Enhancing Professional Training with Single-User Virtual Reality: Unveiling Challenges, Opportunities, and Design Guidelines

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Figure 1: Single-User VR Training Across Three Scenarios: Electricians, Medical Trolley, and Spatial Orientation, from left to right.

ABSTRACT

An immersive single-user virtual reality system possesses the potential to induce a paradigm shift in the realm of professional training, particularly within safety-intensive and complex procedural domains. This innovative system offers a safe, adaptable, engaging, and efficacious training experience, thereby fostering better task performance, reduced errors, and more favorable outcomes. Our goal is to delve into the opportunities and challenges associated with such training programs, while also providing guidelines for their seamless integration into educational curricula. Three case studies were conducted to gauge the efficacy of single-user VR training: the electricians' scenario (N=30), a spatial orientation scenario (N=20), and a medical trolley scenario (N=21). Employing mixed methodologies, encompassing workshops, semi-structured interviews, and observatory data collection, insights were gathered. The core objective of this investigation was to assess the perceptions of potential users, notably those partaking in apprenticeships or vocational training, toward prototypes of single-user VR training. The study's findings emphasize the inherent value and constructive attributes of integrating single-user VR training within the realm of professional development. This integration fosters practical experiential learning in procedures and essential competencies for ensuring safety, resulting in enhanced training outcomes. The study showcased augmented individualized learning tempos, expanded opportunities for repetition, heightened concentration, and deeper engagement within the VR-based instructional environment. Moreover, the study underscored the crucial role of personalized design enhancements and continuous content evolution to maximize the effectiveness of VR-based training methodologies. Integral to the comprehensive evaluation was the significance of user experience and the perceived value of the VR system. In parallel with the empirical investigation, foundational design principles were derived from the challenges and prospects unveiled across all three case studies.

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CCS CONCEPTS

• **Human-centered computing** → **User studies**; **Virtual reality**; *HCI theory, concepts and models.*

KEYWORDS

Professional Training, Head-Mounted Display, Case Study, VR-based Learning Environment, Apprenticeship, Learning Methods, Safety-intensive Domains, Mixed Methods

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1 INTRODUCTION

Virtual reality (VR) technology is increasingly finding its place in education and professional training due to a host of advantages it offers. These include the flexibility of learning from anywhere, the ability to practice hazardous tasks safely, and the allowance of errors [14, 33]. VR enables the visualization of three-dimensional (3D) information and creates interactive settings that enhance the feeling of being immersed. This technology promotes learning by involving learners in interactive activities and dynamic interactions, enabling them to delve into and explore various objects and phenomena within the learning environment. This is particularly advantageous in fields where authentic learning settings are impractical within a conventional classroom setup such as healthcare, aviation, and emergency response. By integrating 3D objects that replicate real-world items, and subsequently incorporating them into real-time virtual simulations [4], learners gain the opportunity to immerse themselves in a simulated reality [27]. Apprentices and trainees currently have limited opportunities to practice the tasks, making VR training a promising solution as it provides a safe environment for making mistakes and repeating efforts, which is crucial for skill acquisition [33, 35].

Research has indicated that utilizing VR for learning can amplify motivation and interest, ultimately resulting in more effective learning outcomes and heightened self-confidence [16, 26, 33]. Moreover, virtual learning environments offer the advantages of affordability, safety, and increased flexibility. Numerous educational systems have effectively established impactful virtual learning environments [10, 29].The success of immersing individuals in a VR environment hinges on the extent of their engagement [39]. Educators are actively exploring ways to leverage this immersive quality of VR to enhance learners' willingness to participate in educational activities [15]. Despite the observed positive impacts of VR, particularly with head-mounted displays (HMDs), there remains a paucity of evidence on the optimal utilization of this technology for training, particularly in real-world scenarios [12, 23, 24].

Thoroughly assessing learning objectives, activities, evaluations, and seamless curricular integration is indispensable before embracing VR training, recognizing that it cannot wholly replace hands-on experience [17]. Nevertheless, as a supplementary learning tool, it holds the potential to enhance existing instructional techniques, thereby meriting serious consideration for effective and efficient training paradigms. Exploring the full scope of VR training's limitations and its accessibility across diverse demographics is of paramount importance [14]. Furthermore, we must actively recognize and remove any barriers that might impede the adoption of VR training, while also shaping design and usage guidelines based on real-world VR training contexts.

Our research encompasses the development and assessment of functional prototypes for single-user VR applications using HMDs. The primary objective of this study is to contrast the learning outcomes of two cohorts: one utilizing VR training, and the other relying on printed materials. These learning exercises pertain to tasks that involve spatial orientation and procedural competencies. In addition, the study aims to identify suitable teaching and learning paradigms for VR training that consider the real-world context. The study also evaluates the acceptance of VR training, identifies potential barriers and obstacles, and delves into associated challenges. Through comprehensive exploration and comparison, this research investigates the deployment of VR training in various domains as shown in Figure 1. Guided by the findings, the study furnishes recommendations for the future evolution of VR training that caters to a diverse array of users, including both learners and instructors. The objective is to harness the potential of this technology for long-term integration into professional training. By comprehending the impact of VR training on learning outcomes, identifying best practices for design and use, and addressing potential challenges, the study endeavors to contribute to the formulation of efficient VR training curricula. These curricula have the potential to elevate safety and enhance skill acquisition within vocational education. A substantial component of our investigation is of an exploratory nature. Consequently, we have formulated the following research questions:

- **Research Question 1 (RQ1):** What are the opportunities and challenges of employing single-user VR HMD in modern professional training in terms of accessibility, learning outcomes, acceptability, and technology motivation?
- **Research Question 2 (RQ2):** What are the best practices and recommendations for designing and implementing single-user VR HMD training in a real-world context?

2 RELATED WORK

The existing literature highlights the multifaceted advantages of immersive VR training, encompassing heightened emotional engagement, enhanced learning processes, elevated motivation, and enjoyment [14]. It has exhibited superior efficacy compared to video training or desktop VR, particularly in the context of procedural skills and the exploration of hazardous scenarios [33]. Nonetheless, the effectiveness of immersive VR training hinges on trainer guidance and supervision, while also presenting limitations in terms of haptic feedback [24, 42]. While it facilitates repetitive training without necessitating additional equipment and can truncate training time, its integration requires judicious consideration to maximize learning outcomes [3, 28].

