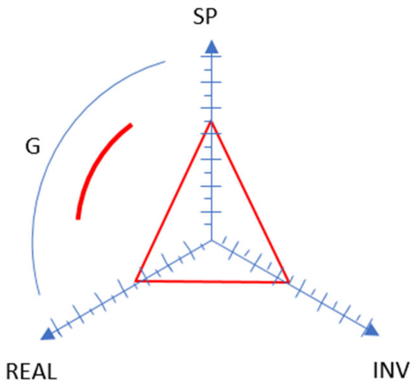

Fig. 8. Mean IPQ results for each category.

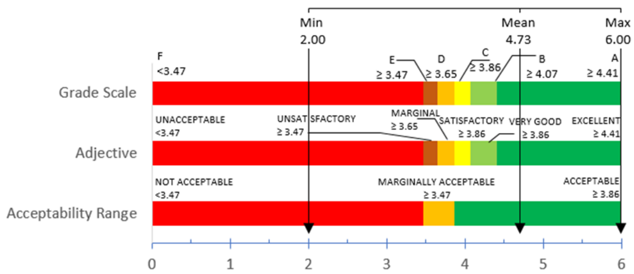

Fig. 9. Rating for general presence of this research.

SP category is rated as acceptable, has a satisfactory adjective rating, and C Grade (Fig. 10). Grade C means the system performs satisfactorily but has room for improvement [36].

INV category is rated as marginally acceptable, has an unsatisfactory adjective rating, and E grade (Fig. 11). Grade E means the system has unsatisfactory performance and could be used in particular scenarios cases but shall not be distributed to the public.

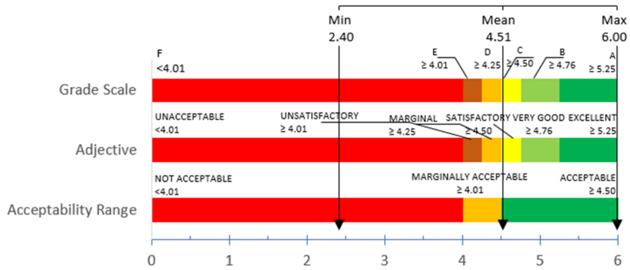

Fig. 10. Rating for spatial presence of this research.

The REAL category is rated as acceptable, has a satisfactory adjective rating, and C grade (Fig. 12). Grade C means the system has satisfactory performance with a margin for improvement.

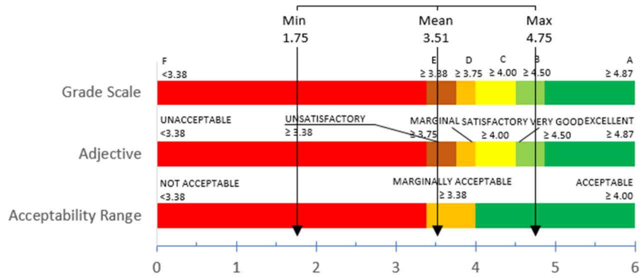

Fig. 11. Rating for involvement result of this research.

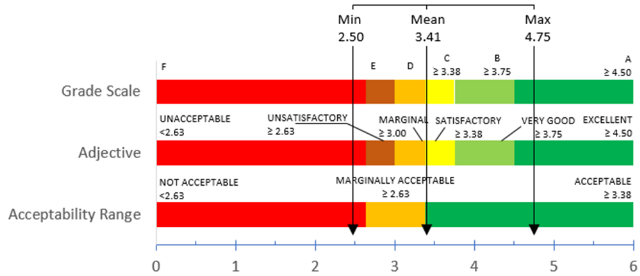

Fig. 12. Rating for experienced realism result of this research.

D. Discussion

Two of the 10 SUS items contribute scores below the average, namely item 4 (technical support need) and item 10 (need to learn the system). This low score is consistent with most respondents (70.00%) having no VR technology experience. Hence, they need assistance and time to learn when using this virtual laboratory system for the first time, and it will improve after several experiences [37].

The IPQ results show that most categories are rated acceptable, although the INV category is marginally acceptable. The lowest item in the INV category is the INV3 item (still pay attention to the real world). The attention to the real world is related to the player's desire to pay attention to the surrounding environment because the arena created for the simulation is small, and the player is not familiar with moving in a virtual environment with a controller, making them afraid being collided with surrounding [38]. This condition can be improved by providing a larger room and increasing player's ability to move virtually using an analog button in the touch controller rather than moving with their feet, which provides user comfort in a virtual environment without paying attention to the real environment.

Several studies about the development of virtual laboratories for practicum class purposes have different characteristics compared to our study. Table 6 shows these differences one by one. Anshary *et al.* [39] is developing a virtual laboratory for plant anatomy class, which can only be played by a single user. Kapilan *et al.* [40] is developing a virtual laboratory for mechanical engineering majors to replace the physical laboratory during COVID-19. The system has the limitation that only one user can access it at a time and lacks an interactive environment. The main advantage of our systems compared to the previous two is the ability to play with multiple users. It makes the system an online practicum learning platform supporting collaborative or cooperative learning.

As mentioned in the introduction, this system is suitable for reaching students from a broader range. Key success of this system is its ability to hold class with many users, a virtual reality that resembles the real world. The system's success needs to be supported by a high level of immersion to resemble a conventional practicum class [37] more closely. This system also can be adopted for other practicum class when the improvement has been made.

Table 6. Virtual laboratory characteristic comparison

Ref	Class/Topics	Player mode	Usability evaluation	Virtual Presence evaluation
[39]	Plant anatomy	Single player	√	-
[40]	10 Mechanical engineering topics	Single player	√	-
ours	Computer Assembly	Multi player	√	√

V. Conclusion

Collaborative and cooperative learning by utilizing VR-based metaverse technology, such as the system we developed, can be an alternative to expand the reach of students and teachers who are limited by distances, especially for lessons that require physical practical tools such as computer assembly. The score of usability testing using SUS is 69.88, rated as marginally acceptable. A score of virtual presence using IPQ is 4.73 for general presence; 4.51 for spatial presence; and 3.41 for expected realism, rated as acceptable, and 3.51 for involvement, rated as marginally acceptable. We conclude that this system can be used on a limited basis with other students according to the criteria of the respondents tested. The system can improve by providing players more time to learn how to behave with VR, especially for users with no experience before entering the practicum class. An improvement in how to operate the touch controller can also include inside the system, as players may need to remember the function of each button. Further research may include motion sickness tests for the system. Several respondents experienced motion sickness when using the system and evaluating the learning curve compared to the offline practicum class.

Conflict of Interest

The authors declare no conflicts of interest.

Author Contributions

The conceptualization of this research developed by Y.M.A and H.N. Scenario of gameplay designed by A.F.K. Result analysis conducted by A.F.K. Review and editing done by H.N and Y.M.A. All authors contributed to the writing of the article, had read and approved the final version of the manuscript.

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