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Evaluating the Effectiveness of Avatar-Based Collaboration in XR for Pump Station Training Scenarios

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***Abstract*—Immersive Virtual Reality (iVR) and Augmented Reality (AR) have become increasingly accessible tools for enhancing learning and training experiences. This study aims to evaluate the effectiveness of avatar-based collaboration within each platform, particularly in the context of pump station training scenarios, so an application was developed: *EduAvatars: Pumpstation XR*. A total of four concepts were prepared: on-site AR instruction with avatar, on-site AR instruction without avatar but with manual, iVR instruction with avatar, and iVR instruction without avatar but with manual. In each concept, users are supposed to proceed with two experimental tasks: speed control and bypass control, following the same procedure: check valves and level indicators. The usability of this application was validated as a preliminary study, and the results are promising for its introduction to lectures to improve student learning. The preliminary results indicate user satisfaction with the integration of EduAvatars and a significant interest in using it frequently. However, our work also discusses identified areas for improvement.**

I. INTRODUCTION

Immersive Virtual Reality (iVR) has emerged as an increasingly accessible tool for enhancing learning and training over the past decade. Widely recognized for its capacity to seamlessly integrate various simulations and adapt them to various forms of assessment, iVR stands as a formidable technological asset. However, amidst its ongoing evolution, a recent addition has stirred significant interest: the advent of the Metaverse, particularly notable for its introduction of avatar implementation and multi-user collaboration. While iVR has solidified its standing within developer, researcher, and instructor communities, Augmented Reality (AR) remains a potent ally. Offering even greater affordability and portability, AR presents an enticing alternative, enriching experiences with tangible overlays of physical reality and experiencing rapid advances in efficacy.

Both iVR and AR have demonstrated considerable efficacy in learning and training contexts, as well as collaboration in these virtual environments. So, for this study, the research question is: Which technology—iVR or AR—is better suited for educational applications, and does avatar-based collaboration enhance efficacy within each platform?

To investigate these inquiries, a pump station environment was selected as the focal point. Pump stations, which are critical in water management systems, demand precise control and interpretation of data for optimal performance. To aid in learning these intricacies, a use case involving two core tasks was developed: one dedicated to speed control and the other to bypass control. An application was developed for this purpose, called *EduAvatars: Pumpstation XR*. Four concepts were developed: AR with avatar collaboration (AR-AC), AR without collaboration (AR-NC), iVR with avatar collaboration (iVR-AC), and iVR without collaboration (iVR-NC). Avatar implementation is truly novel in the extended reality (XR) field, and even more so when it comes to learning or training applications, such as the digital twin (DT). There exist different ways of avatar integration in the iVR context, as shown in the review of [1]. In the case of AR, avatars are not that common. However, this technology offers the possibility of combining virtual visualization without hindering interaction with physical and real tools, as some research proposes [2]–[4]. Furthermore, for training scenarios and DT applications, iVR is commonly used among researchers [5], [6]. Specifically, there are some research studies related to the pumping station environment in iVR, such as [7]. Although all the related literature has promising results using XR in the

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DT context, there is not enough to conclude which technology is more helpful for learning: AR or iVR in the training or DT context. So the main key point of this research is to provide a response to which technology can be better for this context and if collaboration with an avatar implementation results useful for this purpose.

This paper is structured as follows: In Section II, the related work is presented, followed by an explanation of the concept and its implementation in Section III, along with its usability validation in Section IV. The study results are summarized in Section V and discussed in Section VI, concluding with the experiment conclusions in Section VII.

II. RELATED WORK

iVR and AR have gained significant importance in educational and training contexts, as well as in industry. A review [8] highlights their limitations, including user experience levels, control challenges, and localization accuracy. Usability and user experience are crucial for optimal performance in AR and iVR industry applications.

In the realm of AR, smartphones and tablets are the most commonly used devices, reflecting their popularity. Despite these limitations, AR and iVR are of significant importance in learning, including fields such as civil engineering, operation guidance for construction equipment and assembly performance, as well as safety training, as classified in the aforementioned review. Another review contributes to the positive results of AR in STEM education [9], highlighting studies that found positive outcomes when AR applications were used in outside-of-class activities. Additionally, other studies have found that AR improves the representation of abstract concepts and increases interaction and motivation among students [10].