2.1 Virtual Reality in Professional Training

Initially utilized predominantly in military training, the broader adoption of VR across different domains remained constrained due to the prohibitive expenses associated with the required equipment [9]. However, with advancements in hardware and the gradual reduction in the cost of VR devices, the horizons of potential applications have expanded. VR has the capacity to replicate both real-world and imaginative scenarios, offering a secure avenue for immersive hands-on training. This evolution renders VR increasingly indispensable for educational and training contexts [14, 40]. Despite this, the integration of VR into mainstream education remains largely experimental, and its inclusion in standard curricula has yet to materialize [32].

VR training proves particularly invaluable in contexts where errors could result in personal or collective harm, or where real-world training is unfeasible, such as emergency preparedness or scenarios with products that do not yet exist [37]. The growing interest in

VR simulations for vocational and safety training stems from their capability to facilitate the practice of critical and hazardous tasks within a safe and realistic environment [14]. These simulations offer a diverse array of scenarios, featuring personalized content, feedback, and varying levels of complexity [24, 42]. The benefits of VR training encompass decreased fabrication time, cost-efficiency vis-à-vis traditional training, and the flexibility to repeat training sessions as necessary [30, 35, 41]. Highly motivating and engaging for users, VR training fosters heightened learning efficiency, higher confidence, and easier recovery from errors than in real-world environments [24]. The interactive and immersive nature of the environment encourages experiential learning through real-time experimentation and exploration [31]. Studies have found that VR training is effective for training memory, procedural skills, spatial tasks, and orientational skills, primarily focusing on procedural skills for assembly and maintenance [14, 33]. Evidence suggests a correlation between high immersion levels in VR applications and spatial memory capabilities [33]. However, a crucial differentiation needs to be drawn between VR applications in educational settings and those geared towards occupation-centric professional training, as the latter is inherently more intricate and challenging to evaluate [33]. Plotzky et al. [30] found that although VR training theoretically enables self-directed learning without direct supervision, its effectiveness is notably enhanced when complemented by guidance and support from trainers. Integrating VR technology into the curriculum is imperative, and it should be regarded as a complementary tool rather than a substitute for conventional learning methods, underscored by the necessity of proper instructional guidance [3, 28].

2.2 Orientational Skills in VR

A study by Krokos et al. [20] examined how spatial information representation impacts memorability and recall. They used a 3D virtual castle with designated information, similar to memory places. Participants were split into three groups: VR with HMDs, desktop 3D model, and a list of items. The VR group had better recall, focus, and presence. Even those new to HMDs outperformed desktop users in VR. However, König et al. [19] had a different perspective, exploring the effects of VR and non-VR media on spatial learning. Despite similar knowledge acquisition between the learning methods, the VR cohort displayed enhanced proficiency in judging straight directions between landmarks, while the non-VR group excelled in estimating cardinal directions. Schrom-Feiertag et al. [36] orchestrated an experiment within a CAVE virtual environment to evaluate an indoor guidance system. Participants navigated through way-finding tasks, leveraging the inherent ease of movement within the CAVE setup. Quantifiable metrics such as completion times, traveled distance, walking speed, and visual exploration were measured. The assessment extended to gauging participants' perception of presence in the virtual milieu. The results notably underscored the effectiveness of virtual environments in scrutinizing human navigation behaviors and spatial orientation. These findings suggest that harnessing VR technology can yield substantial benefits in enhancing cognitive processes such as memorability, spatial orientation, and navigation.

2.3 Presence and Immersion

The terms "presence" and "immersion" are often used to describe the VR experience, but their distinctions are not always clear, sometimes leading to confusion or conflicting definitions [8]. Presence is the sensation of being in the virtual environment [21], while immersion relates to the technology that creates this sensation [3]. How immersive the technology is and how users navigate within it can affect presence, which then influences user acceptance and perceived utility [5, 34, 43]. Immersive VR uses headsets and CAVEs. Questionnaires are often used to measure presence after a VR experience [38]. Understanding presence is important for creating new technologies and training scenarios.

2.4 Fidelity

Fidelity is a key aspect in VR applications, commonly categorized into three types: display fidelity, interaction fidelity, and scenario fidelity (related to storytelling) [7]. Display fidelity pertains to the level of detail and realism in the visual elements, which can improve users' attention but does not necessarily increase their sense of presence in VR [8]. Research by Buttussi and Chittaro [7] explored different display fidelity levels in safety training, revealing that higher fidelity increased presence and engagement but didn't significantly improve learning outcomes. Uncertainty remains regarding the impact of higher interaction fidelity on learning outcomes, especially in tasks involving physical actions. Further investigation is required to comprehend the role of scenario fidelity. Remarkably, Feng et al. [12] noted that heightened fidelity and realism elevate engagement with the subject being taught.

2.5 Procedural Skills

Electricians. In a study by Górski et al. [14], an experiment centered around a VR training system for electricians was conducted, exploring three distinct navigation and interaction methods. The objective was to identify the optimal fusion of interaction techniques and evaluate the viability of VR simulation for future electrician training within a facility context. Participants engaged in standardized scenarios, involving switching operations and simulated cable placement, with an assisting avatar offering brief tips. A pre-and post-questionnaire captured insights, and implementation times and hint usage were compared across different setups. Overall, 90% of participants found the technology useful, with 54.5% considering it a potential replacement for traditional training. In another study by Tanaka et al. [41], a VR training system tailored for electricians stationed at substations was conceived and investigated as a supplementary training tool. Users explored the facility and inspected equipment for errors. The study concluded that VR training effectively complements traditional training. A subsequent investigation delved into various movement methods and the broad applicability of such training, ultimately proposing teleportation as the default choice. As current training for electricians and network operators tends to focus on theoretical knowledge, lacking practical experience, VR training fills a vital void in cultivating best practices [41].

Healthcare. As per Renganayagalu et al. [33], VR training is widely embraced within the medical realm, with medical training-oriented VR systems exhibiting greater specialization and sophistication than those used in other sectors. While VR training in nursing education is relatively nascent and warrants further exploration, research such as the study conducted by Bracq et al. [3] underscores VR's suitability for procedural training in nursing. This is particularly evident for tasks requiring repetitive practice devoid of equipment or patient involvement. The study revealed increased interest in VR post-training, with age, gender, and gaming or VR familiarity exerting minimal influence on user acceptability. However, the study acknowledged the necessity for additional research to assess the real-world impact of VR training on procedural skills. In a comprehensive assessment, Plotzky et al. [30] performed a systematic review of VR usage in nurse education, revealing systematic procedure training, emergency response training, soft skills training, and psychomotor skills training as the most common areas of focus. Furthermore, Butt et al. [6] delved into the effectiveness and user experience of a game-based VR simulation for urinary catheterization training, a procedure with limited opportunities for practice before patient interactions. The VR simulation allowed hands-on interaction via interactive gloves, with both groups receiving expert feedback during their one-hour practice. Outcomes indicated a strong inclination toward repeated practice, and a retention test conducted two weeks later demonstrated comparable performance between groups. Intensive care nurses frequently grapple with chronic stress due to the persistent stressors of interruptions and time pressure. A study conducted by Weiß and Heuten [44] within a virtual environment corroborates that both subjective and objective stress levels increase under these circumstances. This finding underscores the feasibility of integrating stress inoculation training into nursing education curricula, particularly in scenarios that emulate safety-critical situations during early professional training. Overall, the VR simulation was well-received, with participants expressing a willingness to incorporate it into their practice.

