Received 16 January 2024
Revised 15 March 2024
22 April 2024
Accepted 23 April 2024

Gamified immersive safety training in virtual reality: a mixed methods approach

Amir Haj-Bolouri and Jesse Katende
Department of Informatics, University West, Trollhättan, Sweden, and
Matti Rossi
Department of Information Systems, Aalto University, Helsinki, Finland

Abstract

Purpose – The reemergence of immersive virtual technology (IVR) provides both opportunities and challenges for workplace learning (WPL). The purpose of this study is to explore and develop knowledge about how gamification influences the WPL experience by addressing two research questions: *RQ1*. What characterizes a gamified immersive safety training experience with IVR technology? and *RQ2*. How does gamified immersive safety training with IVR technology impact the WPL experience?

Design/methodology/approach – The study adopted a mixed methods approach by combining a systematic literature review with a case study on an empirical project about immersive fire safety training for train operators that are used at the Swedish train operating company SJ. The case study included data from semistructured interviews, Web survey and observation studies. The data was analyzed in two stages combining inductive and deductive data analysis for identifying themes and categories.

Findings – The findings of the study are twofold: (1) themes that conceptualize the gamified immersive safety training experience based on outputs from both the literature review and the first round of data analysis; and (2) a framework with three overarching categories that are mapped with the identified themes, and which were deduced throughout the second round of data analysis.

Originality/value – The originality of the findings stresses the implications of how a body of knowledge that synthesizes gamification concepts with immersive safety training, can inform the design of WPL experiences that are facilitated with IVR technology. As such, the implications of the findings are targeted toward both the advancement of the IVR discourse in the WPL field, but also toward practical considerations for design of immersive learning experiences that enrich WPL practices and culture.

Keywords Gamification, Workplace learning, Safety training, Immersive virtual reality, Mixed methods

Paper type Research paper

1. Introduction

The idea of producing knowledge that is integrated with work activities has occupied scholars within the domain of workplace learning (WPL) for nearly two decades (Malloch *et al.*, 2010)

The authors would like to thank SJ for providing this study access to their training program accompanied with generous set of empirical data.

Journal of Workplace Learning
Vol. 36 No. 7, 2024
pp. 516-538
Emerald Publishing Limited
1366-5626
DOI 10.1108/JWL-01-2024-0008

and a large body of research on WPL has been produced over time by a variety of scholars to nuance the rich integration between work and learning (e.g. Billett, 2004; Bontemps-Hommen *et al.*, 2020; Lemmetty and Collin, 2020). Such research is rooted in social learning theories, which treat learning as a situated and socio-cultural phenomenon (Lave and Wenger, 1991), typically facilitated through participation, engagement, and innovative technology (Billett, 2004; Vaughan, 2008). One reemerging class of innovative technology that is particularly promising for facilitating engaging and motivating learning activities, is immersive virtual reality (IVR) technology.

IVR technology refers to simulated and interactive experiences that imitate the real world, using specialized software and hardware (Cavusoglu *et al.*, 2019). IVR's popularity has been increasing only recently due to the availability of affordable and powerful consumer-grade IVR head-mounted displays (HMDs) (McGill *et al.*, 2016). The HMDs offer an immersive VR experience that sets current IVR technology apart from traditional VR (e.g. desktop VR) due to high-quality image rendering, photorealism, multimodal features for interaction and feedback and various peripherals that allow embodied movement and an increased sense of presence in the virtual environment (Dincelli and Yayla, 2022). IVR research is primarily published in specialized journals, such as healthcare (e.g. Howard, 2017), retail (e.g. Magrath and McCormick, 2013), tourism (e.g. Yung and Khoo-Lattimore, 2019), human–computer interaction (e.g. Vinnikov *et al.*, 2017) and education and training (e.g. Jensen and Konradsen, 2018).

Research on the implications of IVR technology for WPL is emerging, yet scarce. The studies have mostly focused on narrow research areas of WPL and seldom in relation to IVR technology (e.g. Bauerle *et al.*, 2016), and virtual teams (e.g. Arnison and Miller, 2002). More importantly, there is a need for a comprehensive work on the current state of IVR technology that identifies opportunities and challenges from a WPL perspective. In this research paper, we address this gap and provide findings that advance the discourse on IVR technology and WPL through a mixed methods research approach on gamified immersive safety training with IVR.

By using a mixed methods approach, we synthesized findings on IVR technology and gamification in the context of safety training (Radhakrishnan *et al.*, 2021). With "gamification" and "gamified", we simply mean training procedures that incorporate game elements as a strategy for enhancing the training experience and the trainees' extrinsic/intrinsic motivation for learning (Haj-Bolouri *et al.*, 2023a, 2023b). Gamification has in recent years gained momentum in the IVR literature (Sirvermez and Baltaci, 2023), whether it is directed to discussing the possibility of a gamified metaverse (e.g. Tayal *et al.*, 2022) or in IVR and education (e.g. Pinto *et al.*, 2021). Yet, the prevalent mentioned research on gamification for immersive safety training and WPL is scarce. Hence, in light of the outlined background, this research paper asks the following research questions:

RQ1. What characterizes a gamified immersive safety training experience with IVR technology?

RQ2. How does gamified immersive safety training with IVR technology impact the workplace learning experience?

While a systematic literature review helped us to generate a comprehensive view that relates to our research questions, we supplemented the review by conducting a case study of an ongoing empirical project about immersive fire safety training. The case study involved evaluation of immersive fire safety training together with Sweden's largest train operating company, SJ. Observations and interviews were conducted during two different periods of time, which helped us to transform the findings from our literature review with empirical

material into seven themes for gamified immersive safety training with IVR, which we then deduced into three overarching categories of WPL experiences.

Our findings revealed that despite the early stage of understanding the implications of gamification for IVR safety training, a WPL perspective about the challenges and opportunities of IVR technology is not solely about technology, but also about unraveling the power of IVR technology for simulating real-world scenarios that provide meaningful and motivating training experiences for end-users' practices. We conclude our paper with a discussion about their implications for WPL, together with a discussion about the themes' implications for the design of gamified workplace safety training with IVR. Finally, we outline potential research directions for the WPL field.

2. Related research

This section outlines related research that is relevant for this study with respect to safety training as an instance of WPL, together with related research on immersive safety training and gamification.

2.1 Safety training as an instance of workplace learning

In this paper, we address safety training as an instance of WPL. This is mainly because of (1) the learning outcomes' relevancy for organizations' knowledge development and (2) practitioners' lifelong learning. We rely on the nature of training exercises that are designed and conducted to enhance employees' safety awareness and procedural skills (Lefor *et al.*, 2020). Examples of such settings include emergency preparation (e.g. Zhu *et al.*, 2020), fire prevention (e.g. Fromm *et al.*, 2021), first aid (e.g. Chryssolouris *et al.*, 2008) and preparation for workplace accidents (e.g. Kim and Leem, 2020).

Through hands-on training procedures, training participants are exposed to potential risks that are situated within their daily workplace activities (Conges *et al.*, 2020). However, safety training exercises that are conducted in a physical space can also require expensive, fragile or rare equipment, which can be difficult to secure for training use (Zhang *et al.*, 2019). One domain of practice that is affected by such issues is that of safety training, where operators can use IVR technology to become prepared with new skills in a safe way (Morélot *et al.*, 2021).

2.2 Research on immersive safety training and gamification

Immersive safety training includes safety training exercises and procedures that are done with IVR technology. The "immersive experience" in IVR is characterized by *immersion, presence* and *embodiment* (Mütterlein, 2018); through immersion, IVR users become absorbed into the virtual environments as embodied avatars, which in turn, increases their sense of presence as "being-there" in the virtual reality (Haj-Bolouri *et al.*, 2023a, 2023b). IVR technology is practical, low risk/cost, and the safety and efficiency of end-user devices provides a detailed experience (e.g. HTC Vive Pro, Meta Quest 3, Varjo, Valve Index VR) (Makransky *et al.*, 2019). Current research on immersive safety training (e.g. Haj-Bolouri *et al.*, 2023a, 2023b; Ravichandran and Mahapatra, 2023) reports how IVR technology can pedagogically benefit trainees' motivation for training. This allows trainees to explore the training setting, and experiment under secured circumstances (Dhalmahapatra *et al.*, 2022).