Further studies have emphasized the relevance of iVR in learning experiences [11] compared to traditional teaching methods or even computer applications. However, while AR and iVR are still in development, so is the implementation of collaboration between users in these experiences. An intriguing study [12] proposes the collaboration of two workers through AR and iVR to provide guidance from iVR to AR. In this setup, the AR user provides the 3D model to the iVR user, who is also able to manipulate it and offer instructions. Moreover, this study reveals that users who tested the system application preferred the field of maintenance for its use.

Despite the promising applications, it is rare to find ones that have been properly tested in the learning or industry fields. Additionally, when collaborating between two or more users, it is necessary to represent them in the virtual environment, often accomplished through avatar implementation. A review examined this in the context of AR and iVR technologies [13]. In the realm of industry and training, there remains a gap to be filled with further research, as avatars increase presence, but this can lead to decreased performance in some studies, particularly among novice iVR users. Furthermore, most experiences do not find positive effects with more realistic avatars, although another study showed that users preferred photorealistic avatars [14]. Another study [15] explored remote collaboration between Spatial AR and iVR, in which the actions of the iVR user were projected to the Spatial AR user during tasks. The results indicated increased social presence, interest, co-presence, and enjoyment, while also demonstrating that visual cues were key for communication between users.

DT offers a powerful tool for application in industry and learning, commonly implemented and visualized through AR technology, as reviewed [16], due to the fact that AR display devices do not require experienced users, unlike iVR devices. However, the analyzed articles in that review concluded that interactions were mainly not intuitive, hindering proper use of the application by most non-technical users. Another review highlights the promising future of AR for DT [17], particularly in machine interaction, as supported by some studies [18], which also demonstrated that AR in DT provides safer training or learning experiences and improves accessibility.

III. CONCEPT AND IMPLEMENTATION

A. Concept

1) Pumps and compressors lecture: This work explores the integration of iVR into educational environments, with a specific focus on engineering training. As a use case, the engineering lecture series at the Mannheim University of Applied Sciences was selected, which includes hands-on exercises in a laboratory at the Institute of Plant Engineering and Plant Safety with a pump station, as shown in Figure 1. Pump station operations require a blend of theoretical knowledge and practical skills, often challenging to master without hands-on experience. However, limitations due to geographic, logistical, or safety concerns can restrict access to such facilities. IVR bridges this gap by creating realistic and interactive training environments that allow learners to gain practical experience remotely or through virtually enhanced on-site training.

2) iVR lecture: The aim of this study is to evaluate the education effectivity of a novel method for digitalizing practical courses in engineering, utilizing virtual avatars as instructors. Employing pre-recorded avatars in iVR offers an innovative and easy to use content creation approach within

Fig. 1. Pump station used in the lecture Pumps and Compressors in Mannheim University of Applied Sciences.

education. IVRs with avatars serving as virtual instructors or peers enrich the learning process by providing dynamic, interactive instructions.

For evaluation, the avatar approach is compared with text-based instructions, which is a common modality in iVR. Avatar instructions are crafted by capturing the voice and movement data of a lecturer who performs the practical exercises on-site at the pump station. This is done using a Mixed Reality (MR) Head Mounted Display (HMD) capable of displaying passthrough AR and iVR. During the capture phase, the lecturer wears the HMD and views the real environment in AR while demonstrating the instructions step by step.

The avatar instructions are subsequently utilized in iVR, with a virtual representation of the pump station, for remote individual training or as preparatory material for on-site lectures. This study has digitalized two interactive exercises related to pump station operations: flow control and bypass management. These tasks involve manipulating various components, such as valves, flow meters, and level indicators, reflecting the complexities commonly faced in industrial settings.

Avatar instructions are compared against text-based instruction within both AR and iVR, resulting in four conditions: iVR avatar instruction, AR avatar instruction, iVR text-based instruction, and AR text-based instruction. Text-based instructions are presented on simplified virtual screens within the iVR environment, serving as control conditions.