Safety Training. Realistically simulating emergency training is a notable challenge that VR effectively addresses [37]. VR provides hands-on training, allowing trainees to engage in diverse scenarios and actively partake in various situations without actual risk. However, high-fidelity systems remain cost-intensive and primarily find use within the military domain [28]. Feng et al. [12] explored the use of VR in serious games and evacuation training, finding that traditional training methods lack emotional engagement and feedback. VR-based training yields several advantages, encompassing enhanced recall, immediate feedback, and the ability to study behavioral patterns [12]. Fire safety, in particular, stands as a significant application area, leveraging VR to replicate lifelike scenarios, amplify engagement, and evoke emotional responses. Lovreglio et al. [22] conducted a comparative study between VR and traditional video training for fire extinguisher usage. The findings indicated that the VR group exhibited noteworthy knowledge gain and improved retention compared to the video group. Most participants favored VR training over video training, however, the study didn't directly compare their performance in real tasks. In a separate study by Makransky et al. [24], immersive VR, desktop VR, and printed manuals were pitted against each other to teach laboratory safety to undergraduate students. The immersive VR and desktop VR groups displayed significantly higher enjoyment and intrinsic motivation than the printed media group. The study underscores VR's potential to enhance enjoyment and motivation in learning, subsequently bolstering the effort put into learning. Furthermore, VR training's value extends beyond academic settings into real-world performance improvement.

3 APPROACH

To formulate recommendations and guidelines for the utilization of single-user VR HMDs in professional training, our stance favors the adoption of a case study methodology. The case study approach stands as an optimal choice for delving into the connections between contextual conditions, phenomena, and underlying reasons. Additionally, employing a multi-case study approach proves valuable in dissecting differences and commonalities across diverse cases [2]. This methodology allows for a holistic comprehension of the subject matter by amalgamating both qualitative and quantitative data [1]. The primary objective of this study is to introduce VR technology into professional training programs aimed at diverse target groups. We seek to enrich the conventional learning approach reliant on printed materials, images, and videos, by providing a more immersive and interactive learning experience. Our experimental framework was meticulously designed to leverage potential synergies, and these experiments were conducted within settings that closely resembled their real-world applications. These settings encompassed vocational schools, training facilities, and a simulated hospital environment. An iterative development approach was adopted, involving workshops with experts, mixed methods in experiments and field studies, and qualitative interviews focused on task-related measures to analyze the behavioral patterns of different groups and identify the underlying challenges for the effective use of single-user VR training. The interview aimed to assess participants' perceptions of VR training by inquiring about its strengths, weaknesses, satisfaction, improvement suggestions, the advantages of VR over conventional methods, and the potential integration of VR into education and training. Importantly, the same hardware devices, specifically the Oculus Quest 2, were used in all the case studies. The collected data not only shed light on potential opportunities and roadblocks within single-user VR HMD training but also contributed to the formulation of design guidelines.

3.1 Case Study 1 - Knowledge Transfer in Electrical Engineering

The research commenced by gathering requirements through a comprehensive analysis of similar projects in the literature. We used an iterative approach to develop a functional prototype in collaboration with Mindconsole[1]. We held two workshops with experts and potential users to determine the content for the VR training scenario. In the first workshop, 8 trainers and experts from partners like AVL List GmbH[2] and WIFI Steiermark[3] participated. The second workshop involved 9 apprentices from AVL Traning Center for Apprentices. The workshops aimed to pinpoint training

[1] https://mindconsole.net/
[2] https://www.avl.com/de
[3] https://www.stmk.wifi.at/

scenarios that would be pertinent to both trainers and students. To uncover potential scenarios and learning material for the VR training, we delved into work accident statistics [4] and organized design-fiction workshops. This approach was undertaken with the objective of proactively identifying and mitigating potential forthcoming challenges within the training system and evaluating its advantages and disadvantages.

3.1.1 Initial Findings. In both workshops, participants focused on improving electrical engineering safety education, discussing VR scenarios for complex situations and the need for more hands-on learning. They noted that apprentices seek greater tactile experiences and often rely on self-guided online learning. The main challenge discussed was teaching the "Five Safety Rules" due to limited hands-on training opportunities. To address this, they proposed integrating VR scenarios for tasks like cable laying and power line work, although precision tasks may be challenging in VR due to restricted feedback. VR was considered beneficial for its safer and more realistic learning environment, along with the advantage of training at different locations.

3.1.2 Study Design and Task. Case study 1 was designed to simulate a flat with potentially damaged electric installations as shown in Figure 2. The objective was to follow a protocol and ensure that the basic protection according to DIN VDE 0100 is met [18]. The scenario encompassed 15 distinct variables, each representing a facet of electrical installations, as depicted in Figure 3. This includes elements such as impaired sockets and malfunctioning appliances. Ten electrical sockets at four distinct locations, or the fuse box itself, had the potential to have been damaged or incorrectly installed in the past. Manifestations of these issues included non-functioning sockets, visible burn marks, or improper installation. Furthermore, the following electrical devices may have incurred damage: a standing lamp, a table lamp, a television, and a toaster. Each time a scenario was initiated, these variables were randomly generated. The simulated apartment comprised three rooms, granting users the freedom to traverse and interact with diverse measuring devices. Within the proximity of the user's access, an imaginary conveyor belt housed various measurement instruments, including a voltage tester, a test lamp, and two locks designed for securing fuses and the fuse box. The user had the discretion to choose the methods and order for examining the essential electrical safety measures in the residence. The study was conducted in two distinct phases. The first phase commenced with a kickoff workshop, wherein the project was introduced, and participants were given an ID and tutorial on how to use the VR headset and interact with the scenario. Participants were granted access to the VR headset for a duration spanning two to three weeks. At the training facility of AVL List GmbH, VR training took place voluntarily during breaks. Conversely, Landesberufsschule Voitsberg[5] and Energie Steiermark AG[6] seamlessly integrate VR training into their standard curriculum. Culminating this phase, a qualitative semi-structured interview was conducted to gather insights. The objective of these interviews was to accumulate insights concerning the acceptance and viability of VR training. Carried out via telephone, each interview spanned approximately 20 minutes. Participants were extended invitations during the inaugural kick-off workshop, resulting in a total of 30 participants being interviewed. The data collected from these interviews was analyzed employing thematic analysis by three researchers. The analysis of interview data in this study followed a structured process of transcription, coding, category creation, and theme development. Each interview's data categorization underwent a second review by at least one researcher to determine the final categorization.

