Virtual Reality for Competency Assessment: A Usability Study of MUVE PCA with VRSUQ and SUS

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ABSTRACT

The development of Virtual Reality (VR) technology for competency assessment with multiple users is a breakthrough in the assessment of skills. The Multi-User Virtual Environment for Professional Certification Assessment (MUVE PCA) is a VR-based application that provides a VR experience to users. This study aimed to obtain information on the usefulness of the application and whether it can be accepted by users using the Virtual Reality System Usability Questionnaire (VRSUQ) and the System Usability Scale (SUS). Data collection was carried out by piloting the MUVE PCA application installed on the Oculus Head Mounted Device (HMD) to vocational school students, vocational school teachers, students, and lecturers in the field of Information Technology (IT) in computer network environments. The results showed a SUS score of 70.41, slightly above the global SUS standard, indicating that the system is considered acceptable. The average VRSUQ score of 3.52 is slightly below the standards, indicating that the system needs to be improved in some areas, especially in terms of convenience.

Keywords-multi-user virtual environment; virtual reality; professional certification assessment; simulation; immersion

I. INTRODUCTION

The development of an increasingly competitive world of work has made professional certification a vital tool for demonstrating competence and skills in specific fields. Traditional assessment methods, such as written exams and interviews, often fail to capture the actual practical abilities. The shift from paper-based written exams to computer-based exams has been carried out for a long time, where the use of computer-based exams has been able to replace them with almost equal results [1-3]. Virtual Reality (VR) technology, including psychology, has been widely used in assessments. VR is at the same time a simulated, cognitive, and embodied technology. VR is the perfect experiential assessment and learning tool with significant clinical potential [4]. VR provides different experiences for the same task and can be presented with various interfaces for the same cognitive process [5]. This VR technology can also replace job training processes that pose a safety risk or have potential hazards, such as training technicians at high altitudes or related to fire or other hazards

[6]. VR environments are also utilized to enhance user skills and efficiency [7]. Virtual laboratory technology in the STEM field provides ease of understanding to students [8]. In the vocational field, one such example is the micropower generation learning in vocational schools in Indonesia, which is adopted in microscopic learning [9, 10].

Interaction in a virtual environment can enhance the feeling of being and acting in a virtual world [11]. Head-mounted VR provides a multisensory and engaging experience by immersing users in a computer-generated 360° environment. This technology offers the opportunity to transform the way perception and action research are conducted, presenting the potential for naturalistic experiments that are tightly controlled but can be carried out while participants are on the move. Historically, action-perception research generally involved a relatively rigid experimental setting in which simple stimuli were presented, with participants demonstrating their perception by pressing a button [12]. The implementation of VR technology in this research is a form of innovation to answer world challenges in the future [13], where people's mobility will be reduced with metaverse technology that integrates the physical with the digital world, video conferencing, and other system integrations [14].

The latest VR technology allows for smoother tracking of hand movements, allowing for empirical integration between perception and movement. VR assesses how multisensory information and cognitive demands affect hand movements while reaching virtual targets. As a result, it can offer multisensory facilitation, providing a fast and highly sensitive isolated proprioceptive accuracy measure. VR can be used as an efficient and powerful spatial memory measurement [12]. The use of VR as an assessment tool to analyze body movements in people with Autism Spectrum Disorder (ASD) demonstrates the feasibility of applying machine learning methods and VR-based tasks to identify body movement biomarkers and improve the diagnosis of ASD [15]. VR experiences for assessment and treatment in mental health require an interdisciplinary approach, which integrates knowledge and ideas from disciplines such as computer graphics, neuroscience, social and cognitive psychology, multisensory perception, cognition, multimedia development, and healthcare [4].

VR is, at the same time, a simulation, a cognitive, and an embodied technology [16]. The five propositions of using the metaverse in education are as follows [17]: (i) Metaverse in education should reflect the real-world learning environment for learners and educators; (ii) Metaverse can facilitate new forms of better training beyond the combined capabilities of physical classrooms and e-learning platforms; (iii) Educators must improve their pedagogical methods and course syllabi to accommodate teaching in the metaverse; (iv) New metrics should be developed to evaluate learning experiences in the metaverse; (v) Education providers must offer new techniques to equip and train educators to serve their learners in the metaverse. In [18], the use of VR and Mixed Reality (MR) technology in occupational safety learning in the architecture, engineering, and construction sectors was investigated.

