

# Improving Collaborative Learning and Performance in Industrial Training: An Approach to Multiplayer Virtual Reality Serious Games

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**Abstract.** *Virtual Reality (VR) has become a key platform for serious games, especially in high-risk industries that require immersive and safe training. Although single-player simulations help with individual development, they are insufficient to develop team skills such as communication and coordination. This paper presents a multiplayer VR serious game that transforms individual training into a collaborative experience. The multiplayer approach improves both technical mastery and interpersonal skills, including cooperation and situational awareness. Research shows that this model increases engagement, satisfaction, and performance. By addressing challenges such as latency and social interaction, the study offers a more effective method for industrial training in virtual collaborative environments.*

## 1. Introduction

Virtual reality has emerged as an effective platform for the development of serious games applied to industrial training. Previous work by this team, such as [Borges et al. 2023], explored immersive simulations aimed at individual development of technical skills. However, limitations inherent in single-player experiences still compromise the advancement of collaborative skills essential to the industrial environment. Continuing the evolution of the application, this paper anticipates the future integration of multiplayer functionality. Furthermore, with the aim of expanding the pedagogical scope of the simulation and incorporating the dynamics of cooperation, communication, and coordination in real time among users.

## 2. Serious Games in Industry: Performance and Significance

The use of games in educational settings, as a tool to reinforce concepts and aid memorization, has been common for decades. However, in recent years, a transformation has taken place in how games are applied in these contexts, driven by the emergence of serious games. The application of serious games for skill development and technical training, both in academic and professional environments, has increased significantly [Boyle et al. 2016]. This growth is partly due to technological advancements that allow greater interactivity, such as virtual reality headsets, which offer highly immersive and visually realistic experiences. Serious games are defined as those that employ entertainment

elements to train, educate, or communicate, focusing on objectives beyond the enjoyment of the user. Their applications span various fields, including the military [Zyda 2005], industry [Borges et al. 2023], and healthcare [Graafland et al. 2012].

Virtual reality has further expanded the potential of serious games in training contexts. Immersive environments make it possible to simulate real-world situations with key advantages: cost reduction by avoiding machinery downtime, risk elimination by training in hazardous environments, and decision-making practice during for example, emergencies whether in industrial or healthcare scenarios. More and more companies are adopting VR-based serious games to train employees. In addition to the benefits mentioned above, these games also contribute to high knowledge retention and the development of motor skills. In many cases, users improve through task repetition, and studies have demonstrated a correlation between training with serious games and improved real-world performance [Wouters et al. 2013].

Finally, it is important to note that ongoing technological advances continue to enhance game immersion, realism, latency, and fluidity, thereby increasing their effectiveness in practical applications.

### **3. Challenges in Implementing Multiplayer in Serious Games**

#### **3.1. Technical Obstacles**

In current literature addressing the impact of multiplayer experiences associated with virtual reality, it suggests that the technical capacity of these systems faces certain hurdles, mainly related to the player interface and the sense of isolation caused by head-mounted displays (HMDs).

[Rogers et al. 2021] highlight that the requirement for a sufficiently large physical space to accommodate multiple players interacting without the risk of physical collision—combined with the high system costs—limits the use of multiple HMDs simultaneously. The paper also points out other obstacles, such as interface asymmetry, which encompasses differences between players with and without HMDs and requires caution regarding network design and balancing the distribution of roles within the game, since discrepancies in agency and control can negatively affect the user's experience.

#### **3.2. Design and User Experience Challenges**

Regarding user experience, [Piispanen et al. 2024] observed that the nursing students who participated in their study reported negative feedback related to difficulties in identifying the location of their colleagues' avatars and mentioned how challenging it was to manipulate and interact with objects in the virtual environment due to visual inaccuracies. These obstacles compromise situational awareness, which is fundamental in serious games designed for collaborative training. Furthermore, differences in skill and familiarity with the system among users are factors that can undermine engagement and the educational effectiveness of multiplayer serious games, as they disrupt users' sense of collaboration [Rogers et al. 2021].

#### **3.3. Best Practices and Solutions**

To mitigate these challenges, specific intervention proposals have emerged for each scope. [Piispanen et al. 2024] encourage participants to verbalize their actions during activities

and to use haptic feedback, improving mutual awareness and facilitating cooperation among users. According to [Rogers et al. 2021], the recommendation is to adopt a consciously asymmetric design that values interdependence between players and ensures a balanced distribution of responsibilities. Therefore, it is evident that these proposals enable the creation of more inclusive and collaborative virtual environments—and it is precisely these environments that allow us to harness the educational potential that serious games in VR can offer.