Figure 2: Hallway, the starting point of the scenario (left), and the living room of the virtual flat (right).

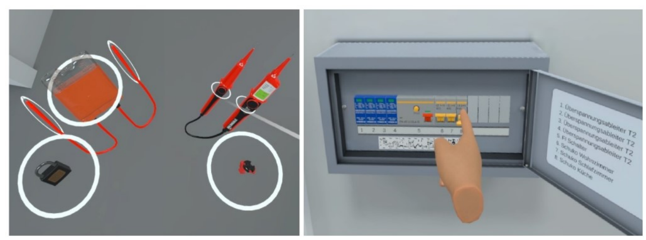

Figure 3: Voltage tester, test lamp and two locks (left), and the fuse box in the hallway (right).

Participants. The study involved 30 apprentices drawn from diverse project partners, including entities such as AVL List GmbH, Landesberufsschule Voitsberg, and Energie Steiermark AG. These collaborators expressed future interest in incorporating VR training systems and requested their respective apprentices to participate in the study. Prior to involvement, all participants, as well as their legal guardians in the case of minors, were comprehensively briefed about the study's nature and objectives, ultimately granting their explicit consent to partake. The majority of study participants were male, while the number of female apprentices partaking was limited to 5. Merely 10 individuals surpassed the age of 20. The mean age of participants was calculated at 18.2 years, with the youngest participant aged 16 and the eldest aged 27.

3.1.3 Results. Individuals involved in the field study exhibited a moderate to strong inclination towards technology, as indicated by the ATI-S scale [13]. The average score on this scale, which ranges from 1 to 6, was 4.25 (SD = 0.84). The overall training approach garnered positive feedback, particularly for its alignment with contemporary learning preferences. A participant reported *"You can learn better that way, today's youth can deal better with*

[4]https://www.statistik.at/en/statistics/labour-market/labour-and-health/accidents-at-work-work-related-health-problems
[5]https://www.lbs-voitsberg.ac.at/
[6]https://www.e-steiermark.com/ueber-uns/unternehmen/management

such a system and the Internet than with lots of slips of paper, we are more used to that. That something like this is developed at all is great!" (p. 10). Participants noted that young learners are better equipped to engage with digital systems like VR compared to traditional methods. The innovative nature of VR-based training was well-received. Students who pursued electrician apprenticeships found value in hands-on experience for tasks that were previously only taught theoretically. Conversely, participants in other apprenticeships highlighted unfamiliar and complex content but appreciated the exposure to different specializations and scenarios. The need for varied levels of difficulty was acknowledged. A small portion of the participants encountered initial difficulties with the system, primarily related to the unfamiliarity with teleportation mechanics, resulting in unexpected collisions with virtual objects. A participant reported *"Only when teleporting, there it was confusing when you're suddenly standing right in front of a wall" (p. 25).* When asked in further detail about their initial interactions, a minority reported issues operating controllers, orienting within the VR environment, or using tools within the scenario, for example, one participant said *"...that you suddenly found yourself in a wall or in the fuse box" (p.17).* A couple of participants experienced dizziness, attributing it to the confined physical classroom space available for VR interaction, one mentioned *"I had difficulties setting up the play area (p. 13)."* The analysis revealed the following prominent themes:

- **Overall Satisfaction with VR-Based Training:** Despite these challenges, an overwhelming amount of participants expressed satisfaction with the VR-based training. The realism of the learning scenarios was highlighted, which also contributed to user satisfaction, with participants noting the benefit of practicing complex topics in VR before real-world application. A participant said *"for preparing for the final apprenticeship exam because you have to master exactly these topics well" (p. 27).* The simulation's close alignment with real-world movements was appreciated for facilitating effective learning. One participant emphasized *"...that it was good to be able to practice such topics in VR first and only then in reality.. it is much safer that way (p. 9).* Another participant pointed out *"It's good that you make similar movements with the controllers as you do in real life: that's why you learn it quickly" (p. 9).*
- **High Presence and Comfort:** Participants also reported a sense of high presence. Some reported comfort with wearing HMD for example, one said *"I almost forgot I am wearing it" (p. 13).*
- **Interest in Integrating VR into Curriculum:** Most of the participants expressed interest in incorporating VR-based training into their curriculum, citing practical relevance, safety, and the ability to grasp complex concepts as driving factors. One participant said *"...because I would have understood many things more easily. One remembers concepts better than only if taught theoretically" (p. 10)."* Another participant reported *"... because this exercise is very instructive, and I can concentrate better than in normal lessons" (p. 4)."*
- **Practical Relevance and Enjoyable Learning:** Engaging in VR training allows individuals to perceive complex connections and gain insight into the bigger picture. In the absence of such immersive experiences, practical knowledge often remains isolated. A handful of participants expressed that the system's practical relevance and enjoyable nature motivate them to embrace this approach. They mentioned *"you can't break anything" (p. 17)* and *"I also think it's good that you can try things out before you do them in reality." (p. 12).* Suggestions emerged for integrating VR into vocational education, with a proposed model of alternating theory and VR practice. A participant said *"I would do it by scheduling the theory lessons beforehand, for example, two weeks; and then practice with VR for maybe a week; (so that) you can then directly apply what you have learned in theory; then you remember things much better" (p. 10).* The potential benefits of VR-based training included improved memory retention, a better understanding of tasks, and enhanced focus. As a participant said *"One is really focused and actively dealing with the topic" (p. 8).*
- **Anticipated Challenges and Recommendations:** Anticipated challenges included concerns about technology acceptance, teacher adaptation, monitoring student progress, and costs. Some participants feared diminished dedication to traditional theory and hands-on learning. Addressing this, recommendations were made to stream VR content to screens or use introductory videos and tutorials, provide tutorials, and involve teachers during training. Participants stressed the importance of instructor involvement during VR practice for guidance and technical support. A contact person was deemed essential for addressing questions and maintaining a structured learning environment. The consensus was that trainers' presence ensured effective training sessions, fostering focus and discipline among learners. A participant mentioned *"It certainly doesn't work without a teacher; they always have to be there when practicing, otherwise it would be far too unsettled (and noisy in the class)" (p. 20).*

3.2 Case study 2 - Spatial VR Training for Healthcare and Emergency Responders

This work aimed to create and evaluate VR-based training scenarios for healthcare and emergency response personnel, specifically focusing on spatial navigation and evacuation training. The comprehensive case study involved conducting a literature review centered on VR training for first responders, developing outlines for training scenarios, and ultimately implementing and assessing these scenarios with medical professionals. Following a methodology similar to Case Study 1, the project placed a strong emphasis on understanding users' subjective experiences, their confidence in using the VR training system and identifying skills and activities suitable for VR support. VR-based scenarios were developed to measure training effectiveness: designed to improve spatial orientation skills during hospital evacuations, which was then compared to a printed map-based training approach.