MUVE is a platform that allows multiple users to interact simultaneously in a virtual environment with computer graphics, voice simulation, and computer networking technologies that simulate 3D interactions. Users can collaborate, communicate, and participate in various activities within this environment. MUVE offers a range of benefits, including flexibility, accessibility, and the ability to simulate complex and dynamic situations. Activities in the virtual environment can be recorded with the event listener feature [19], so that the manipulative movement of objects in the virtual environment played by the user can be measured and assessed with predefined references.VR technology is often used to improve learning performance and understanding in training [20-23], both with 2D and 3D objects [5], especially in the field of science [10, 24] and engineering [25, 26]. With the advancement of technology, especially in the field of VR and MUVE, new opportunities have emerged to create more effective and realistic assessment methods for professional certifications, according to the VR roadmap [13]. The Professional Certification Institute (PCI) competency test at the vocational high school level uses the demonstration observation method, using the practical equipment that has been determined in the requirements of the competency test venue for each competency test scheme. However, the reality in the field is that not all vocational high schools have uniform equipment in dimensions and specifications [27].

PCI is the implementing institution for professional competency certification activities, having received a license from the National Professional Certification Agency of Indonesia, "Badan Nasional Sertifikasi Profesi" (BNSP). PCI is an extension of BNSP to carry out competency certification tasks on its behalf, which is responsible for work competency certification decisions, including the grant, maintenance, extension, addition, reduction of scope, freezing, and revoking certification [28]. PCI must ensure the availability of certification schemes for each category of professional competency certification. If no certification scheme is available, PCI must develop a certification scheme that can be traced to work competency standards and refer to the Kerangka Kualifikasi Nasional Indonesia (KKNI) or the National Occupation standards contained in the Standard Kompetensi Kerja Nasional Indonesia (SKKNI) or standards that have been determined by the technical agency [29]. MUVE PCA technology is a breakthrough in the implementation of competency tests in professional certification, combining certification test assessments and VR technology.

The dimensions and specifications of the tools used for different professional certifications are the obstacles faced by the competency test site. The design and development of the MUVE PCA presents competency test technology in a virtual environment with virtual workpieces to provide convenience in the provision of performance work equipment. To ensure that such applications are acceptable to users, an investigation was performed using an instrument encompassing VRSUQ and SUS.

VRSUQ is an instrument developed to measure the usefulness of VR systems [30]. This instrument assesses how effective, efficient, and satisfying a VR system is for its users.

The instrument was developed from the SUS instrument and is devoted to VR applications. This instrument consists of 9 questions to measure Ease of Use, Effectiveness, Efficiency, Satisfaction, Physical Comfort, System Reliability, Immersion, Accessibility, and Task Suitability [31]. VRSUQ evaluates VR prototypes in education, training, gaming, or other VR-based professional applications. SUS was developed to assess the usability of a system, such as software, hardware, websites, and mobile applications, and consists of 10 statements evaluated using the 5-point Likert scale, ranging from "Strongly Disagree" to "Strongly Agree". The assessment covers the following aspects: Learnability, Efficiency, User Satisfaction, Reliability, Flexibility, and Control. This instrument provides a single score that reflects the overall perception of users on the usability of the system being tested [32]. SUS can be used to select images known as P-SUS [33].

This technology is expected to provide a solution in competency tests, where the need for tools and materials availability in each PCI can be met with HMD equipment and the MUVE PCA application. Equipment standardization can also be achieved using the same equipment with exact dimensions and specifications in a virtual environment. Based on data obtained from a search in Scopus journals, a total of 473 papers were found with the theme of VR assessment. Temporal analysis reveals an increased focus on VR and simulation, with significant growth in post-2020 publications. This trend reflects the integration of new technologies into the professional certification and training environment.

These findings suggest incorporating VR and simulation technologies to improve skills assessment. However, there is still a gap in the scalability and standardization of this technology for multiuser applications. Future research should explore methods to address these challenges and ensure equitable access to MUVE-based assessments. This study aimed to obtain information on the usefulness of the MUVE PCA application in providing new experiences to vocational school students in the computer and network engineering expertise program.

II. MATERIALS AND METHODS

A. 4D Development Model

This research begins with defining the product, and continues with design, development, and deployment of the MUVE PCA application until the dissemination stage. Figure 1 illustrates the research and development methods using a 4D model (Define, Design, Development, and Deploy) [34].