One central theme in recent research on immersive safety training is gamification (Miguel-Alonso *et al.*, 2023). Gamification is "[[. . .]] the application of lessons from the gaming domain in order to change stakeholder behaviors and outcomes in non-gaming situations" (Liu *et al.*, 2017). The centrality of incorporating game elements to elevate a

training experience is a common theme that depicts gamification as a viable strategy for increasing trainees' motivation (Crossler *et al.*, 2013, p. 3):

> The common theme that emerges from the various definitions over the past decade are gamified systems must have a specific user engagement and instrumental goals, and the way to achieve these is by the selection of game design elements.

Another feature of gamification of training experiences is that a game-like user experience activates the end-users' individual motives and make the training experience meaningful for them (Bui *et al.*, 2015; Huotari and Hamari, 2017). However, Bui *et al.* (2015) seminal review of gamification disclosed that most gamification studies do not explain the relation between game elements and pedagogical design features for facilitating meaningful training experiences. Only a few seminal sources exist that provide practical guidance on how to gamify immersive training experiences (e.g. Bucchiarone, 2022; Ulmer *et al.*, 2022). The general research trend on gamification and immersive safety training calls thus for further systematic inquiry in how gamified immersive safety training enhances the WPL experience of trainees.

3. Methodology: mixed methods approach

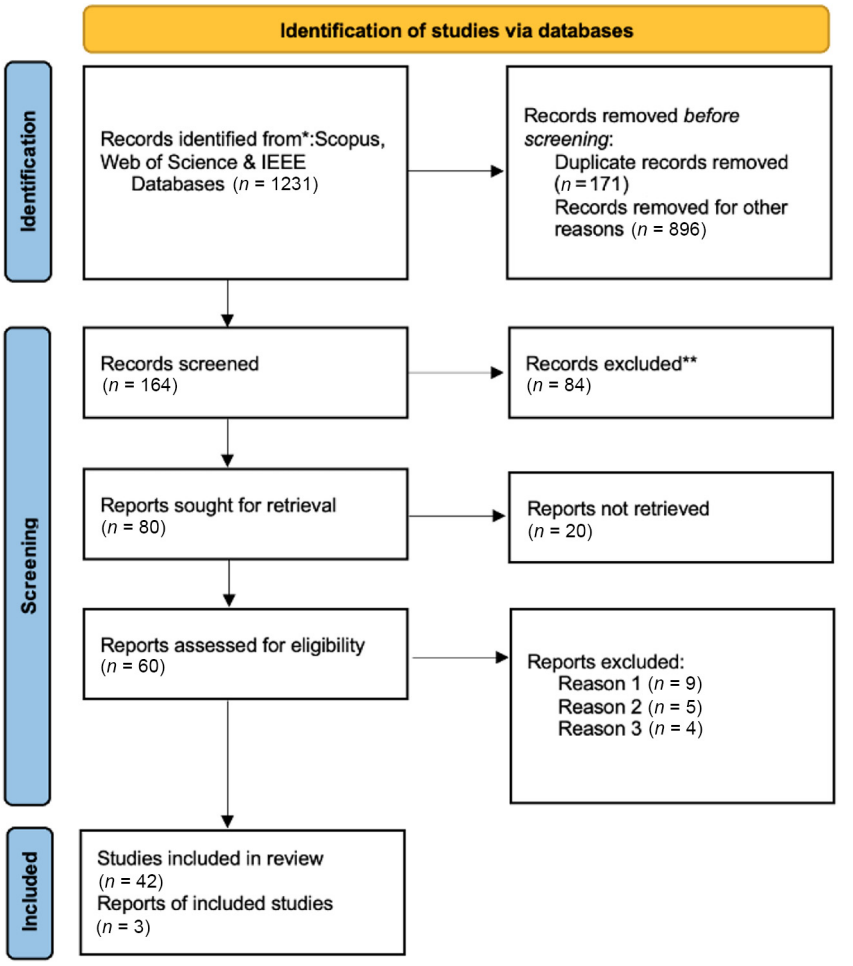
By using a mixed methods approach (Venkatesh *et al.*, 2013), we used a systematic literature review to establish a state-of-art synthesis on research that emphasizes gamification and immersive safety training, which in turn, served to examine the practical influence of IVR technology for gamified immersive safety training and its outcome using rich data from a case study on immersive fire safety training. In the following sub-section, we outline how we used each component of our mixed methods research approach.

3.1 The systematic literature review

The systematic literature review approach was used following a variant of the PRISMA method inspired by Caligiuri and Thomas (2013) shown in Figure 1. The first stage of our literature review emphasized the identification of literature on WPL, gamification and immersive safety training with IVR. We used search terms that have been frequently used by previous review studies that emphasize our topic (Wang *et al.*, 2018; Xie *et al.*, 2021) such as: "virtual reality", "immersive virtual reality", "immersive virtual environment", "gamification" and "immersive safety training".

Consequently, our inclusion criteria focused literature that is mainly situated within industrial settings because it is aligned with this study's empirical setting. For this purpose, we included the term "industry" in conjunction with logical operators such as "AND" and "OR" (e.g. "gamified" AND "industry" AND "immersive safety training". Moreover, the search terms were applied to Web of Science, IEEE, Scopus and Google Scholar as our databases, which resulted into an initial corpus of 1231 manuscripts, ranging from 2013 to 2023. Finally, the inclusion criteria focused on manuscripts from conference proceedings and peer-reviewed journals, as shown in Figure 1.

We then filtered the initial corpus of 1231 manuscripts by operationalizing exclusion criterion inspired by Caligiuri and Thomas' (2013) use of the PRISMA approach: (1) exclude manuscripts that are not at least four pages long and exclude duplicates; (2) exclude manuscripts with abstracts that do not align with the research topic and/or are considered to be incomplete/gray papers; and (3) exclude papers on WPL that are not focusing the industrial setting or high-risk environments for gamified immersive safety training. Same exclusion criterion was then used to condense the corpus of literature to 60 manuscripts assessed for eligibility, which then resulted into a final corpus of $42 + 3$.



Source: Adapted from Caligiuri and Thomas, 2013

Figure 1.
Overview of systematic literature review process

3.2 The case study: immersive fire safety training for train operators

This study supplements the systematic literature review approach with a case study approach because case studies are particularly effective for exploratory research that generates novel insights about innovative technologies and their implications for a research area (Yin, 1994). Case studies do also allow to investigate research objectives and questions that explicate findings from research projects that have adopted a particular methodology or approach (Klein and Myers, 1999).

3.2.1 Empirical setting. The empirical setting of the case is rooted in an ongoing project on immersive fire safety training. The case takes place at Sweden's largest train operating company, known as SJ, and enables train operators use IVR technology to facilitate immersive fire safety training. The case was initiated in 2020 and is still ongoing. The case initially used the HTC Vive Pro Headset together with a fire extinguisher that was

integrated with the immersive fire safety training environment, which is the equipment that constituted this study's IVR technology. Figure 2 shows the equipment.

The IVR technology mediates a fully immersive training experience where the users must use the extinguisher nozzle to aim and press the extinguisher handle to extinguish fire in the IVR space. Consequently, the training environment was designed so that it represented a train setting and the IVR application also consists of performance analytics (e.g. how much the fire spread). The specific purpose of exercising fire safety training with IVR, rather than only doing it through traditional methods in a physical environment, is to provide train operators an immersive space where they can, under safe circumstances, develop procedural skills that prepare them for fire safety situations onboard trains. This, in turn, will help train operators to increase their safety awareness which the IVR technology helps the participants with through a distinct kind of training procedure.

3.2.2 Training procedure and participants. The immersive fire safety training procedure that SJ used was designed according to the following steps:

- A participant is equipped with the IVR equipment shown in Figure 1 (e.g. HMD, hand control and fire extinguisher)
- An instructor from SJ goes through the training episode and objectives verbally.
- The participant gets "teleported" to the IVR training space.
- The participant undertakes a trial-and-error process exploring the training environment, familiarizing himself/herself with the setting, to embody the training scenario.
- After the performance, data is saved in the application and the participant has a reflective dialogue together with the instructor.

The participants were 10 train operators (adults) at SJ aged between 28 and 50+ years old. Participants were selected based on their inclusion in SJ's fire safety training program and a list of information about the participants is depicted in Table 1.

3.2.3 Data processing and analysis. Table 2 depicts an overview of the research design with respect to the undertaken methods for data collection and analysis in the case study.