This study aims to explore the potential of iVR to augment traditional educational methods by providing additional interactive, engaging, and accessible learning experiences. Our insights will inform educational strategies and technological implementation in engineering training, potentially transforming how practical skills are taught and acquired.

B. Implementation

This project utilizes Unreal Engine (UE) 5.3 and the Meta Quest Pro HMD, alongside additional plugins not pre-installed with UE: MetaXR v60.0, and Runtime Audio Importer. The implementation includes two main steps: creating the virtual pump station environment and interactive exercise instructions.

1) Virtualization of the Pump Station: For virtualization, a Computer-Aided Design (CAD) model - created with Autodesk Inventor 2023 - of the pump station was imported using UE Datasmith, as depicted in Figure 2. The model parts were merged to a single mesh to improve the performance on the standalone, Android powered HMD. The interactive parts, such as the valves, were not merged, but included separately in the mesh. This allows to add animations and interaction to these parts and allow students to interact with them as part of their tasks in iVR. Additionally, labels were placed to help identify valves and dynamically visualize pump station measurements such as volume flow, frequency, and pressure.

The application called *EduAvatars: Pumpstation XR*, incorporates hand tracking for interactive tasks. However, to facilitate experiment setup, such as calibration of the virtual pump station, toggling avatar capture mode, and switching between avatar and text-based instruction modes, controller interaction was added.

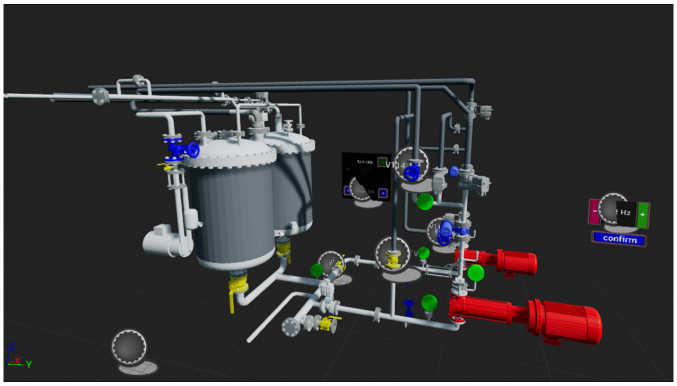

Fig. 2. CAD model of the pump station and two virtual displays integrated into the Unreal Engine iVR project.

In AR mode, passthrough AR is enabled for operation on the real pump station. The virtual model of the pump station is automatically registered by the MetaXR system and can be further calibrated using the controllers to adjust the orientation and scale of the model for finer placement.

2) Interactive Task Instructions: Two types of interactive task instructions were implemented within the iVR environment: text-based and avatar recordings. Text-based instructions are displayed on a simplified virtual screen, which includes a text widget and buttons that students can use to navigate between different instructions and tasks. This virtual display is embedded within the 3D environment of the pump station, as shown in Figure 2.

The avatar-based instructions utilize the avatar replay system, previously introduced in [19], [20]. This system now features full-body self-avatars and employs UE Metahumans for the avatar during instruction playback. Lecturers create these avatar instructions by performing the tasks while wearing the MR HMD. The system captures their voice and movement data, storing it on the HMD in text format for tracking information and in WAV format for audio. Separate recording files are created for each instructional step. This setup facilitates step-by-step playback functionality where students can use a virtual menu attached to their left hand to select, play, or pause the instructional steps. As the corresponding data files are loaded and played, the instructor avatar is animated to demonstrate the tasks. During playback, students can simultaneously continue working on their tasks.

IV. VALIDATION

The implemented prototype of the iVR lecture was tested in a pilot user study to gather preliminary results and validate our study approach. In the pilot study the both AR modalities, with text instructions and with avatar instructions, were compared. This section provides a brief overview of the user study conducted.