#### **4. Impact of Multiplayer Implementation in Serious Games**

The integration of multiplayer functionalities into Serious Games (SGs) transforms them into dynamic social learning environments, addressing the core challenge of aligning educational goals with engaging gameplay [Arnab et al. 2015]. The impact of this shift is evident across three key areas: improved collaboration, heightened player motivation, and the diversification of learning scenarios.

##### **4.1. Improvement in Collaboration and Communication**

Multiplayer SGs are powerful platforms for developing collaboration and communication skills by requiring players to build mutually shared knowledge of the problems they face [Van den Bossche et al. 2006]. This shared understanding is stepped through team-learning behaviors, such as the shared creation of meaning and the negotiation of different perspectives through constructive conflict.

The emergence of these behaviors is highly dependent on the team's interpersonal context. According to [Van den Bossche et al. 2006] and [Wendel et al. 2010], the key facilitating factors include a sense of psychological safety, which allows for risk-taking; task cohesion, a shared commitment to the goal; and interdependence, the recognition that success is only possible through a collective effort. Game design can intentionally foster these conditions by setting common goals and assigning unique roles or resources to players, which makes collaboration essential for progress [Boyle et al. 2016].

##### **4.2. Increase in Engagement and Motivation**

Motivation is a critical prerequisite for learning, and multiplayer dynamics significantly boost player engagement [Wendel et al. 2010]. This is often achieved by inducing a state of "flow," where players are fully immersed in an activity that balances high challenge with their personal skill level. Previous research suggests that challenge is a strong predictor of learning, both directly and through its impact on engagement. In contrast, perceived skill does not appear to affect learning outcomes directly but plays an important role by increasing the learner's involvement in the task [Hamari et al. 2016]. The social context of multiplayer games further amplifies motivation through mechanics like competition, cooperation, and social recognition, which are powerful drivers of continued participation and effort [Boyle et al. 2016, Arnab et al. 2015].

##### **4.3. Diversification of Training and Assessment Scenarios**

Multiplayer platforms provide a scalable solution to the high cost of manual content creation through Procedural Content Generation (PCG). PCG enables the algorithmic creation of a vast and varied range of game content, including maps, systems, and entire scenarios, ensuring high replayability [Hendrikx et al. 2013]. This forces learners to apply

their skills adaptively to novel situations rather than relying on memorization of static content. This diversity is also invaluable for evaluation, as it facilitates embedded assessment, where player competencies are measured organically through their in-game actions without disrupting the learning experience [Arnab et al. 2015]. The rich data generated from player interactions in these varied scenarios allows for a robust and authentic assessment of both individual knowledge and collaborative capabilities [Wendel et al. 2010].

## 5. Conclusion and Future Works

This work explored the shift from individual to collective digital experiences, emphasizing the growing centrality of multiplayer and multi-user functionalities within contemporary technological ecosystems. Through the analysis of collaborative software, entertainment games, and particularly serious games, we identified the cognitive, social, and pedagogical advantages that emerge from multiplayer interaction.

The research further highlighted the value of establishing a robust conceptual taxonomy and pointed to the distinct pedagogical potential of multiplayer dynamics in educational and training contexts. Despite these promising findings, the implementation of multiplayer features in VR especially within serious games remains technically and pedagogically challenging.

Critical issues include precise synchronization in complex interactive environments, latency and performance limitations on standalone VR devices, instructional design constraints for multiplayer learning scenarios, and the need for scalability to support heterogeneous user profiles. These factors can significantly compromise user immersion, system performance, and the overall effectiveness of serious VR applications.

In addition to these implementation barriers, broader challenges persist, such as cybersecurity and real-time moderation, interface design for coordinated group tasks, economic and accessibility constraints, and the physical and cognitive demands associated with prolonged immersive experiences. Addressing these challenges is essential to unlock the full potential of multiplayer interactions in VR and other platforms.

As future work, we propose the development of frameworks and methodologies that facilitate the integration of multiplayer functionality into serious games, with particular emphasis on virtual reality environments. Advancements in this direction are expected to enhance user experience by improving interaction and immersion, thus contributing to the evolution of VR as a transformative educational and collaborative medium.

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