As depicted in Table 2, this study used three distinct methods for collection of primary data, including 10 semistructured interviews with train operators at SJ, a Web survey that

Source: Authors' Own Work

Figure 2.
IVR equipment for immersive fire safety training

Participants	Gender	Role	Fire safety training experience	Immersive fire safety training experience in VR
P1	M	Train conductor	Yes	No
P2	M	Train conductor	Yes	No
P3	M	Train driver	Yes	No
P4	F	Train driver	No	No
P5	F	Train conductor	No	No
P6	F	Train conductor	Yes	No
P7	M	Manager	Yes	No
P8	M	Train driver	No	No
P9	M	Instructor	Yes	Yes
P10	F	Instructor	Yes	Yes

Table 1. Information about the participants

Source: Authors' own work

Semistructured interviews	Web survey	Observations	Data analysis
- 10 Interviews - Period: 2021–2022 - 4 Train conductors - 3 Train drivers - 1 Managers - 2 Instructors	- 1 Web survey - Period: 2022 - 12 questions - 361/368 respondents	- Immersive safety training sessions - Period: 2021–2022 - 2 Observations - 10 + 10 participants	- Memos - Open coding - Axial coding - Categorization - Thematization

Table 2. Data collection and data analysis methods

Source: Authors' own work

was provided to 361/368 train operators working in different cities of Sweden, and observations of two immersive fire safety training sessions. We used the different methods to evaluate and understand the impact of the immersive fire safety training sessions for the employees' WPL experience, and what opportunities and challenges they experienced throughout the training sessions. Moreover, the methods supplemented each other for the purpose of evaluation.

For instance, the semistructured interviews helped the case to grasp an in-depth insight into the individual participants' first-hand immersive experience and learning outcomes. Here, the case followed an interview protocol, together with the formulation of questions, following Seidman's (1991) three-stage process where questions about the participants' immersive experiences, their perceived opportunities, limitations, and future directions of reinforcing the gamified elements of their training, were asked. Each interview lasted between 45 and 60 min. The Web survey, on the other hand, gave the case a broader overview about a larger population of employees and their overall experience of SJ's educational platform, which focused fire safety training through classroom teachings, e-learning, simulation, 360-degree training for developing spatial awareness and skills, teams meeting, practical/physical fire safety training and immersive fire safety training. The survey was structured with 12 questions, where 7 of them were with multiple choice and five were open-ended. Moreover, we conducted observations of two immersive fire safety training sessions, which gave "insights about the specific procedures and steps of the immersive fire safety training sessions".

Finally, the gathered data from the case study was analyzed by following a pragmatic mixed methods analysis approach that toggles back and forth between deduction and induction (Venkatesh *et al.*, 2013). More specifically, our analytical procedure encompassed two main stages. In the first stage, our primary focus was to explore thematic patterns and relationships between our interview and survey material. This stage began inductively, categorizing statements through open coding, analytical memos, followed by inductive coding to spotlight emergent insights that were then used to identify themes related to our first research question. An excerpt example from this stage of analysis is depicted in Table 3.

Following the first data analysis stage, our findings surprisingly indicated that gamified immersive safety training provides opportunities for WPL with IVR, which moves beyond safety training alone. This finding was unexpected, given the prevalent assumption from our literature review that safety training pertains to a specific kind of learning experience. Hence, in the second stage of our analytical procedure, we revisited the open codes and concurrently deduced the themes into three overarching categories of WPL experiences that relate to our second research question. Here, we specifically focused on extracting experiential factors from gamified immersive safety training, which might expand opportunities for WPL with IVR technology beyond an industrial setting of safety training. More precisely, we investigated generic experiences of WPL with IVR that could benefit and inform future IVR research in the field of WPL.

4. Findings: themes for gamified immersive safety training

In this section, we present the findings from our mixed methods approach. The findings are presented as seven themes for gamified immersive safety training and they were identified across seven main industrial settings of safety training: manufacturing industry, construction sector, high-risk environments, military, health and safety domain, roofing and steel industries. Additionally, we incorporated literature from education, where IVR technology has been well-studied, and where gamification concepts have been used to elevate the learning experience (e.g. Vahdatikhaki *et al.*, 2023). A full list of the final corpus of reviewed papers are available in supplimentry material and a synthesized review matrix, which maps central elements from our review (e.g. IVR technology such as hardware, software and type of safety training) with the final corpus of reviewed manuscripts, is available in supplimentry material.

The seven identified themes that emerged from the analysis of the data are presented below with two or three representative data extracts to enrich comprehension. Additional extracts are presented whenever a notable aspect of the theme is described, and acronyms are used to address the respondents in two ways: "P" and an annotating number (e.g. P1) refer to an interview participant, whereas "SR" and annotating number (e.g. SR1) refers to a survey respondent. An overview of the themes, as being the findings/results of this paper, is depicted in Table 4.

4.1 Theme 1: trigger a motivating interest

Throughout our interviews and literature review, it became clearly apparent triggering a motivating interest among users of immersive safety training with IVR, was a recurring theme. For instance, interviewees mentioned terms such as "triggering", "encouraging", "motivating" or even "seducing" when asked what increases their interest for doing safety training with IVR:

Transcripts (excerpts)	Analytical memos	Emerging insights
I was first sceptic to using virtual reality for fire safety training, but I changed my mind completely because it is a perfectly fine supplement to real fire safety training and it is entertaining like a game. However, there are still elements of real fire safety training that was omitted, like the smell of smoke and fire. (Train conductor 1)	- Initial skepticism and change in perception of the meaningfulness of IVR technology for fire safety training - IVR as a supplement for traditional training	Elements of realism in IVR are not complete, but the immersive experience is still motivating and complementary to traditional training

Source: Authors' own work

Table 3.
Examples of an excerpt from first stage of data analysis

Theme	Description
Theme 1. Trigger motivating interest	Emphasizes that a gamified immersive safety training environment triggers motivating interests among participants by providing gamified features that engage the user through journeys, and performance goals that are measurable through scores and rewards
Theme 2. Mediate a safe space	Emphasizes that a gamified immersive safety training environment provides a safe space for training that reduces risks for physical injury, damage and thus increases the well-being of the participants during the training process in a motivating and fun way through gamified scenarios
Theme 3. Emulate safety awareness	Emphasizes that a gamified immersive safety training environment emulates an increased form of safety awareness by combining realistic risk perception elements with game elements (e.g. health bar, danger indicators) to visualizing contrasts between "being safe" and "being unsafe"
Theme 4. Clarify training goals	Emphasizes that a gamified immersive safety training environment mediates a clarification of training goals by contextualizing them into a quest with various levels of difficulty and advancement, which the user can reflect upon before and after their performance
Theme 5. Elicit curiosity and uncertainty	Emphasizes that a gamified immersive safety training environment incorporates game elements such as moods and atmosphere that immerses the user into a first-hand experienced situation that elicits both curiosity and uncertainty for how to act, react and learning by doing
Theme 6. Highlight progress and evaluation	Emphasizes that a gamified immersive safety training environment has the multimodal ability to enrich users' awareness around their learning progress through scoreboards and evaluation measures that correlate with learning objectives and parameters (e.g. time-length and level)
Theme 7. Connect to the workplace	Emphasizes that a gamified immersive safety training environment can model the workplace environment with authentic workplace elements (e.g. surrounding, office spaces and trains) to create a sense of familiarity and spatial awareness among users

Source: Authors' own work

Table 4.
Overview of themes

> It felt like a game but still encouraging to learn the training objectives! The feeling was very different though because I did not have to move much but just use the fire extinguisher (P1).

Studies from our review (e.g. Staneva *et al.*, 2023) indicate that the triggering of a motivating interest will cause users to become "attracted" or even "addicted" to the gamified aspect of the immersive safety training experience, a feeling which was reflected by one of the interviewees as following:

> I can see why people become addicted to games in VR because it is attractive and fun, yet meaningful when it is useful with a purpose you know (P2).

One of the studies (Jacobsen *et al.*, 2022) also pointed out that this may boost the training with a feeling of elevation and more energy, whereas another study pointed out that triggering a motivating interest can also be considered a way of inducing "activation", which was also observed by the interviewees:

> You definitely feel the difference in virtual reality because you become so focused and active while doing the training exercises [. . .] it was fun (P4).

4.2 Theme 2: mediate a safe space

A central aspect of gamified immersive safety training that manuscripts from our literature review revealed is the experience of being in a safe space. Data from our Web survey and interviews also reinforce the importance of a safe space. For instance, manuscripts (e.g. Seo *et al.*, 2021) mentioned terms such as "sense of safety" and "feeling safe", whereas interviewees and survey respondents mentioned "a safe space" and "safe spaces" when asked what they felt when doing immersive fire safety training:

> It was safe to know that I can do plenty of mistakes without getting hurt in this safe space (P3).