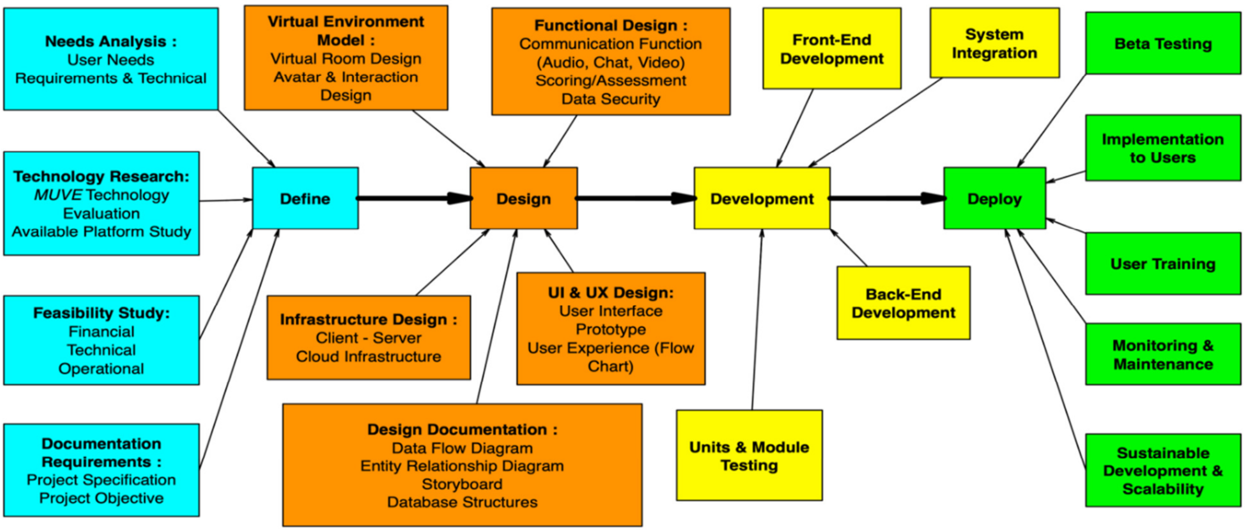

Fig. 1. 4D model of MUVE PCA development.

B. Analysis of Requirements

The requirement for communication between users in a virtual environment was a basic one, and then 3D object assets were defined, such as several network devices, laboratory furniture, and server racks. The Unity 3D engine application was used, considering the mastery of researchers and programmers, along with the cost. For infrastructure needs, cloud hosting was chosen, with a client-server architecture for multi-user purposes. The related study was conducted to obtain information on VR development and assessments through journals and books indexed in Scopus.

In the design stage, the application flow was designed with use case diagrams, flow charts, interface design, and user behavior with storyboards and entity diagrams. Infrastructure design requirements were encoded in data flow diagrams, database structure designs, and client-server topologies. Front-end interface design was carried out on the fly using Unity 3D applications to save time and C#, JSON, and PHP scripts to provide properties and behaviors to objects in the virtual environment as part of the design and implementation of the application back-end.

Unit and module tests were conducted, along with black-box testing as a MUVE PCA functionality test. Then, improvements were made to non-conformal findings. In the deployment stage, a more extensive user trial was carried out to determine the usefulness of the MUVE PCA application. The application was installed on HMD Oculus and tested on potential users in the professional certification competency test.

The next stage was monitoring data traffic on the application server, CPU, and memory processes. Development and updates, as well as scalability tests, were carried out since the beginning of development, namely from version 1.0 to version 1.6. Later, continuous development will be carried out, such as bug fixes, additions, and feature enhancements. The development documentation was performed using the GitHub repository to make it easier for researchers and programmers to monitor and update the source code of the MUVE PCA application.

C. Virtual Environment Design

A realistic virtual environment was designed in the context of the professional certification to assess. The environment reflected real work situations, with enough detail to accurately assess skills and competencies. For some of the components in the proposed virtual environment, several aspects were adopted, namely: (i) visual, (ii) audio, (iii) haptic or tactile, (iv) interactivity, (v) movement, (vi) rules and roles, (vii) contextual, (viii) challenge, and (ix) social. Visual aspects and movement dominate these aspects. The rule aspect is highly correlated with all other aspects except audio [35]. Figures 2 and 3 show a use case diagram and a flow chart on the development of MUVE PCA.