A. Study Participants

A total of $N = 11$ (3 females and 8 males, aged 21 to 65) individuals participated in the study, comprising professors and research assistants from various academic disciplines. The group of participants was characterized by its heterogeneity in terms of subject area and gaming experience. The fields of expertise of the participants ranged from process engineering, chemical engineering, and biotechnology to social sciences and instructional design. Regarding gaming experience, more than half of the participants (64%) reported no prior gaming experience. However, 54% of the participants had previously tried iVR technologies, and one individual reported regular use of iVR.

B. Experiment Task

The learners had the task of commissioning a pump station and determining its characteristic curve. In contrast to iVR, the AR task offers the unique opportunity to interact with a real system by opening and closing real valves. Before the experiment, participants were required to verify that the valves displayed and explained by the avatar were in the correct position. Then they checked the level indicator on the tank on the computer to make sure it was filled to the required level. The experiment could only continue if all the necessary conditions were met. The objective of the experiment was to determine the characteristics of the system at two different valve positions. To achieve this, participants were required to conduct a series of measurements in which the pump frequency was increased from 8 to $32Hz$ in increments of $2Hz$, after each increment the flow rate was read and documented in a laboratory protocol. In order to provide the participants with clear instructions, a laboratory assistant recorded the individual steps of the procedure in advance. Then these recordings were made available to participants in the form of a virtual avatar, allowing them to carry out the task at their own pace and at their own convenience. If necessary, it was possible to repeat the recording.

C. Questionnaires

For validation, participants were asked to provide qualitative feedback and completing the following questionnaires:

- Demographic Questionnaire: This questionnaire collected demographic information such as users' age, gender, previous experience with iVR and video games, and their field of knowledge in education. Additionally, it included a question related to users' perceived level of cybersickness for consideration in subsequent experiments.
- Avatar Experience Questionnaire (Open Questions): This questionnaire consisted of three open-ended questions aimed at assessing users' perception of the avatar during the experience, including aspects such as its scariness, tracking issues, placement in the environment, and user discomfort when it was nearby.
- NASA-TLX Questionnaire [21] (Likert-Scale Questions): This questionnaire, adapted for the iVR experience, measured users' effort during the learning experience using six items, each rated on a scale from 1 (low) to 10 (high). The items evaluated: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration.
- Social Presence Questionnaire [22] (Likert-Scale Questions): This questionnaire included five questions designed to measure how users perceived the avatar in the virtual environment, rated from 1 (strongly disagree) to 5 (strongly agree), treating it as if it were a real person rather than a simulated one.
- System Usability Scale (SUS) Questionnaire [23] (Likert-Scale Questions): This questionnaire, adapted for the iVR experience, aimed to assess users' ease of understanding and controlling the application using ten questions, rated from 1 (strongly disagree) to 5 (strongly agree). Feedback will be used to improve the usability, interface, and interaction of the application.

Fig. 3. The virtual avatar, is instructing a person in the real laboratory set-up.

In the next section, Results, the findings from the aforementioned questionnaires will be analyzed.

V. RESULTS

In this section, we present the findings of our preliminary study. These results are analyzed in the context of the total number of subjects and further subdivided based on their gaming experience. Specifically, we have $N_{XP} = 4$ participants experienced with gaming and iVR and $N_{NOXP} = 7$ participants without experience. All $N_{female} = 3$ subjects are within the inexperienced group. More data and visualizations can be found in the supplementary material [24].