One study (Haj-Bolouri *et al.*, 2023a, 2023b) has highlighted the importance of providing a safe space for increased experimental learning while doing safety training with IVR. One of the interviewees confirmed the correlation whereas two survey respondents focused on the feeling of safety:

> I could experiment and explore the train without getting burned or completely soaked by the smoke. I guess that's good but at the same time not always realistic [. . .] more like a game it felt because I could just start over again without losing my real life (P5).

> I felt safe and secure. Not sure if that is always good because in real life, I would feel stressed (SR1).

> It is good that we can do this kind of training and feel safe about it in VR (SR2).

4.3 Theme 3: emulate safety awareness

A central aspect that builds upon the previous theme of safe spaces, is that of emulating safety awareness in the gamified immersive safety training experience. Studies from our review revealed that the gamified environment enables the users to "feel in control" and use that "freedom" (Gauthier *et al.*, 2022) to develop safety awareness systematically by doing things they are otherwise not "allowed" to do to become aware of the cause-and-effects of a safety situation. One of the instructors from the training sessions commented on this aspect as follows:

> What we want is to give the employees a chance to be playful and do the things they usually don't during fire safety training, so it gives them an increased awareness of their surroundings and objectives without forcing it upon them in a stressful way (P9).

However, some of the manuscripts (e.g. Hoang *et al.*, 2021) from our literature review pointed out that the power of having increased freedom in a gamified setting, is just something experienced by IVR users, but that in reality, users could be controlled by the gamified setting, which also is the negative side of gamification that should be avoided during immersive safety training. The instructor did also touch upon this potentially negative aspect by saying that:

> Sometimes VR gives our employees the impression that they're having an increased awareness, but the technology seems to make them feel so by controlling them to do certain things. And that's the downside of this game-like experience I think that we must avoid in reality (P6).

4.4 Theme 4: clarify training goals

Another aspect of a gamified immersive safety training setting identified by our literature review is having a clear training goal. Manuscripts from our review stress that setting clear goals gives users a feeling of "being guided" or being on a "quest" (Peretti *et al.*, 2021), the latter being a typical gamification concept. One of the interviewees stated that goals were motivating in two ways:

> I felt motivated with clear goals due to the fear of losing and through the happiness I felt when I achieved it (P6).

With "losing", the respondent was pointing toward "winning" and "losing" as if the training experience was a game. The respondent further elaborated on this aspect as follows:

> I mean it is like the motivation to achieve a goal, or like winning in a game, whereas losing the game means failing the exercise. But in the end, it is like a game, I can retry and once I achieve the goal it results in some sort of happiness (P6).

Moreover, one of the instructors from the immersive fire safety training session nuanced the importance of providing clear training goals by saying:

> When the training participants say that they have had positive training experiences, I think that they feel so because they have had a kind of goal or a kind of a clear calling that they need to achieve with the VR training (P9).

4.5 Theme 5: elicit curiosity and uncertainty

Several manuscripts from our literature review (e.g. Haj-Bolouri *et al.*, 2023a, 2023b) indicated that the uncertainty of a gamified immersive safety training setting, and curiosity about the situation are two significant aspects in gamification. The studies emphasized that when IVR users are faced with the "uncertainty" or "mystery" of the gamified setting, they also become curious for their "thrill of the unknown". Similarly, one of the instructors from the immersive fire safety training sessions indicated that the participants enjoyed:

> The discovering of the unknown [. . .] they like exploring new things without getting injured or facing real consequences of their actions (P10).

Another aspect that of gamification that may increase uncertainty during training is, according to one of the interviewees, the "risk of losing" certain achieved rewards.

Correspondingly, two studies from our literature review have identified suspense (Luo *et al.*, 2023) and uncertainty as components of gamified experiences. Or as the instructor stated:

> The level of unpredictability when we are dealing with fire is important to capture [. . .] it is quite similar to game and one's own ability to challenge that game, feel the thrill, but still understand that it has real consequences in real life [. . .] we can get both aspects with VR fire safety training it seems (P10).

4.6 Theme 6: highlight progress and evaluation

Another aspect of the gamified immersive safety training experience that was revealed by our literature review is the user's awareness of progress and evaluation of their performance. The users of a gamified IVR setting have "multimodal timely feedback", which serves as an "affirmation" of the users' learning progress (Staneva *et al.*, 2023). An interviewee also said that they will be aware of the things that "need to be improved" and their current status in terms of their "performance" compared to each other. Moreover, respondents from the survey did also emphasized the importance of evaluation as a way to affirm whether or not their training performance is meaningful for real fire safety tasks or not:

> In VR we can get more feedback in different ways than when we can in the classroom reading theory about fire safety. It gives a more immediate affirmation of where I am in my process (SR3).

> I liked the combination of information in VR we got for our performance. Sometimes it became too much because of the variety, but after a couple of times, I can see the value of recording and tracking one's progress over time (SR4).

4.7 Theme 7: connect to the workplace

The final theme focuses on the importance of connecting the gamified immersive safety training experience to the workplace. Our literature review revealed that the "meaningfulness" of the gamified setting or the possibility of connecting to a different "reality" as an immersive feature of gamified IVR, needs to be connected with the "realness" of the workplace in a way that may not occur in traditional, nongamified safety training settings (Yoo *et al.*, 2023).

Interviewees stated that this feeling of "real" happens due to the "engaging" nature and "interactivity" of the gamified immersive setting in IVR. One of the interviewees highlighted the feeling of an "authentic engagement" and "genuine quality interaction" of the gamified immersive fire safety training experience, by saying that:

> The VR training is simply a way to connect with our workplace tasks on a train but without becoming too bored through mere theory about fire training (P8).

Interviewees also said that they may not feel isolated in the gamified IVR setting and that they can "relate" to the immersive safety training experience as "real workplace scenarios" due to the "scaffolding" created in the gamified setting:

> There is a sense of meaningfulness or a sense of being presented with a training procedure that actually matters and is not only entertaining and fun [. . .] that is why as an instructor think that the connection with you as the user, your job and workplace, is extremely important so that the training becomes meaningful for the employee (P10).

Excitement and feeling of exploring fire safety situations in a safe IVR space need thus not only to be fun and ensure excitement, as a gamified IVR experience typically does

(Al-Adawi and Luimula, 2019) but also be meaningful through a connection with the reality of employees' workplace settings.

5. Discussion: overarching categories

While the preceding seven themes allowed us to answer the first research question, namely, *RQ1*. The themes can be further mapped into three overarching categories using a deductive approach. The purpose is to map the gamified immersive safety training experience to a higher-level thematic structure for better conceptual clarity and practical utilization. This allows us to address the second research question of this study, namely, *RQ2*. Doing so, we can discuss the implications of IVR technology for WPL from a broader perspective. Therefore, we mapped the identified themes into three overarching categories that, together, we propose as a framework for gamified immersive safety training experience. Table 5 depicts the framework.

The *first overarching category*, "Pull and Push Experience", deduces themes one and five and comprises aspects of the gamified experience that alters users' behavior in a predictable way without forbidding any options or significantly changing their training objectives and incentives. The factors of this category were derived from both qualities of the themes but also mapped with findings from our literature review. For instance, as mentioned in the related research section of this paper, gamification is the use of game design elements or affordances for creating gamified experiences (Huotari and Hamari, 2017). Taking into the context of WPL, gamification should thus create a pull and push experience for users to enhance the WPL process by triggering a motivating curiosity (both intrinsic and extrinsic) as well as eliciting curiosity and uncertainty. This might generate opportunities for companies to for instance organize their WPL strategies and training methods in accordance with the affordances of IVR technology for safety training or plan for how to overcome challenges with bridging theory about safety training, which typically becomes tedious (as pointed out by one of the participants of this study), with motivating exercises that feel realistic and meaningful for the user's workplace identity.

The *second overarching category*, "Flow Experience", deduces themes one, three and four into a flow experience, which was originally developed by Csikszentmihalyi (2014) as feeling a sense of exhilaration or a deep sense of enjoyment that can be into four conditions of flow:

(1) clear goals;
(2) immediate feedback;
(3) skill-challenge match; and
(4) the possibility of control (Csikszentmihalyi, 2014; Hamari and Koivisto, 2014).