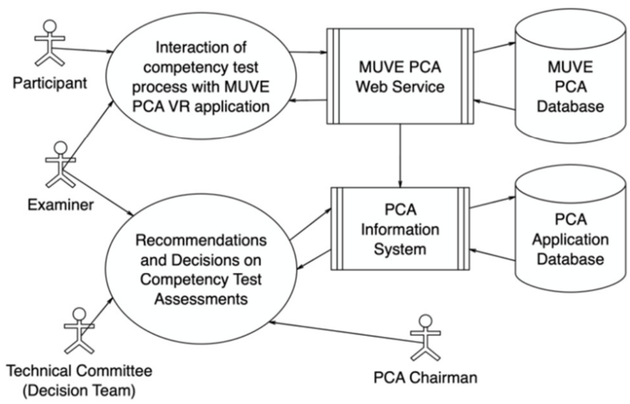

Fig. 2. MUVE PCA use case diagram.

The use cases, as shown in Figure 2, describe the interaction of users with the system, fellow users, and system entities with other systems. User interactions between participants and examiners are processed by the MUVE PCA web service and stored in the MUVE PCA database. The test process carried out at MUVE PCA is sent to the PCA information system application, where the technical committee and the PCA chairman make assessment decisions.

Figures 4 and 5 illustrate the design of the MUVE PCA interface, which represents a virtual environment close to reality. This design is intended to provide ease of operation and attractiveness for users.

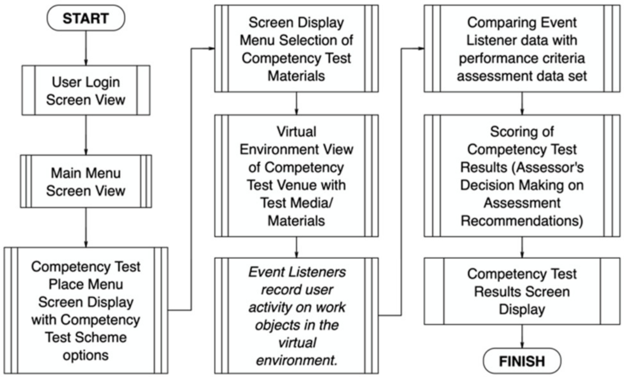

Fig. 3. Flow diagram.

Fig. 4. Main menu.

Fig. 5. Virtual environment design.

Figure 4 shows several menu options in the main menu design, leading to the virtual laboratory environment or another representation of the work environment. Inside the MUVE PCA, a large mirror shows the user's avatar, which can be replaced with a Male or Female option. The virtual environment design, as shown in Figure 5, is a data center laboratory containing several racks with servers, routers, UPS, and other network devices, such as switches, access points, routers, wireless routers, personal computers, printers, and network cables with RJ45 connectors. The design aims to provide a virtual sensation in a laboratory, a unique experience in a competency test.

D. Scenario Design

Next, an assessment scenario is prepared. Assessment scenarios are designed to assess various aspects of professional competence, including technical skills, communication abilities, and teamwork skills. They should be designed to be objectively measured and repeatable for multiple participants. In Figure 6, the test participant's activity (session) refers to the Structured Instruction List (SIL) embedded in the application that can be read and heard in the MUVE PCA virtual environment. These instructions are retrieved with the web service API from the PCI information system. The assessment activities in the MUVE PCA are recorded by the event listener to be forwarded to the scoring system, which is compared with the SIL scoring reference data.

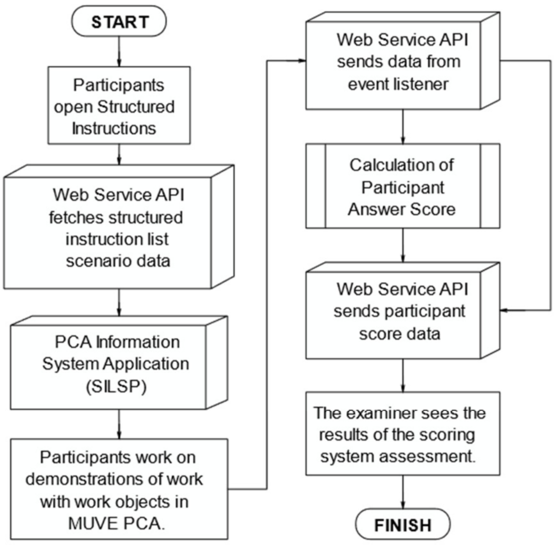

Fig. 6. Scenario design in MUVE PCA.