A. Task Load

The NASA-TLX Questionnaire was utilized to assess task load. During the initial study, the participants reported that physical and time-related demands were relatively low ($M = 2.36$, $SD = 1.12$ and $M = 2.73$, $SD = 1.68$). In addition, it appeared that they experienced minimal effort ($M = 2.64$, $SD = 1.36$) and low levels of frustration ($M = 2.64$, $SD = 2.34$). The participants expressed a considerable level of satisfaction with their achievement of the task objectives ($M = 6.64$, $SD = 2.94$) and their own performance ($M = 6.64$, $SD = 2.54$). The mental load was regarded as moderate ($M = 4.09$, $SD = 2.77$). The workload was comparable between experienced and inexperienced participants (experienced $M = 3.57$, $SD = 1.41$, inexperienced $M = 3.16$, $SD = 1.05$). The most noticeable difference between the groups was in terms of success and satisfaction. Inexperienced participants felt they had achieved the task objectives more successfully ($M = 7,14$, $SD = 2,71$) compared to experienced participants ($M = 5.75$, $SD = 3.77$). Furthermore, inexperienced participants were more satisfied with the outcomes of the task ($M = 7.71$, $SD = 2.42$) than experienced participants ($M = 4.75$, $SD = 2.87$). Overall no statistically significant difference between the experienced (XP) and not experienced (NO_XP) groups could be found, except for the performance subcategory. To assess subjective perception of performance, users were asked two questions: *"How successful do you think you were in accomplishing the goals of the task set by the experimenters?"* (Performance I) and *"How satisfied are you with your performance?"* (Performance II). Only for Performance II could a statistically significant difference between the groups be found ($t(9) = 2.18, p = 0.03$), where inexperienced subjects were more satisfied with their own performance ($M = 7.71, SD = 1.7$) than experienced ($M = 4.75, SD = 2.87$).

TABLE I
Overview about the mean and standard deviation of the NASA-TLX Questionnaire between the expert (EX) and non-expert (NO EX) groups

	XP	NO_XP	All
Frustration level	2.75 ± 2.87	2.30 ± 2.45	2.64 ± 2.34
Mental demand	3.50 ± 3.00	3.80 ± 2.82	4.09 ± 2.77
Physical demand	2.50 ± 1.12	2.20 ± 1.34	2.36 ± 1.12
Temporal demand	2.00 ± 0.82	3.20 ± 1.83	2.73 ± 1.68
Performance I with goal achievement	5.75 ± 3.77	7.70 ± 3.00	6.64 ± 2.94
Performance II with own performance	4.75 ± 2.87	8.10 ± 2.79	6.64 ± 2.54
Effort	2.75 ± 1.71	2.80 ± 1.48	2.64 ± 1.36

B. System Usability Scale

The system received an overall *"ok"* to *"good"* evaluation, according to SUS (see Figure 4), with a score of 69.55. Experienced users gave it a 75 (*"good"*), while inexperienced users rated it at 66.43 (*"ok"*). Across different user groups, notable differences emerged between experienced and inexperienced participants. Inexperienced participants exhibited a greater need for technical support ($M = 4.43$, $SD = 0.79$), compared to experienced ($M = 3.25$, $SD = 0.58$). Regarding system complexity, inexperienced participants perceived the system as less complex ($M = 1.29$, $SD = 0.49$) than experienced participants ($M = 1.5$, $SD = 0.5$). Experienced participants showed a stronger tendency to use the system regularly ($M = 4.75$, $SD = 1.0$), than inexperienced participants ($M = 3.75$, $SD = 3.57$) with a statistically significant difference ($t(9) = 2,38, p = 0.02$). Additionally, a statistical significant difference ($t(9) = 2.07, p = 0.03$) was found between the groups in rating the integration of functions more positively (EX: $M = 4.5$, $SD = 1.29$ and NO_EX: $M = 3.43$, $SD = 1.13$). The report of system inconsistencies was higher among experienced participants ($M = 2.0$, $SD = 0.5$) than among inexperienced ones ($M = 1.57$, $SD = 0.98$), but overall low. Finally, experienced users felt more confident using the system ($M = 4.25$, $SD = 0.82$) compared to their inexperienced counterparts ($M = 3.71$, $SD = 0.95$).

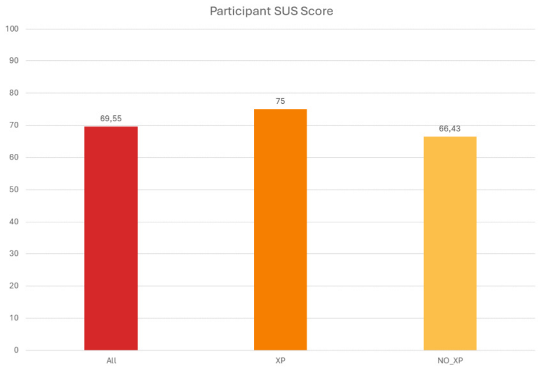

Fig. 4. The diagram illustrates the mean SUS score for three user groups: total (left), experienced (middle), and inexperienced users (right).