The flow experience, we claim, occurs in a safe space that is free from the fear of failure, as expected in the possibility of control (Seo *et al.*, 2021). Here, our findings showed that gamified elements such as challenges/quests, and storytelling, might not only help organizations overcome typical downsides of traditional safety training that puts the individual's well-being at risk (Ulmer *et al.*, 2022), but also enable them to reinforce an increased sense of meaningful safety awareness that coincides with clear training goals. Consequently, our analysis discovered that challenges might emerge from the case-to-case basis of a gamified immersive safety training experience and deal with the particular design of a safe space because safe spaces and their features (e.g. triggers and safety indicators) are peculiar for the sensibility of users' prior experiences in relation to expected goals of learning (Haj-Bolouri *et al.*, 2023a, 2023b).

Table 5.
A framework for gamified immersive safety training experience: Overarching categories and themes

Overarching category	Theme	Empirical example (representative extract)	Mapping to Literature
Pull and push experience	1. Trigger motivating interest	*It felt like a game but still encouraging to learn the training objectives! The feeling was very different though because I did not have to move much but just use the fire extinguisher*. (P1)	Creating arousal (Hoang *et al.*, 2021) Inducing 'activation' (Jacobsen *et al.*, 2022)
	5. Elicit curiosity and uncertainty	*The discovering of the unknown [. . .] they like exploring new things without getting injured or facing real consequences of their actions.* (P10)	Suspense (Luo *et al.*, 2023) Uncertainty (Ramstorfer *et al.*, 2022)
Flow experience	2. Mediate a safe space	*It was safe to know that I can do plenty of mistakes without getting hurt in this safe space.* (P3)	Sense of safety (Seo *et al.*, 2021) Feeling safe (Haj-Bolouri et al.2023a, 2023b)
	3. Emulate safety awareness	*What we want is to give the employees a chance to be playful and do the things they usually don't during fire safety training, so it gives them an increased awareness of their surroundings and objectives without forcing it upon them in a stressful way.* (P9)	Feel in control (Chen *et al.*, 2021) Freedom (Gauthier *et al.*, 2022)
	4. Clarify training goals	*I felt motivated with clear goals due to the fear of losing and through the happiness I felt when I achieved it.* (P6)	Goal as an essential aspect (Roofigari-Esfahan *et al.*, 2022)
Integrating experience	6. Highlight progress and evaluation	*I mean it is like the motivation to achieve a goal, or like winning in a game, whereas losing the game means failing the exercise. But in the end, it is like a game, I can retry and once I achieve the goal it results in some sort of happiness.* (P6)	Multimodal timely feedback (Staneva *et al.*, 2023) Affirmation (Mas *et al.*, 2018)
	7. Connect to the workplace	*The VR training is simply a way to connect with our workplace tasks on a train but without becoming too bored through mere theory about fire training.* (P8)	Connecting to the learning at the workplace is seen as an essential aspect of simulations and immersive safety training (Abbas *et al.*, 2023; Babalola *et al.*, 2023)

Source: Authors' own work

The *third overarching category*, "Integrating Experience", deduces themes six and seven into an integrated experience, which emphasizes the importance of integrating work with learning and vice versa by connecting the gamified immersive safety experience with the workplace. Here, we suggest that the WPL experience becomes "integrated" with gamified immersive features when skill development coincides with workplace affordances that engage employees into an expansive learning discourse at work (Billett, 2001; Kerosuo and Engeström, 2003). WPL initiatives can for instance benefit from an incorporation of "virtuality" and by refining the meaning of a real workplace space through spatial expansion (Saker and Frith, 2020), which is an exciting aspect of gaming in alternate reality games (Montola *et al.*, 2009). This can be done without compromising with the realism of training goals and workplace characteristics. Similarly, connection to the reality of the workplace is a noteworthy characteristic of simulations and immersive safety training experiences (Li *et al.*, 2022). Furthermore, organizations might benefit from integrating a multimodal approach to highlighting progress in training by providing both performance measures over time (e.g. through scoreboards in IVR), as well as using a reflective approach to evaluating both individual performance (e.g. from a user's perspective) and/or collective performance together with a tutor (e.g. an instructor such as in the SJ case). A central challenge, however, might be to experiment with finding realistic boundaries for what kind of game elements the training environment needs, and to what extent they must balance fiction with realism for a gamified immersive safety training to become meaningful for WPL.

6. Implications and conclusion

While there are research studies that examine the opportunities and challenges of using IVR technology for safety training (e.g. Haj-Bolouri *et al.*, 2023a, 2023b), and studies that examine the game elements of certain safety training experiences with IVR (e.g. Ulmer *et al.*, 2022), according to our knowledge this is the first study that contributes to WPL by synthesizing collected insights from both literature and practice on the mentioned topics. Our case study supplements the state-of-art knowledge from the literature review and offers the IVR discourse in WPL an overall framework outlining the various categories and themes of gamified immersive safety training experiences. As such, we believe that this study has a number of implications for WPL research.

First, various experiences that provide different opportunities for enhancing WPL with IVR technology, and which are associated with gamification, have been identified and classified into three overarching categories. The categories consist of themes that can for instance inform the design and development of gamified virtual learning environments that are immersive and viable for safety training. For instance, future WPL research might use the categories/themes as theoretical guidelines to test their viability for training in a different context than safety training and evaluate them together with designers that design an immersive learning environment for a gamified version of "workplace participatory practices" (Billett, 2004).

Secondly, the study highlights the importance of focusing on the practical outcome of gamified immersive safety training environments, rather than only stressing the immersive training process with IVR. This is mainly done to generate opportunities for simulating interactive WPL scenarios that enhance employees' procedural and behavioral skills during safety training procedures. For instance, we think that opportunities for illustrating how gamification can extend beyond straightforward use of game elements for nongamified training might be meaningful when used in relation to "pedagogically rich activities" (Billett

et al., 2018) that enhance accessibility, permission and availability of training modules with IVR.

Third, the identified characteristics of a gamified immersive safety training experience are clarified by mapping the characteristics to an established synthesis of concepts, which may encourage future research to extend the meaning or scope of gamification and IVR for WPL. As such, we believe that this study contributes to the theory-building of the gamified immersive safety training experience that emphasizes the opportunities and challenges of using IVR technology for immersive safety training experiences that may prompt future research on the interrelatedness of gamification, IVR and WPL.

Finally, the findings of this study offer practical guidance for assessing WPL that takes support from gamified immersive safety training experiences. The framework with categories and themes can explain how workplaces could provide their employees with progressive challenges or highlight their progress to create an experience of flow. For example, the categories inform the instigation of curiosity (Category 1), or provide rewards for an integrated experience, and how such a WPL experience that integrates the characteristics of gamified immersive safety training, emerges (Category 3). Designers and researchers might also use the findings as directions for using certain gamification concepts and elements to understand the mechanism of gamified immersive experiences of WPL, and design for a pull-and-push experience that triggers increased motivation among participants of training.

However, the study has various limitations as well. One major limitation is that the study only reported one case study in the domain of fire safety training. Another limitation deals with the scope of the literature review, which was narrowed down to studies within industrial settings. Even though the industrial setting is widely acknowledged as one of the most well-reported ones for safety training, it is still possible that other settings of WPL might benefit from a gamified immersive safety training experience. Future studies could explore the context-specific relevance of gamified immersive safety training experiences.

To conclude, the aim of this study was to address the research questions: *RQ1* and *RQ2*. As indicated previously, gamified immersive safety training experiences provide prominent opportunities for different facets of WPL and have the potential to contribute to several different settings, where the industrial one is prevalent, especially in the new era of the metaverse. As eliciting a gamified immersive safety training experience is to the heart of increasing IVR users' motivation for learning, both practical and theoretical insights are valuable for WPL literature that emphasizes IVR research. This study could thus also represent a quintessential step toward conceptualizing and evaluating the meaningfulness of IVR technology and gamification for WPL, enhancing safety training and furthering the WPL research in this domain.

References

Abbas, A., Seo, J., Ahn, S., Luo, Y., Wyllie, M., Lee, G. and Billinghurst, M. (2023), "How immersive virtual reality safety training system features impact learning outcomes: an experimental study of forklift training", *Journal of Management in Engineering*, Vol. 39 No. 1, doi: 10.1061/(ASCE)ME.1943-5479.0001101.

Al-Adawi, M. and Luimula, M. (2019), "Demo paper: Virtual reality in fire safety – electric cabin fire simulation", 2019 10th IEEE International Conference on Cognitive Infocommunications (CogInfoCom), pp. 551-552 doi: 10.1109/CogInfoCom47531.2019.9089938.