3.2.1 Study Design. To compare learning outcomes across two training methodologies effectively, participants were randomly assigned to either a VR scenario or a printed materials condition. The choice of the printed media condition stemmed from its widespread usage, enabling self-guided practice regardless of time and location. Each group was provided with 8 minutes of training time for the task. After the training phase, participants carried out the task in an authentic environment to assess their performance. At the study's commencement, participants received an explanation about the experiment's objectives and its timeline, following which they granted their consent to partake. Every participant was allocated a distinctive ID and advised against sharing their experience with others. The individuals were randomly divided into either the VR or non-VR groups, receiving instructions on navigating the VR system before embarking on an 8-minute training session. Subsequent to the task, participants underwent brief interviews aimed at capturing their personal perceptions of the experience.

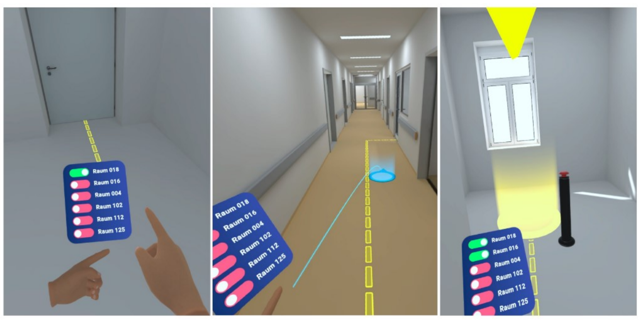

Figure 4: The view of the user when starting the scenario (left), user's view of the hallway with pointing teleport (middle), and a room to be marked as visited (right).

Figure 5: The path leading to the first room (016) in the VR (left) and the real hallway (right).

Task. The spatial orientation scenario showcased a virtual representation of SIM Campus in Eisenerz, Styria, Austria[7]. The virtual scenario commenced within room 018 on the ground floor, mirroring the actual starting point as depicted in Figure 5. The VR scenario aimed to closely replicate the building's attributes such as flooring, doors, windows, room numbers, and descriptions, though room furnishings were omitted. Participants were tasked with memorizing a sequential route within a building comprising five rooms labeled 016, 004, 102, 112, and 125. Notably, rooms numbered with a prefix of 0 were situated on the ground floor, while those bearing a prefix of 1 were positioned on the first floor. However, explicit instructions on how to memorize the route were intentionally withheld. The primary objective was to visit the designated rooms in the specified sequence, tracing the dashed pathway illustrated on the map or within the VR simulation (as depicted in Figure 4), all the while adhering to the route without adopting shortcuts or diversions. It's noteworthy that none of the participants had previously visited the building. Participants were required to sequentially visit the five designated rooms, with the list of rooms displayed on the left controller, featuring green and red checkmarks denoting visited rooms. Participants were advised to maintain their regular walking pace, refraining from running or walking excessively fast. Movement within the scenario could be executed by walking or teleportation, guided by a yellow dashed line traced across the floor. Upon entering a room from the list, a yellow circle appeared on the floor, accompanied by a buzzer indicating the room has been visited. The final buzzer prompted a "restart" command, transporting the participant back to the initial starting position. The yellow dashed line can be turned on and off by pressing the joystick on the right controller. In both the VR simulation and the map, each group was granted an 8-minute period to prepare for the task. During the real-world tasks, an observer recorded participants' movements within the building, mapping their routes onto a paper representation of the premises and documenting relevant variables.

[7]https://www.simcampus.eu/

Participants. 20 nursing students from FH Sankt Pölten[8] and Akademie für Gesundheitsberufe Wien[9] participated in the study. Those who indicated their interest registered via an online form. Participants who experienced VR training had an average age of around 33.10 years(SD = 8.99). Those without VR training had an average age of approximately 34.05 years (SD = 9.65). The overall average age for all participants was approximately 33.58 years(SD = 9.22). Among VR-trained participants, 85.00% were female and 15.00% were male, while in the no VR group, 95.24% were female and 4.76% were male. Interviews were conducted with seven participants who had undergone training using the VR simulation. In order to encompass a broad spectrum of responses, including those from individuals who exhibited better performance in terms of time efficiency, and error rates, as well as those who encountered challenges during the task. Additionally, participants with performance levels approximating the mean were included in the interview pool. The interviews were analyzed using the qualitative content analysis method as proposed by Mayring [25].

3.2.2 *Results.* Performance variation between VR and map-based learning to navigate was characterized by VR participants emphasizing visual cues over room numbers, finding the VR experience immersive. In contrast, map-based learners relied more on room numbers for navigation. While VR offered benefits such as increased engagement, challenges like motion sickness needed to be addressed in the design and implementation of VR scenarios. Overall, the complexities of orientation and locomotion revealed the need for further research.

[8]https://www.fhstp.ac.at/de
[9]https://gesundheit-studium.at/

- **Attention and Focus on Environmental Cues:** Through our observations and follow-up interviews, participants within the no VR group displayed a heightened attentiveness toward room numbers, while their counterparts in the VR group directed their focus toward visual cues encompassing glass doors, the door count between rooms, and the room's positioning relative to corners. Notably, the significance of room numbers was notably diminished within the VR group compared to the no VR group.
- **Emphasis on Visual Cues in VR Training:** VR group emphasized on visual cues, as evidenced by their attentiveness towards the glass door situated at the hallway's end and the glass window positioned to the right. Furthermore, the majority of participants conveyed a favorable assessment of the VR training experience, citing attributes such as realism, novelty, enhancement of procedural skills, and heightened focus as the pivotal factors contributing to their positive appraisal. One participant said *"Remembering the surroundings is much better when I experience it directly instead of through pictures and videos" (p. 3).* Some pointed out *"more detailed visual cues would have been helpful"(p. 9, 15).*
- **Motion Sickness and Disorientation:** In terms of the motion sickness encountered during VR training, the findings indicate that most participants did not encounter significant issues related to nausea, dizziness, or fatigue. In general, approximately 20% of the participants reported moderate to intense feelings of disorientation, while another 20% reported very intense or extreme sensations of disorientation. This suggests that these challenges could potentially arise from the specific scenario design and the method of movement within the virtual space.