E. Testing and Evaluation

Testing and evaluation were conducted by involving participants from vocational students of the Computer Network Expertise Program, vocational teachers in Computer Network Expertise, students of Systems and Information Technology, and lecturers in IT. The PUN-VR (MUVE PCA) application was installed on hardware of Oculus Quest, Oculus Quest 2, and Oculus Quest 3 HMDs with a WiFi network connection on the same network. Each participant followed this scenario: (i) wearing an HMD and opening the MUVE PCA application, (ii) entering a name, (iii) selecting tasks, (iv) interacting with network equipment objects, and (v) interacting with fellow users in a virtual environment. The results were evaluated based on predetermined criteria to assess the accuracy, objectivity, and effectiveness of this assessment method.

This test employed usability tests with VRSUQ [31] and SUS, providing a wide view of subjective usability assessment [36]. Participants were asked to complete a questionnaire using the VRSUQ and SUS instruments. The questionnaire included open-ended questions, such as criticism and suggestions, to obtain qualitative information from the participants.

The trial involves users with computer network experience at the secondary education level, namely, students and teachers of vocational high schools. The selected teacher has an educational background in informatics education. Students and lecturers of the Informatics Education Study Program at Ivet Semarang University in Central Java, Indonesia, conducted the trial on higher education segmentation. The users were lecturers and students with knowledge of VR and computer networks. This selection was made because the MUVE PCA application's material or substance is computer networking.

Fig. 7. Student's user experience testing.

Fig. 8. Teacher's user experience testing.

Fig. 9. Lecturer's user experience testing.

The virtual environment on MUVE PCA allows users to interact virtually in the same room. Each user has a name tag, as seen in Figure 10(a), and can communicate with each other. The microphone image in Figure 10(b) indicates that the user is speaking and can be heard by the other user. User interaction with objects in the virtual environment can also be performed, such as holding workpieces, tools, and other objects, as shown in Figure 10(b), or with a virtual hand, as seen in Figure 10(c).

(a)
(b)
(c)

Fig. 10. Virtual environment of MUVE PCA.

This interaction will later become between the participant (competency test participant) and the examiner (competency tester) in RCC. The participant is also seen virtually by the examiner. The examiner can ask questions to support observation with communication facilities on the MUVE PCA application, including hearing the answers to the assessment directly in the virtual environment.

III. RESULTS AND DISCUSSION

A. Respondent Demographics

The respondents were 25 people aged 15-40, 16 of whom were male and 9 of whom were female. 84% of the respondents were adolescents up to 18 years old, students of the computer network competency program in 3 different schools. The rest were teachers, students, and lecturers in IT. The proportion of respondents in Figure 13 represents the ratio of the number of test participants and examiners in professional certification assessments in general, where the number of test participants in each test schedule ranged from 10-15 participants with 1 examiner. 21 respondents were adolescents (<18 years old) and 4 were adults (>18 years old).

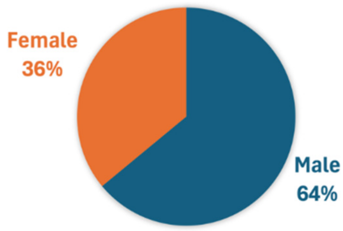

Fig. 11. Gender of respondents

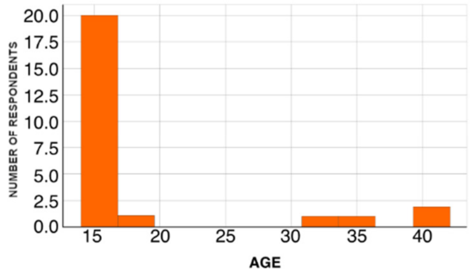

Fig. 12. Age distribution of respondents.

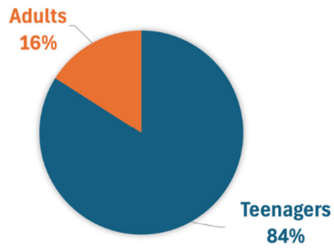

Fig. 13. Age category of respondents.

Some respondents were users of minus, plus, and cylindrical glasses, but most did not wear glasses. Figure 14 shows the demographics of users' eye conditions to find out any effect on user response. Analysis related to the relationship between glasses use and average score is shown in Figure 20.

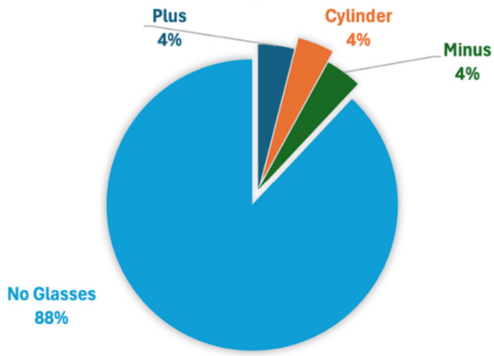

Fig. 14. Distribution of respondents wearing glasses or not.