Al-Khiami, M.I., Jaeger, M. and Soleimani, S.M. (2023), "A gamified approach to concrete structure's interpretation using virtual reality: a study of performance and simulation

sickness", 2023 IEEE Global Engineering Education Conference (EDUCON), pp. 1-6 doi: 10.1109/EDUCON54358.2023.10125180.

Arnison, L. and Miller, P. (2002), "Virtual teams: a virtue for the conventional team", *Journal of Workplace Learning*, Vol. 14 No. 4, pp. 166-173.

Babalola, A., Manu, P., Cheung, C., Yunusa-Kaltungo, A. and Bartolo, P. (2023), "Applications of immersive technologies for occupational safety and health training and education: a systematic review", *Safety Science*, Vol. 166, p. 106214, doi: 10.1016/j.ssci.2023.106214.

Bao, L., Tran, S., Nguyen, T., Pham, H., Lee, D. and Park, C. (2022), "Cross-platform virtual reality for real-time construction safety training using immersive web and industry foundation classes", *Automation in Construction*, Vol. 143, doi: 10.1016/j.autcon.2022.104565.

Bauerle, T., Brnich, M.J. and Navoyski, J. (2016), "Exploring virtual mental practice in maintenance task training", *Journal of Workplace Learning*, Vol. 28 No. 5, pp. 294-306.

Billett, S. (2001), "Learning through work: workplace affordances and individual engagement", *Journal of Workplace Learning*, Vol. 13 No. 5, pp. 209-214.

Billett, S. (2004), "Workplace participatory practices: conceptualising workplaces as learning environments", *Journal of Workplace Learning*, Vol. 16 No. 6, pp. 312-324.

Billett, S., Harteis, C. and Gruber, H. (2018), "Developing occupational expertise through everyday work activities and interactions", *The Cambridge Handbook of Expertise and Expert Performance*, Vol. 2, pp. 105-126.

Bontemps-Hommen, M.C., Baart, A.J. and Vosman, F.J. (2020), "Professional workplace-learning. Can practical wisdom be learned?", *Vocations and Learning*, Vol. 13 No. 3, pp. 479-501.

Bucchiarone, A. (2022), "Gamification and virtual reality for digital twins learning and training: architecture and challenges", *Virtual Reality and Intelligent Hardware*, Vol. 4 No. 6, pp. 471-486.

Bui, A., Veit, D. and Webster, J. (2015), "Gamification–a novel phenomenon or a new wrapping for existing concepts?".

Çakiroğlu, Ü. and Gökoğlu, S. (2019), "Development of fire safety behavioral skills via virtual reality", *Computers and Education*, Vol. 133, pp. 56-68.

Caligiuri, P. and Thomas, D.C. (2013), "From the editors: how to write a high-quality review", *Journal of International Business Studies*, Vol. 44 No. 6, pp. 547-553.

Cavalcanti, J., Valls, V., Contero, M. and Fonseca, D. (2021), "Gamification and hazard communication in virtual reality: a qualitative study", *Sensors*, Vol. 21 No. 14, p. 4663, doi: 10.3390/s21144663.

Cavusoglu, H., Dennis, A.R. and Parsons, J. (2019), "Immersive systems", *Journal of Management Information Systems*, Vol. 36 No. 3, pp. 680-682.

Checa, D., Bustillo, A., Saucedo-Dorantes, J.J., Osornio-Rios, R.A. and Cruz-Albarran, I.A. (2021), "Virtual reality-based tool applied in the teaching and training of condition-based maintenance in induction motors", *IECON 2021–47th Annual Conference of the IEEE Industrial Electronics Society*, pp. 1-6, *IEEE*.

Chen, H., Hou, L., Zhang, G. and Moon, S. (2021), "Development of BIM, IoT and AR/VR technologies for fire safety and upskilling", *Automation in Construction*, Vol. 125, p. 103631, doi: 10.1016/j.autcon.2021.103631.

Chen, Z. (2022), "Exploring the application scenarios and issues facing metaverse technology in education", *Interactive Learning Environments*, doi: 10.1080/10494820.2022.2133148.

Cheng, Y.M. and Liao, H.Y. (2021), "Task-oriented VR safety training in construction falls", IEEE Int. Conf. Ind. Eng. Eng. Manag, *IEEM*, pp. 1518-1525, *Scopus*, doi: 10.1109/IEEM50564.2021.9672950.

Chryssolouris, G., Mourtzis, D., Stavropoulos, P., Mavrikios, D. and Pandremenos, J. (2008), "Knowledge management in a virtual lab collaborative training project: a mini-formula student car design", *Methods and Tools for Effective Knowledge Life-Cycle-Management*, Springer, Berlin Heidelberg, pp. 435-446.

Conges, A., Evain, A., Benaben, F., Chabiron, O. and Rebiere, S. (2020), "Crisis management exercises in virtual reality", 2020 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW), pp. 87-92, *IEEE*.

Crossler, R.E., Johnston, A.C., Lowry, P.B., Hu, Q., Warkentin, M. and Baskerville, R. (2013), "Future directions for behavioral information security research", *Computers and Security*, Vol. 32, pp. 90-101.

Csikszentmihalyi, M. (2014), *Applications of Flow in Human Development and Education*, Springer, Dordrecht, pp. 153-172.

Dhalmahapatra, K., Das, S. and Maiti, J. (2022), "On accident causation models, safety training and virtual reality", *International Journal of Occupational Safety and Ergonomics*, Vol. 28 No. 1, pp. 28-44.

Dincelli, E. and Yayla, A. (2022), "Immersive virtual reality in the age of the metaverse: a hybrid-narrative review based on the technology affordance perspective", *The Journal of Strategic Information Systems*, Vol. 31 No. 2, p. 101717.

Feng, Z., Lovreglio, R., Yiu, T.W., Acosta, D.M., Sun, B. and Li, N. (2023), "Immersive virtual reality training for excavation safety and hazard identification", *Smart and Sustainable Built Environment*, doi: 10.1108/SASBE-10-2022-0235.

Fernández, A., Rivera, F.M.L. and Mora-Serrano, J. (2023), "Virtual reality training for occupational risk prevention: application case in geotechnical drilling works", *International Journal of Computational Methods and Experimental Measurements*, Vol. 11 No. 1, pp. 55-63, doi: 10.18280/ijcmem.110107.

Fromm, J., Radianti, J., Wehking, C., Stieglitz, S., Majchrzak, T.A. and Vom Brocke, J. (2021), "More than experience?-on the unique opportunities of virtual reality to afford a holistic experiential learning cycle", *The Internet and Higher Education*, Vol. 50, p. 100804.

Gauthier, S., Leduc, M., Perfetto, S. and Godwin, A. (2022), "Use of virtual reality to increase awareness of line-of-sight hazards around industrial equipment", *Safety*, Vol. 8 No. 3, doi: 10.3390/safety8030052.

Gauthier, S., Leduc, M., Perfetto, S.J. and Godwin, A. (2022), "Use of virtual reality to increase awareness of line-of-sight hazards around industrial equipment", *Safety*, Vol. 8 No. 3, p. 52.

González-González, S. (2020), "A case of gamification in virtual environments with RV/RA", 2020 X International Conference on Virtual Campus (JICV), pp. 1-3, doi: 10.1109/JICV51605.2020.9375816.

Gupta, A. and Varghese, K. (2020), "Scenario-based construction safety training platform using virtual reality", Proc. Int. Symp. Autom. Robot. Constr., ISARC: From Demonstr. Pract. Use - New Stage Constr. Robot, pp. 892-899, Scopus, available at: www.scopus.com/inward/record.uri?eid=2-s2.0-85109385253&partnerID=40&md5=38da1084c2e813408813e8060f0495d1

Haj-Bolouri, A., Katende, J. and Rossi, M. (2023a), "A mid-range theory for designing sustainable safe spaces of immersive learning environments: a design-science based gamification approach", *International Conference on Design Science Research in Information Systems and Technology*, Springer Nature Switzerland, Cham, pp. 449-469.

Haj-Bolouri, A., Katende, J. and Rossi, M. (2023b), "A mid-range theory for designing sustainable safe spaces of immersive learning environments: a design-science based gamification approach", in Gerber, A. and Baskerville, R. (Eds), Lect. Notes Comput. Sci, Vol. 13873 LNCS, pp. 449-469, *Springer Science and Business Media Deutschland GmbH; Scopus*, doi: 10.1007/978-3-031-32808-4_28.