3.3 Case study 3 - Medical Trolley Scenario

The study aimed to compare the effectiveness of virtual reality training with printed materials in assisting medical professionals in learning the placement of medical instruments on a trolley for intubation. Participants in the VR group underwent training using a virtual representation of the medical trolley and its contents. In the printed materials group, participants received printed materials, including written lists and images of the instruments and their correct layout on the medical trolley.

3.3.1 Study Design. The study commenced by obtaining informed consent and registering participants with unique IDs. Subsequently, participants were escorted to a waiting area, where they were briefed on the study's procedure, timeline, and objectives. To optimize resource utilization and minimize wait times, the experiment was conducted simultaneously with the spatial orientation scenario. Participants were randomly assigned to either the VR or no-VR group for different experiments. VR group participants were acquainted with the VR headset and scenario usage, while the no-VR group received printed instructions. Both groups were allocated an 8-minute preparation period. Afterward, they proceeded to the room containing the actual trolley. The researcher reiterated task steps and addressed questions before participants performed the task, with no time limit. Brief interviews were conducted with participants after the task to gather insights.

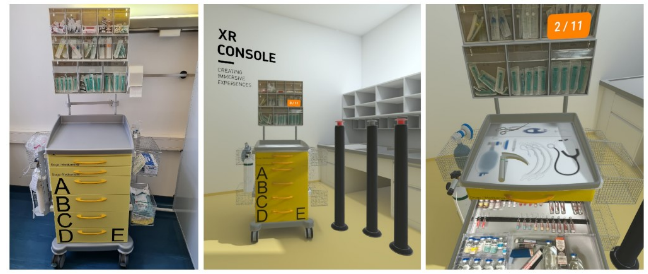

Figure 6: The real medical trolley (left), the virtual trolley and the whole setup with buttons (middle), and a detailed picture of the top of the trolley (right).

Figure 7: Participant training in VR (left), participant's view of the trolley (middle), the buttons next to the trolley (right).

Task. The VR simulation included a room featuring a medical trolley that accurately replicated the trolley used in the experiment, as depicted in Figure 6. The objects within the simulation were positioned in the same locations as those on the real trolley. Within the simulation, three buttons—labeled "stencil," "check," and "reset"—were situated next to the trolley. The "stencil" button displayed a diagram illustrating the intubation instruments and their placements. Notably, the oxygen mask was positioned within a basket on the left side of the trolley, while other instruments were stored within its drawers. Participants were tasked with memorizing the locations of 11 medical instruments required for intubation. Participants had to locate, pick up, and position items onto the stencil using controllers. A counter kept track of the items placed. The "check" button, initially grey, turned red when an error was detected and green when everything was correct. The "stencil" button could activate or deactivate the background stencil, as seen in Figure 7. Users had the option to practice without the stencil, and the "reset" button restored the trolley to its original configuration by clearing items and returning them to their initial positions. During the task, a researcher recorded task completion time and requested hints, and errors using a protocol. After completing the task, a photograph of the top of the medical trolley was taken for documentation purposes and for further investigation during the interview.

Participants. The study was conducted with 21 participants, including nursing school students, medical students, and nursing school teachers. Nursing students of FH Sankt Pölten and Akademie für Gesundheitsberufe Wien were offered participation in the study. They were drawn from the identical pool of participants who were recruited for Case Study 2. Following the medical trolley task, 9 participants who underwent VR training were invited to partake in semi-structured interviews. The selection was guided by task performance, encompassing three participants who excelled, three who faced challenges, and three who performed at an average level. The interviews underwent analysis through the qualitative content analysis method proposed by Mayring [25]. The transcription procedure was uniformly implemented for all interview records. A collective effort of three researchers was employed for the comprehensive analysis of the interview data. Subsequently, each interview's data categorization underwent a re-evaluation by at least one researcher to arrive at the definitive categorization.

3.3.2 Results. The following themes have surfaced from the analysis of interview data:

- **Ease of Use and User-Friendly Nature:** The majority of participants expressed ease and comfort in using VR, highlighting its user-friendly nature and quick learning curve. Within the VR group, the feedback regarding the medical trolley training scenario was predominantly positive, with the majority of participants expressing satisfaction. Nevertheless, a subset of participants faced challenges due to reduced accessibility, potentially linked to visual blurriness, as certain individuals couldn't wear glasses during the training.
- **Interaction and Learning Experience:** The majority of participants found the interaction to be straightforward, with a few expressing appreciation for the haptic sensations associated with object manipulation, as opposed to mere textual learning. Predominantly, positive feedback stemmed from the well-structured introductory tutorial, aiding comprehension of interactions and fostering familiarity with the VR environment. However, a notable concern pertained to the scenario's interaction *"Once I got stuck with the hand in the drawers and also accidentally teleported myself" (p. 2)*. Additionally, few participants encountered challenges involving fine motor skills while placing instruments on the trolley (p. 12, 16). Emphasis was placed on the link between theoretical and practical knowledge, with the sentiment that such connections imbued confidence, as a participant reported *"You can gain confidence in situations when theoretically learned, and then done practically in VR, then in real" (p. 4)*. Another salient observation highlighted the significance of movement congruence during task preparation and execution. A participant said *" I was well prepared (for the exercise), I've seen it before the exercise, it was then the same moves again" (p. 6)*. Suggestions for enhancing the training included incorporating greater variety and realism. This could entail minor adjustments to the initial object placement to emulate real-world imperfections.
- **Integration of VR Training:** In terms of integrating VR training, the majority of the participants advocated for its inclusion in the vocational school's curriculum. This integration could manifest through concentrated modules or regular sessions featuring VR training. The virtue of practicing in VR prior to real-world application was highlighted, with the concept of virtually enacting emergency scenarios and subsequently replicating them, in reality. A participant said *"Re-enact emergency situations and then again in real life, i.e. first experience them virtually instead of just explaining them" (p. 8)."* The most frequently cited advantages encompassed improved retention, the authenticity of VR training, and the absence of risk or fear. A participant reported *"Practical exercise helps me more than the theory" (p. 6)*. Another participant said *"The repetition makes it totally memorable. It's really not the real world, but very close. You are not afraid of making mistakes, trying things out, and training" (p. 12)*. The main concern regarding the use of VR in education is the level of acceptance among trainers and their knowledge of the technology which is a premise for successful integration and application of VR in the curriculum. The majority mentioned that the trainers should explain how the system works and then supervise the training, and do training evaluation. A participant said *"Explain - what will happen, explain tasks, clarify questions about VR and be available" (p. 12)*. The proposition emerged that VR supervision could be facilitated by a virtual representation of the trainer or through the trainer's involvement in a multiplayer mode.