C. Replay Avatar

Overall, the avatar, illustrated in Figure 3, was well received. The ratings of the experienced users were generally higher, except for the overall look, which was rated better by the less experienced users. A summary of the participants' perceptions of various aspects of the avatar can be found in Table II.

As shown in Figure 5, none of the users from either group perceived the avatar as falling into the uncanny valley (Q1), malfunctioning its skeleton (Q3), or displaying inconsistencies in the speed of the avatar replay (Q5). However, some users, one per group, found the avatar "creepy," although most users did not share this opinion (Q7). The biggest difference in

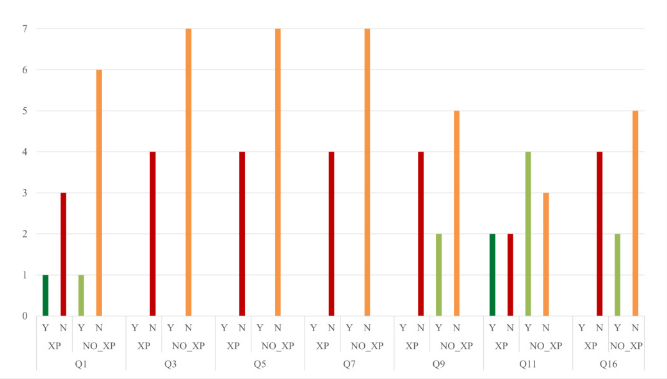

Fig. 5. Bar graph of 7 avatar-related questions showing the number of users with experience (XP) and without experience (NO_XP) who responded yes (Y) or no (N). Users with experience (XP) are represented at the left (Y) and medium left (N), while users without experience (NO_XP) are represented at the medium right (Y) and right (N).

TABLE II
PERCENTAGE OF PARTICIPANTS WHO REPORTED SPECIFIC AVATAR PERCEPTIONS.

Avatar Perception	Experienced	Inexperienced	All
Avatar Creepiness	25.00%	14.29%	18.18%
Avatar Attractiveness	75.00%	57.14%	63.64%
Proxemics Violation	0.00%	28.57%	18.18%
Uncanny Valley	0.00%	0.00%	0.00%
Skeletal Inconsistency	0.00%	0.00%	0.00%
Playback Inconsistency	0.00%	0.00%	0.00%
Avatar Pose Inconsistency	0.00%	28.57%	18.18%

TABLE III
PERCENTAGE OF PARTICIPANTS WHO REPORTED SPECIFIC AVATAR PRESENCE.

Avatar Presence	XP	NO_XP	All
Feels like a second person	45.00%	62.80%	56.40%
Feels a person recognizing me	45.00%	34.20%	38.20%
The avatar human look real	45.00%	60.00%	54.60%
Interaction was like with an human not device	40.00%	48.60%	45.40%
Interaction was realistic, not simulated	35.00%	40.00%	38.20%

responses can be seen in Q9, where two non-experienced users reported problems with the avatar's positioning. Conversely, half of the users in both groups felt that the avatar's positioning and alignment were satisfactory (Q11). Some non-experienced users felt uncomfortable with the avatar's close proximity (Q16).

These specific questions were highlighted in Figure 5 because they had binary (yes/no) responses. The remaining questions were open-ended, and the authors found several responses noteworthy. Some experienced users described the avatar as "friendly" and "effective in providing guidance through the tasks," although one user noted that the avatar was "sometimes a bit off the beaten track." Non-experienced users commented that the avatar was "correct and natural" and "appropriate." When asked about the avatar's close proximity, users indicated that "knowing it was an avatar, I did not feel disturbed" and "it walked through me once, which was more spooky and funny than disturbing."

A detailed list of questions and statistical analyses can be found in the Supplementary Material.