Hamari, J. and Koivisto, J. (2014), "Measuring flow in gamification: dispositional flow scale-2", *Computers in Human Behavior*, Vol. 40, pp. 133-143.

Harichandran, A., Johansen, K.W., Jacobsen, E.L. and Teizer, J. (2021), "A conceptual framework for construction safety training using dynamic virtual reality games and digital twins", in Feng, C., Linner, T. and Brilakis, I. (Eds), Proc. Int. Symp. Autom. Robot. Constr, Vols. 2021, pp. 621-628, *International Association for Automation and Robotics in Construction (IAARC); Scopus*.

Hoang, T., Greuter, S., Taylor, S., Aranda, G. and Mulvany, G.T. (2021), "An evaluation of virtual reality for fear arousal safety training in the construction industry", 2021 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct), pp. 177-182, *IEEE*.

Howard, M.C. (2017), "A meta-analysis and systematic literature review of virtual reality rehabilitation programs", *Computers in Human Behavior*, Vol. 70, pp. 317-327.

Huotari, K. and Hamari, J. (2017), "A definition for gamification: anchoring gamification in the service marketing literature", *Electronic Markets*, Vol. 27 No. 1, pp. 21-31.

Jacobsen, E.L., Solberg, A., Golovina, O. and Teizer, J. (2022), "Active personalized construction safety training using run-time data collection in physical and virtual reality work environments", *Construction Innovation*, Vol. 22 No. 3, pp. 531-553, doi: 10.1108/CI-06-2021-0113.

Jensen, L. and Konradsen, F. (2018), "A review of the use of virtual reality head-mounted displays in education and training", *Education and Information Technologies*, Vol. 23 No. 4, pp. 1515-1529.

Joshi, S., Hamilton, M., Warren, R., Faucett, D., Tian, W., Wang, Y. and Ma, J. (2021), "Implementing virtual reality technology for safety training in the precast/prestressed concrete industry", *Applied Ergonomics*, Vol. 90, p. 103286.

Kerosuo, H. and Engeström, Y. (2003), "Boundary crossing and learning in creation of new work practice", *Journal of Workplace Learning*, Vol. 15 Nos 7/8, pp. 345-351.

Kim, S.H. and Leem, C.S. (2020), "Factors affecting the transfer intention of VR construction safety training: a task-technology fit perspective", *Glob. Bus. Adm. Rev*, Vol. 17, pp. 300-318.

Klein, H.K. and Myers, M.D. (1999), "A set of principles for conducting and evaluating interpretive field studies in information systems", *MIS Quarterly*, Vol. 23 No. 1, pp. 67-93.

Lave, J. and Wenger, E. (1991), *Situated Learning: Legitimate Peripheral Participation*, Cambridge university press, Cambridge.

Lefor, A.K., Harada, K., Kawahira, H. and Mitsuishi, M. (2020), "The effect of simulator fidelity on procedure skill training: a literature review", *International Journal of Medical Education*, Vol. 11, p. 97.

Lemmetty, S. and Collin, K. (2020), "Self-directed learning as a practice of workplace learning: Interpretative repertoires of self-directed learning in ICT work", *Vocations and Learning*, Vol. 13 No. 1, pp. 47-70.

Li, M., Sun, Z., Jiang, Z., Tan, Z. and Chen, J. (2020), "A virtual reality platform for safety training in coal mines with AI and cloud computing", *Discrete Dynamics in Nature and Society*, Vol. 2020, doi: 10.1155/2020/6243085.

Li, W., Huang, H., Solomon, T., Esmaeili, B. and Yu, L.F. (2022), "Synthesizing personalized construction safety training scenarios for VR training", *IEEE Transactions on Visualization and Computer Graphics*, Vol. 28 No. 5, pp. 1993-2002.

Liang, Z., Zhou, K. and Gao, K. (2019), "Development of virtual reality serious game for underground rock-related hazards safety training", *IEEE Access*, Vol. 7, pp. 118639-118649, doi: 10.1109/ACCESS.2019.2934990.

Liu, D., Santhanam, R. and Webster, J. (2017), "Toward meaningful engagement", *MIS Quarterly*, Vol. 41 No. 4, pp. 1011-1034.

Luo, Y., Ahn, S., Abbas, A., Seo, J., Cha, S.H. and Kim, J.I. (2023), "Investigating the impact of scenario and interaction fidelity on training experience when designing immersive virtual reality-based construction safety training", *Developments in the Built Environment*, Vol. 16, p. 100223, doi: 10.1016/j.dibe.2023.100223.

McGill, M., Williamson, J.H. and Brewster, S. (2016), "Examining the role of smart TVs and VR HMDs in synchronous at-a-distance media consumption", *ACM Transactions on Computer-Human Interaction (TOCHI)*, Vol. 23 No. 5, pp. 1-57.

Magrath, V. and McCormick, H. (2013), "Marketing design elements of mobile fashion retail apps", *Journal of Fashion Marketing and Management: An International Journal*, Vol. 17 No. 1, pp. 115-134.

Makransky, G., Borre-Gude, S. and Mayer, R.E. (2019), "Motivational and cognitive benefits of training in immersive virtual reality based on multiple assessments", *Journal of Computer Assisted Learning*, Vol. 35 No. 6, pp. 691-707.

Malloch, M., Evans, K. and Cairns, L. (2010), "The Sage handbook of workplace learning", *The SAGE Handbook of Workplace Learning*, SAGE, London, pp. 1-504.

Markopoulos, E., Lauronen, J., Luimula, M., Lehto, P. and Laukkanen, S. (2019), "Maritime safety education with VR technology (MarSEVR)", 2019 10th IEEE International Conference on Cognitive Infocommunications (CogInfoCom), pp. 283-288, doi: 10.1109/CogInfoCom47531.2019.9089997.

Mas, A., Ismaël, I. and Filliard, N. (2018), "Indy: a virtual reality multi-player game for navigation skills training", 2018 IEEE Fourth VR International Workshop on Collaborative Virtual Environments (3DCVE), pp. 1-4, doi: 10.1109/3DCVE.2018.8637113.

Miguel-Alonso, I., Guillen-Sanz, H., Rodriguez-Garcia, B. and Bustillo, A. (2023), "Design and development of a gamified tutorial for iVR serious games", *European Conference on Games Based Learning*, Vol. 17 No. 1, pp. 411-417.

Mo, Y., Zhao, D., Du, J., Liu, W. and Dhara, A. (2018), "Data-driven approach to scenario determination for VR-based construction safety training", in Wang, C., Harper, C., Lee, Y., Harris, R. and Berryman, C. (Eds), Constr. Res. Congr.: Saf. Disaster Manag. - Sel. Pap. Constr. Res. Congr Vols. 2018, pp. 116-125, *American Society of Civil Engineers (ASCE); Scopus*, doi: 10.1061/9780784481288.012.

Montola, M., Stenros, J. and Waern, A. (2009), *Pervasive Games: theory and Design*, CRC Press, London.

Moore, H.F., Eiris, R., Gheisari, M. and Esmaeili, B. (2019), "Hazard identification training using 360-degree panorama vs. virtual reality techniques: a pilot study", ASCE International Conference on Computing in Civil Engineering 2019, pp. 55-62, *Reston, VA*: *American Society of Civil Engineers*.

Morélot, S., Garrigou, A., Dedieu, J. and N'Kaoua, B. (2021), "Virtual reality for fire safety training: Influence of immersion and sense of presence on conceptual and procedural acquisition", *Computers and Education*, Vol. 166, p. 104145.

Mütterlein, J. (2018), "The three pillars of virtual reality? Investigating the roles of immersion, presence, and interactivity".

Palmas, F., Labode, D., Plecher, D.A. and Klinker, G. (2019), "Comparison of a gamified and non-gamified virtual reality training assembly task", 2019 11th International Conference on Virtual Worlds and Games for Serious Applications (VS-Games), pp. 1-8, doi: 10.1109/VS-Games.2019.8864583.

Pedram, S., Perez, P., Palmisano, S. and Farrelly, M. (2018), "A qualitative evaluation of the role of virtual reality as a safety training tool for the mining industry", Lecture Notes in Computer Science, 188-200, doi: 10.1007/978-3-319-78795-4_14.

Peretti, O., Spyridis, Y., Sesis, A. and Efstathopoulos, G. (2021), "Gamified first responder training solution in virtual reality", 2021 17th international conference on distributed computing in sensor systems (DCOSS), *IEEE*, pp. 295-301.