4 DISCUSSION

Overall, users and trainers engaged in the experiments embraced the training with positive sentiment. Realism, novelty, and fun emerged as primary positives across all groups, with fun holding particular significance for apprentices. Better focus in the VR environment was consistently cited by all groups, with participants highlighting the exclusion of external distractions, leading to a heightened focus on the task. Initial challenges in steering and navigation abated with time and effective tutorials. Overcoming these challenges hinged on comprehensive guidance, clear goal explanations, and adequate support during training. Participants suggested expanding scenarios and incorporating varied difficulty levels while acknowledging the known limitation of haptic feedback in existing VR HMD systems. In terms of technology acceptance, all scenarios were deemed fun. The VR environment was perceived as closely resembling to reality, a critical factor contributing to user acceptance [21]. The electricians' scenario received slightly less positive feedback regarding ease of use, possibly attributed to participants from diverse specializations requiring more time to grasp the training's background.

Participants in spatial orientation and medical trolley scenarios trained in isolated, controlled surroundings, receiving focused attention from a trainer (a researcher overseeing the training). Conversely, the electricians' scenario group practiced in settings like classrooms or breaks, exposing them to more environmental distractions and noise. Regarding user experience with VR conditions, all scenarios were perceived as clear, efficient, and highly engaging. Distinctions surfaced particularly in perceptions of complexity, ease, intrusiveness, and supportiveness of training. The spatial orientation scenario in Case Study 2 appeared more complex and intrusive, while the medical trolley scenario in Case Study 3 gathered praise for its supportiveness and excitement. All movements could be seamlessly executed through familiar actions mirroring those in the real world, such as walking, rotating, and interacting with objects by grabbing and placing them. Despite teleportation being the recommended mode of movement to alleviate cybersickness [14, 41], it presented challenges in scenarios involving teleportation, leading to higher difficulties and disorientation, as indicated by the results. Concern was echoed in interviews, where teleportation difficulties were cited in both electricians' and spatial orientation scenarios, likely contributing to these variations. One potential explanation could be attributed to the frequency of teleportation required for successfully completing the scenario. Participants noted the uniformity in the visual design of the scenario, underlining the need for a greater variety of visual cues. For Case Study 2, a participant criticized the guidance line leading to the next room, suggesting that it might inadvertently encourage participants to follow the path without fully engaging in the route's comprehension and memorization. The findings indicate a relative mismatch between VR training and tasks involving spatial orientation. However, further investigation into this matter is needed, as our results partially diverge from the conclusions drawn in the study by König et al. [19]. Some participants expressed a preference for authentic walking over teleporting, yet implementing this in cases where virtual distances surpass available training space poses challenges. Moreover, the medical trolley and electricians' scenarios gathered greater overall satisfaction than the spatial orientation scenario. These outcomes align with the research of Renganayagalu et al. [33] and Górski et al. [14], who identified procedural skills training as the most prevalent and fitting content for VR-based training. Even though it is possible to offer individual learning scenarios without the guidance of a trainer, our results support the findings of Popovici and Marhan [31] and Schwarz et al. [37], suggesting that VR training should be always supervised. A substantial majority expressed enthusiasm for integrating VR training into vocational schools, especially for complex procedure practice in a safe virtual environment before real-world application. Trainers should initiate, explain goals, be present during training, and provide feedback. Interacting with the broader class through streaming was also suggested. Integrating such a training system could face challenges from potential trainer disinterest or lack of knowledge and substantial costs, maintenance, and technical hurdles.

The insights derived from the analysis of the three case studies allow us to address the two research questions initially posed in the paper's introduction as follows:

RQ1: The findings from the case studies consistently highlight a strong sense of presence, indicating that the virtual environment is closely aligned with reality, a crucial factor influencing user acceptance. However, certain technical elements within the training scenario, such as the design of the measuring device, don't accurately mirror reality. In terms of user experience, the training scenarios garnered positive evaluations, being perceived as engaging, captivating, and innovative. Participants found the VR-based training to be enjoyable, with some characterizing it as an entirely novel and favorable encounter. The interaction and navigation within the VR training environment garnered praise for being intuitive, although some participants initially encountered challenges. Most participants found the virtual environment easy to navigate and comfortable to use, revealing a substantial level of acceptance for VR-based learning within professional training. Nonetheless, the adoption of teleportation for movement exhibited problems in scenarios requiring more extensive movement, leading to instances of disorientation. On the whole, the study underscored that procedural skills were particularly well-suited for VR training. However, further investigation is warranted to ascertain the efficacy of VR training for tasks that involve spatial orientation.

The limitation of haptic feedback precision in widely used VR systems is acknowledged, rendering it inadequate for intricate activities necessitating precise motor control. These findings come as no surprise, considering that the limitations of haptic feedback in widely employed VR systems are well-established [30]. Nevertheless, VR-based training proves particularly effective for comprehending intricate scenarios and refining complex skills, as it facilitates an enhanced grasp of interconnections and broader contexts. Study participants also reported heightened concentration while using VR and expressed a preference for trainer guidance and support. Our work implies that supervisory oversight remains crucial for VR training, even though proficient users might necessitate reduced assistance. Trainers recommended interactive tutorials and projecting scenario content on large screens to alleviate their workload. However, the guardian system, which visually outlines the safe area, perplexed some participants.

Enforcing mandatory VR training might not be suitable, considering some participants' discomfort. Nevertheless, our work indicates that VR training can complement traditional methods effectively, albeit not replace real-world practice. Schwarz et al. [37] also affirm that VR training is meant to complement traditional training methods. Additionally, it was highlighted that VR-based training serves as a valuable supplement and cannot serve as a complete substitute for real-world practice, a notion echoed in the study by Bracq et al. [3]. The challenge lies in the expense and creation of VR training content and equipment. Implementing VR training in vocational schools, with shared scenarios developed by higher institutions, could mitigate costs. Diversifying training content across difficulty levels and adapting it to different knowledge tiers is advisable. Enhancing scenario flexibility and scalability contributes to a more authentic training encounter. [28] also emphasize the significance of flexibility and scalability. Collaboration with experts is crucial for content development. Thorough briefing, ongoing support, and trainer feedback are imperative for successful integration. Overall, the study underscores that VR-based learning can enhance education and training, while individual preferences and comfort levels should guide its introduction. A concise overview of the primary findings related to the opportunities and challenges associated with RQ1 is presented below in Table 1.