B. Usability Test Results with VRSUQ and SUS

User experience tests using VRSUQ and SUS methods were conducted to obtain information about user experience. The dimensions in these tests are as follows.

- R1, R2, R3, R4: Representations related to responsiveness, feedback, and system ease.
- P1: Physical discomforts such as dizziness or intoxication.
- I1: The desire to use the system more often.
- E1: Ease of use.
- T1: Need for technician assistance.
- C1, C2: System inconsistencies and user confidence.

Based on the system's responsiveness, feedback, and ease of use (R1-R4), the application has a high score, indicating a good user rating. The user's desire to use the system is also relatively high based on the I1 value because the application is considered relatively easy to use, indicated by a reasonably high E1 value. However, there are system inconsistencies and moderate user confidence, where some users feel that they need to be helped by more skilled people in using the devices and applications, as indicated in T1. C1 and C2 show that users feel inconsistencies and self-confidence in using the application because most of them used this technology for the first time, which is in line with some feedback stating that this was a new experience for them.

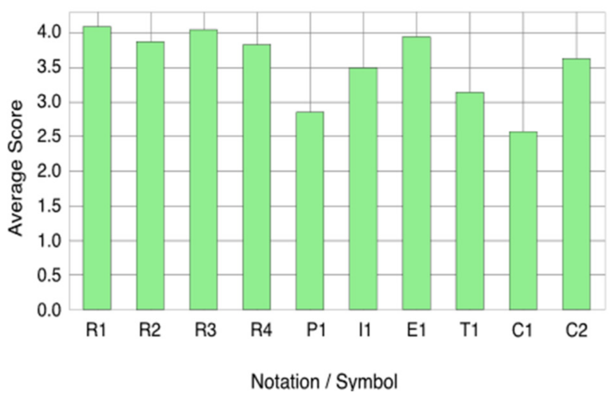

Fig. 15. Average VRSUQ and SUS scores.

The notation of the questions is as follows:

- V1: The system responds to my manipulation as expected without delay.
- V2: I think the VR system gave clear feedback on my manipulation.
- V3: I keep making mistakes when using the VR system.
- V4: I can clearly understand the information presented in the virtual environment.
- V5: I think the system is user-friendly, easy to learn, and designed in such a way that most people will find it easy to adapt.
- V6: I think it's easy to fix mistakes made during virtual reality experiences.
- V7: I enjoy the VR experience.
- V8: I feel dizzy, drunk (like motion sickness), or have a headache when experiencing VR.
- V9: When experiencing VR, I feel mental burdens such as tension, frustration, and time pressure
- S1 = I think that I would like to use this system frequently.
- S2 = I found a system that was unnecessarily complicated.
- S3 = I think the system is easy to use.
- S4 = I think I will need help from a technician to be able to use this system.
- S5 = I find the various functions in this system to be well integrated.
- S6 = I think there are too many inconsistencies in this system.
- S7 = I imagine that most people will learn to use this system very quickly.
- S8 = I am very awkward to use this system.
- S9 = I feel very confident using the system.
- S10 = I need to learn a lot of things before I can use this system.

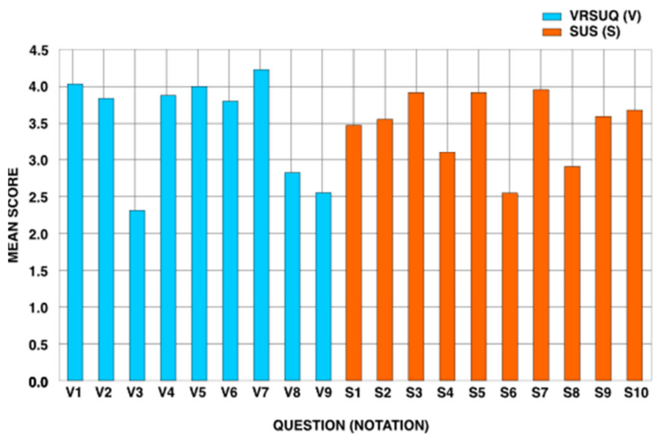

Fig. 16. VRSUQ and SUS MUVE PCA score results.