D. Social Presence

On a scale of 1 (*"totally disagree"*) to 5 (*"totally agree"*), the presence of the avatar was rated low ($M = 2.33$, $SD = 1.18$). For inexperienced participants, the rating was slightly higher ($M = 2.46$, $SD = 1.39$) than for experienced participants ($M = 2.1$, $SD = 0.65$). The lowest rating was for the sense that the avatar was aware of the participant. For participants with less experience, the rating was $M = 1.71$, $SD = 1.5$, while it was slightly higher for those with more experience, $M = 2.25$, $SD = 0.5$.

VI. DISCUSSION AND LIMITATIONS

In evaluating the effectiveness of avatar-based collaboration in iVR for training scenarios, the results of the NASA-TLX and SUS questionnaires, along with qualitative feedback, reveal strengths and areas for improvement of the prototype.

A. Discussion of Results and Feedback

Even though the tasks required minimal physical effort and time, indicating a manageable level of difficulty, moderate mental demand, and high levels of satisfaction suggest that the tasks were still engaging. This is further supported by feedback regarding the ease of following the avatar's guidance through tasks. However, the lack of knowledge about the pump station among some participants highlighted the need for more comprehensive guidance within the training scenario.

The difference in SUS scores between experienced and inexperienced users reflects the system's learning curve. Qualitative feedback underlines several usability concerns. Participants encountered difficulties navigating the hand menu, consistent with identified usability hurdles, particularly a *"sense of lag"*, and visibility issues stemming from red-green color weakness, in addition to translucent buttons, suggesting the need to improve menu responsiveness and visual design.

Issues with avatar recording activation and menu usage inadvertently suggest the interface is prone to false triggers, necessitating a review of interaction thresholds or gestures. Regarding the questionnaires, additional support materials, such as hints in the mobile version, were missed and should be added in the follow-up study.

One participant described the audio sounding artificially generated, suggesting the need for higher quality audio recordings to improve realism and immersion. The occurrence of avatar components like legs disappearing or an avatar's failure to accurately interact with the environment (e.g., missing the valve due to offset) also mitigates the perceived realism and can hinder the learning process.

Spatial registration errors, which occasionally led to incorrect avatar placement, suggest a gap in its integration within the physical environment and should be improved to enhance presence and engagement. Furthermore, the avatar violates the personal proximity, which was surprisingly well perceived, with four participants noticing and reporting it to be *"not disturbing"*. The position of the avatars in the physical space was described as *"floating"* by a participant, as *"good"*, *"fitting"* or *"correct"* by five participants, and as *"too far away"* by two participants. In the follow-up study, the stability of avatar visualization and registration should be improved.

B. Limitations

The limitations of the study provide a roadmap for future enhancements. Technical challenges, such as unintentional stopping of audio recordings and avatar playback, require a robust system capable of providing a seamless learning experience. The scope of the study, with only one of the two lecture tasks currently implemented and the absence of a control group for comparative analysis, limits the conclusions that can be drawn about the overall educational efficacy of the system. This underscores the importance of comprehensive system testing in a variety of tasks. The initial study had a restricted number of participants who were not precisely the intended target group, but rather lecture stakeholders. In our follow-up study, we expand the subject pool, focusing on students and aiming at gender balance.

VII. CONCLUSIONS AND FUTURE WORK

The application, *EduAvatars: Pumpstation XR*, was designed and developed following the guidelines provided by the educators. Additionally, it was prepared to run on two different technologies: iVR and AR, making it more versatile and easy to adapt to lectures and various situations. The usability of the AR application was validated on-site comparing it to textual instructions from the lessons. The pilot experiment yielded promising results for the implementation of avatars in learning experiences. The integration of authentic engagement with the pump station and the structured guidance provided by the avatar facilitated a practical and effective learning experience for participants in navigating complex technical systems.

For future work, the four concepts of the application, in AR and iVR, will be tested with students divided into four groups to measure their improvement in learning and evaluate the effectiveness of the application for education. To achieve this objective, the application will include more annotations to guide users and will undergo improvements in usability and interaction based on usability results.

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