RQ2: Guidelines were created based on the challenges and opportunities that were previously discussed:

(1) When devising scenarios for VR training, it is imperative to adopt a user-centered approach and involve experts and stakeholders throughout the development process. This collaborative effort ensures the relevance and accuracy of the learning content. Early involvement of prospective users in testing can help unveil potential issues from their perspective.

Table 1: Benefits and Challenges of VR Training

Overview		
Parameters	**Opportunities**	**Challenges**
Accessibility	VR training provides a safe and accessible way to practice at one's own pace with more repetitions, leading to increased confidence and less fear of mistakes. Cybersickness is rare.	While individual differences or cybersickness can still be a concern, providing good tutorials, support, and familiarity with VR beforehand can help prevent these issues.
Learning	VR training offers better focus and fewer distractions and is effective for training procedures and complex scenarios that require the application of knowledge. The similarity between the movements in VR and real life promotes better recall.	There is a possibility that risks may not be taken as seriously in VR training scenarios, and trainers may have difficulty learning how to use the system in the classroom.
Acceptance	The majority of participants (over 70%) were satisfied with the VR training, over 85% found it fun, and all but one said they could imagine having similar training in the future. High presence, quality, and low cybersickness indicate high acceptance [11].	It may be challenging to find motivated trainers and directors at vocational schools who are willing to implement VR training and potentially participate as experts in the development process.
Motivation to Use	VR training is enjoyable, novel, and practical, requiring only HMDs and scenarios. There is a low fear of making mistakes, and a safe space is provided for practice.	Implementing VR training requires extra organizational effort for vocational schools and trainers, along with additional costs for equipment and scenario development and maintenance. Haptic feedback precision may be insufficient for some tasks, and high realism and detailed visual cues are necessary.

(2) An effective training scenario should incorporate multiple levels of difficulty to offer an optimal learning experience that caters to all users' motivation and skill levels. Striking a balance between challenges and attainability is vital. To enhance realism and the ability to learn from errors, the scenario should incorporate a direct feedback mechanism.
(3) Employing cutting-edge technology is pivotal for the training system's success, as it contributes to an immersive user experience and a strong sense of presence. Realism and detailed visual cues play a crucial role in engaging learners effectively.
(4) Single-user VR training holds particular promise for developing procedural skills, especially in the context of safety-critical procedures. Complex scenarios that require the integration of diverse knowledge and its practical application are exceptionally well-suited for leveraging VR technology's advantages. Active interaction with the virtual environment fosters effective learning.
(5) During the initial stages of VR training, supervision by a trainer is highly recommended to offer guidance and assistance. Starting with an introduction to the technology and setting clear training goals is essential. Throughout the training, users should have access to help when facing challenges and receive comprehensive feedback upon completion. While trainers can provide supervision, the VR environment can also facilitate group exercises for shared learning experiences. Advanced users can benefit from more independent and frequent practice.
(6) To mitigate potential challenges during initial VR training experiences, users should have the opportunity to familiarize themselves with the virtual environment beforehand. This proactive approach can help prevent issues like cybersickness and reduce stress and frustration levels.
(7) Prior to integrating VR training into educational curricula, it's essential to establish a comprehensive guide encompassing the use of technology, including both hardware and software. Utilizing video tutorials can be a time-efficient approach, saving trainers from repeatedly explaining scenarios.
(8) Clearly defining the responsibilities related to the maintenance of VR equipment is crucial to prevent technical complications and ensure a seamless training experience.
(9) Successful integration of VR training requires a dedicated place within the curriculum. While it should not entirely replace existing practical exercises, the specific mode of integration should be left to the discretion of trainers and vocational schools to align with their unique contexts.

(10) To ensure the efficiency and effectiveness of training, trainers themselves should possess expert proficiency in using VR technology. They should be capable of offering assistance when needed. The choice between training domain-knowledgeable trainers or engaging external experts depends on the nature of the training, its contextual factors, and the educational institution's decision-making process.

Limitations. This study exclusively examines the immediate outcomes resulting from the utilization of single-user VR training prototypes, precluding any inferences regarding the lasting impact of similar single-user VR training solutions. Consequently, further research is imperative to explore the effects over an extended timeframe. The investigation was conducted within the specific context of vocational education, implying that the findings might not be generalizable to other educational frameworks. Instances of participants disregarding instructions to employ their assigned IDs when initiating the scenarios led to complications in HMD calibration and rendered scenario logging data unsuitable for study purposes. Additionally, compliance with COVID-19 regulations mandating the use of FFP2 masks may have influenced the comfort of the VR training system and contributed to issues with fogged glasses.

5 CONCLUSION AND FUTURE WORK

Our research delved into the advantages and impediments associated with the utilization of VR for single-user training in the context of professional education. The investigation encompassed the assessment of three distinct training scenarios involving apprentices and nurses. Employing a combination of workshops, interviews, and observations, the study sought to evaluate the efficacy of VR-based training. The findings unveiled that VR training affords learners the capacity to engage at their own pace and with repetition, thereby fostering increased self-assurance and diminished stress. Nevertheless, individual disparities and cybersickness emerged as potential challenges, which can be mitigated through robust tutorials and requisite support. The study further unveiled that VR training holds the potential to enhance concentration and proficiency in complex scenarios; however, the incorporation of error feedback is vital to sustain the seriousness of learners' engagement. Furthermore, the study revealed that embedding VR training within educational frameworks demands organizational commitment and additional expenditure. Nevertheless, the research highlighted an elevated degree of acceptance among users, accompanied by constructive feedback, indicating the promising prospects of VR training in the realm of professional education. Adopting a user-centric approach during the development and testing of VR training scenarios emerged as a pivotal consideration to cater to diverse user cohorts. Furthermore, trainers must possess a comprehensive understanding of the technology to offer proficient guidance and assistance during training sessions. The insights and recommendations arising from this study are poised to benefit organizations contemplating the integration of VR training into their educational paradigms.

Further research is warranted to explore its potential in other spheres, expanding beyond professional education. A longitudinal exploration of VR training's lasting effectiveness, encompassing changes in learning outcomes and knowledge retention across varying skill levels, is pivotal. The evolution of VR solutions could encompass collaborative and gamification approaches, alongside the integration of AI-based mechanisms for tailoring experiences to users' proficiency levels. Enhanced haptic feedback and novel interaction methods, such as sensor gloves, hold the promise of augmenting the effectiveness of VR training interventions. Also, a detailed evaluation of the proposed guidelines could be conducted in the future.

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