In VRSUQ, the highest responses were in "I enjoy the VR experience," with a score of 4.24, indicating that users enjoy the experience provided by the MUVE PCA system. This reflects high satisfaction with the entertainment or visual appeal aspect of this system. The responses to "The system responds well to my manipulations as expected without delay" had a mean score of 4.04, indicating that users feel that the system responds to their input quickly and accurately, which is essential in providing a good user experience. The responses to "I think the system is user-friendly, easy to learn, and designed in such a way that most people will find it easy to adapt" had a mean score of 4.00, meaning that the MUVE PCA application is considered easy to use and user-friendly, making it accessible to a wide range of users without requiring a lot of training. The responses to "I keep making mistakes/mistakes when using the VR system" had a mean score of 2.32, which means that users experience errors more frequently, which may be due to the MUVE PCA application interface being less intuitive or the system not fully responsive to user input. The responses to "I feel dizzy, intoxicated (like motion sickness), or headache when experiencing virtual reality" showed a score of 2.56, indicating that some users experience physical side effects (e.g., motion sickness) when using the system, which can affect their overall experience, which is confirmed with the suggestions conveyed in the questionnaire. The responses to "When experiencing VR, I felt mental burdens such as tension, frustration, and time pressure" had a score of 2.48, indicating that the system may cause stress or frustration in the user, which may stem from the interaction design, task complexity, or mismatch of expectations on the MUCE PCA application.

In SUS, the highest mean score was in the responses to "I imagine that most people will learn to use this system very quickly" (3.96), indicating that MUVE PCA is considered easy enough for most users to learn and succeeded in its intuitive design. Next, the responses to "I think I will need help from a technician to be able to use this system" had a score of 3.92, which means that most users did not need a technician's help, reflecting the system's reliability and simplicity. Then, the responses to "I find the various functions in this system well integrated" had a score of 3.92, indicating that the functions in the system complement each other and are well integrated, providing a smoother experience. A lower score was obtained on "I think there are too many inconsistencies in the system" (2.56), meaning that some users feel inconsistencies such as misaligned functions or uneven experiences. The score of 2.92 on "I am very awkward using this system" means that some users feel discomfort or difficulty when using this system, which may be related to a load of HMD devices [37, 38] and interfaces, such as exposure [39] or user experience design. In "I found the system unnecessarily complicated," a score of 3.12 indicates that some users feel that their system still had a certain level of unnecessary complexity, which can hinder the user experience.

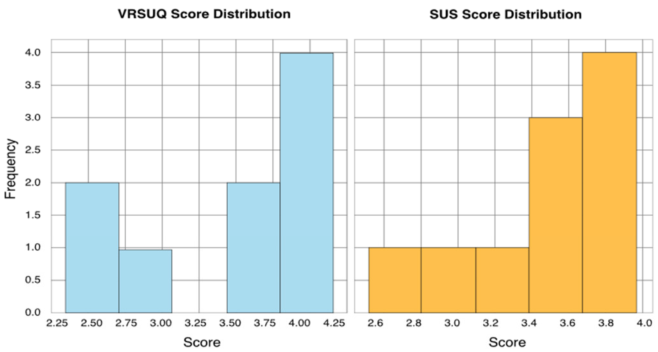

Fig. 17. Distribution of VRSUQ and SUS scores.

Figure 17 shows the distribution of the VRSUQ and SUS scores. The distribution of VRSUQ scores is more concentrated in the upper range, indicating that users generally had a positive experience with the system. Most scores range between 3.5 and 4.5, indicating that users found the system compelling. Meanwhile, the distribution of SUS scores is wider than that of VRSUQ, reflecting more diverse opinions on ease of use or certain usability aspects. Scores tend to cluster between 2.5 and 4.0, which indicates moderate satisfaction and room for improvement.

C. Comparison of VRSUQ and SUS Scores with Global Standards

The average SUS score, as shown in Figure 18, is at a value of 70.41, slightly above the global SUS standard, which is above 70 on a scale of 0-100 [40]. This means that the system is considered acceptable. The average VRSUQ score of 3.52 is slightly below the global standard for VRSUQ, meaning that some areas should be improved, especially in terms of convenience or clarity of use.