Peretti, O., Spyridis, Y., Sesis, A. and Efstathopoulos, G. (2021), "Gamified first responder training solution in virtual reality", 2021 17th International Conference on Distributed Computing in Sensor Systems (DCOSS), pp. 295-301, doi: 10.1109/DCOSS52077.2021.00055.

Pinto, R.D., Peixoto, B., Melo, M., Cabral, L. and Bessa, M. (2021), "Foreign language learning gamification using virtual reality – a systematic review of empirical research", *Education Sciences*, Vol. 11 No. 5, p. 222.

Radhakrishnan, U., Koumaditis, K. and Chinello, F. (2021), "A systematic review of immersive virtual reality for industrial skills training", *Behaviour and Information Technology*, Vol. 40 No. 12, pp. 1310-1339.

Ramstorfer, F., da Silva, S.B., da Silva, L.G., Rivero, V.H., Xavier, B.L. and Demuner, L.M. (2022), "Application of virtual reality simulation as a tool for safety-related training in the steel

industry", AISTech Iron Steel Technol. Conf. Pro, 2022-May, pp. 45-55, *Scopus*, doi: 10.33313/386/006.

Ravichandran, R.R. and Mahapatra, J. (2023), "Virtual reality in vocational education and training: challenges and possibilities", *Journal of Digital Learning and Education*, Vol. 3 No. 1, pp. 25-31.

Riocampo, S.L. (2019), "Virtual interactive system based on gamification for basic military training in the area of management of weapons", 2019 International Conference on Virtual Reality and Visualization (ICVRV), pp. 167-171, doi: 10.1109/ICVRV47840.2019.00039.

Rokooei, S., Shojaei, A., Alvanchi, A., Azad, R. and Didehvar, N. (2023), "Virtual reality application for construction safety training", *Safety Science*, Vol. 157, p. 105925, doi: 10.1016/j.ssci.2022.105925.

Roofigari-Esfahan, N., Porterfield, C., Ogle, T., Upthegrove, T., Jeon, M. and Lee, S.W. (2022), "Group-based VR training to improve hazard recognition, evaluation, and control for highway construction workers", 2022 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW), pp. 513-516, doi: 10.1109/VRW55335.2022.00114.

Saker, M. and Frith, J. (2020), "Coextensive space: virtual reality and the developing relationship between the body, the digital and physical space", *Media, Culture and Society*, Vol. 42 No. 7-8, pp. 1427-1442.

Seidman, I.E. (1991), *Interviewing as Qualitative Research*, Teachers College Press, New York, NY.

Seo, H.J., Park, G.M., Son, M. and Hong, A.J. (2021), "Establishment of virtual-reality-based safety education and training system for safety engagement", *Education Sciences*, Vol. 11 No. 12, p. 786.

Shen, T.-W., Ho, T.-L. and Lee, L.-C. (2020), "Development and evaluation of virtual reality induction electricity prevention education and training tools for construction industry", 2020 IEEE International Conference on Consumer Electronics - Taiwan (ICCE-Taiwan), pp. 1-2, doi: 10.1109/ICCE-Taiwan49838.2020.9258051.

Sirvermez, U. and Baltaci, Ş. (2023), "Metaverse applications in education: Systematic literature review and bibliographic analysis of 2010–2022", *Metaverse*, pp. 397-417.

Staneva, T., Ivanova, K., Rasheva-Yordanova. and D., Borissova. (2023), "Gamification in education: Building an escape room using VR technologies", 2023 46th MIPRO ICT and Electronics Convention (MIPRO), pp. 678-683, doi: 10.23919/MIPRO57284.2023.10159923.

Tayal, S., Rajagopal, K. and Mahajan, V. (2022), "Virtual reality based metaverse of gamification", 2022 6th International Conference on Computing Methodologies and Communication (ICCMC), pp. 1597-1604, *IEEE*.

Toyoda, R., Russo-Abegão, F. and Glassey, J. (2022), "VR-based health and safety training in various high-risk engineering industries: a literature review", *International Journal of Educational Technology in Higher Education*, Vol. 19 No. 1, doi: 10.1186/s41239-022-00349-3.

Ulmer, J., Braun, S., Cheng, C.T., Dowey, S. and Wollert, J. (2022), "Gamification of virtual reality assembly training: Effects of a combined point and level system on motivation and training results", *International Journal of Human-Computer Studies*, Vol. 165, p. 102854.

Ulmer, J., Braun, S., Cheng, C.-T., Dowey, S. and Wollert, J. (2020), "Gamified virtual reality training environment for the manufacturing industry", 2020 19th International Conference on Mechatronics – Mechatronika (ME), pp. 1-6, doi: 10.1109/ME49197.2020.9286661.

Vahdatikhaki, F., Friso-van den Bos, I., Mowlaei, S. and Kollöffel, B. (2023), "Application of gamified virtual laboratories as a preparation tool for civil engineering students", *European Journal of Engineering Education*, Vol. 49 No. 1, pp. 1-28.

Vaughan, K. (2008), "Workplace learning: a literature review".

Venkatesh, V., Brown, S.A. and Bala, H. (2013), "Bridging the qualitative-quantitative divide: Guidelines for conducting mixed methods research in information systems", *MIS Quarterly*, Vol. 37 No. 1, pp. 21-54.

Vinnikov, M., Allison, R.S. and Fernandes, S. (2017), "Gaze-contingent auditory displays for improved spatial attention in virtual reality", *ACM Transactions on Computer-Human Interaction*,)Vol. 24 No. 3, pp. 1-38.

Wang, P., Wu, P., Wang, J., Chi, H.L. and Wang, X. (2018), "A critical review of the use of virtual reality in construction engineering education and training", *International Journal of Environmental Research and Public Health*, Vol. 15 No. 6, p. 1204.

Wareing, J., Lawson, G., Abdullah, C. and Roper, T. (2018), "User perception of heat source location for a multisensory fire training simulation", 2018 10th Computer Science and Electronic Engineering (CEEC), pp. 214-218, doi: 10.1109/CEEC.2018.8674211.

Xie, B., Liu, H., Alghofaili, R., Zhang, Y., Jiang, Y., Lobo, F.D., Li, C., Li, W., Huang, H., Akdere, M. and Mousas, C. (2021), "A review on virtual reality skill training applications", *Frontiers in Virtual Reality*, Vol. 2, p. 645153.

Yin, R.K. (1994), "Discovering the future of the case study. Method in evaluation research", *Evaluation Practice*, Vol. 15 No. 3, pp. 283-290.

Yoo, J.W., Park, J.S. and Park, H.J. (2023), "Understanding VR-based construction safety training effectiveness: the role of telepresence, risk perception, and training satisfaction", *Applied Sciences*, Vol. 13 No. 2, p. 1135.

Yung, R. and Khoo-Lattimore, C. (2019), "New realities: a systematic literature review on virtual reality and augmented reality in tourism research", *Current Issues in Tourism*, Vol. 22 No. 17, pp. 2056-2081.

Zhang, H., He, X. and Mitri, H. (2019), "Fuzzy comprehensive evaluation of virtual reality mine safety training system", *Safety Science*, Vol. 120, pp. 341-351.

Zhu, M., Sun, Z., Zhang, Z., Shi, Q., He, T., Liu, H. ... and Lee, C. (2020), "Haptic-feedback smart glove as a creative humanmachine interface (HMI) for virtual/augmented reality applications", *Science Advances*, Vol. 6 No. 19, p. eaaz8693.

Further reading

Ayed, I., Ghazel, A., Jaume-I-Capo, A., Moya-Alcover, G., Varona, J. and Martínez-Bueso, P. (2019), "Vision-based serious games and virtual reality systems for motor rehabilitation: a review geared toward a research methodology", *International Journal of Medical Informatics*, Vol. 131, p. 103909.

Loureiro, S.M.C., Guerreiro, J., Eloy, S., Langaro, D. and Panchapakesan, P. (2019), "Understanding the use of virtual reality in marketing: a text mining-based review", *Journal of Business Research*, Vol. 100, pp. 514-530.

Perlow, L.A. (2012), *Sleeping with Your Smartphone: How to Break the 24/7 Habit and Change the Way You Work*, Harvard Business Press, Boston.

Suh, A. and Prophet, J. (2018), "The state of immersive technology research: a literature analysis", *Computers in Human Behavior*, Vol. 86, pp. 77-90.

Supplementary material

The supplementary material for this article can be found online.

Corresponding author

Amir Haj-Bolouri can be contacted at: amir.haj-bolouri@hv.se