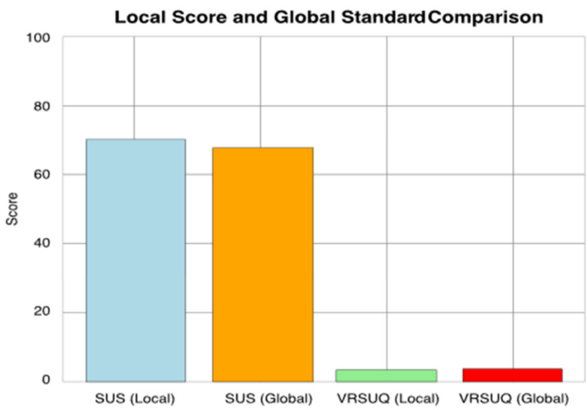

Fig. 18. VRSUQ and SUS scores against global standards.

The system is considered valuable and reasonable compared to global standards, as, according to Bangor & colleagues, a SUS score of less than 50 means not accepted, 50-70 is marginal, and more than 70 means acceptable [41]. The global average SUS score, often used as a reference, is around 68. Scores below that number generally indicate that the system is less usable than international standards.

D. Correlation of User Demographics with VRSUQ & SUS Scores

To determine the relationship between demographics and VRSUQ and SUS values of the MUVE PCA application, a correlation analysis was performed between the age, sex, and glasses usage of the respondents to the VRSUQ and SUS scores, and the results are shown in Figure 19. The age correlation of the respondents with the average score was relatively low, indicating that age was not the main factor that affected the results. The relationship between sex and average score was also low, corroborating previous statistical tests that the differences based on sex were not significant. At the same time, glasses use showed a higher correlation than other factors, which was in line with statistical findings that were close to critical. Based on this analysis, the application of MUVE PCA had no significant influence on the user's gender, age, and use of glasses.

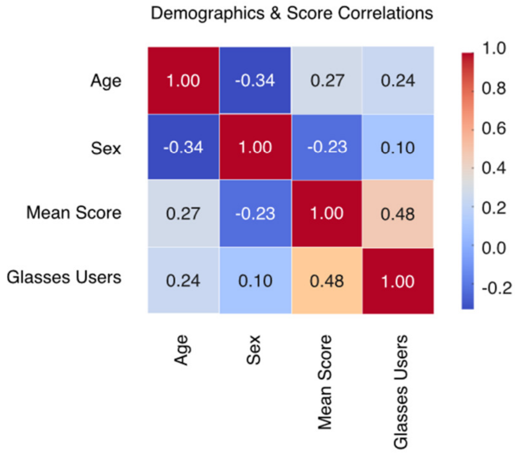

Fig. 19. Matrix of respondents' demographic correlation with VRSUQ and SUS values.

E. *Participant Feedback*

Based on the suggestions given by the respondents, information was obtained where: (i) the frequent appearance of the words "I," "this," and "more" indicates more personalized feedback, focusing on the user experience or suggestions; (ii) the word "again" is repeated, indicating a request for additional features or quality improvement; (iii) the words "no" and "tool" indicate a dissatisfaction that is more focused on the equipment (HMD) used. Suggestions containing "add more apps" and "add more games" indicate more interesting function requests. Some feedback stated that "the tool is perfect," indicating satisfaction with the system. Then, the statement "more animation-like characters " showed the need for improved visual quality and interactive elements. Some said "no advice" or "I have no advice," suggesting that users have had enough of the MUVE PCA application.

Some users felt dizzy and uncomfortable after using the Oculus HMD [41], which may be because they are not used to using this VR device. This is in line with several previous studies on the use of HMDs [42-44].

F. *Implementation Challenges*

Implementing VR-based MUVE for professional certification assessments can be challenging despite the many benefits. These challenges include the cost of developing and maintaining virtual environments, the need for appropriate hardware, and a learning curve for participants who may not be familiar with VR technology.

IV. CONCLUSION

The VRSUQ score generally shows better response, indicating that the system excels in functionality, feedback, or performance. SUS, commonly used to highlight usability and overall ease of use, shows more variability, indicating potential challenges in user-friendly design. The MUVE PCA application is considered to have a cohesive design so that the functions in the system support each other. Based on VRSUQ analysis, there is a need for improvements to reduce the user error rate and enhance physical and psychological comfort of users, with a focus on designs that reduce mental burden and potential physical side effects. Based on VRSUQ and SUS tests, MUVE PCA has met the minimum standards of a software application and has a usability value above global standards, so that users can accept it. In the future, the MUVE PCA can be used in broader demographic and other scientific fields, such as automotive, construction, or other vocational fields. Implementing VR-based MUVE for professional certification assessments can be challenging despite the many benefits. These challenges include the cost of developing and maintaining virtual environments, the need for appropriate hardware, and a learning curve for participants who may not be familiar with VR technology.

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