Gamification and virtual reality in occupational safety teaching

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Abstract. *This study presents a serious game in virtual reality for occupational safety education in construction. Developed in Unreal Engine 5.5® with Meta Quest 2®, it allows free navigation, hazard identification through menus, and real-time feedback in realistic scenarios such as scaffolding, excavations, and sanitary facilities. Preliminary results confirm system functionality, immersive interaction, and potential to replicate inspection practices. Next steps include implementing scoring and assessing educational impact.*

1. Introduction

Occupational safety in the construction industry is a highly relevant topic, given the high incidence of workplace accidents recorded in the sector. According to data from the International Labour Organization (ILO, 2021), construction ranks among the activities with the highest rates of fatal accidents worldwide. In Brazil, the Observatory of Occupational Health and Safety (SmartLab, 2023) reports that falls, cave-ins, and electric shocks remain common causes of workplace injuries and leave of absence among construction workers.

In light of this scenario, it is essential to invest in the technical training of future engineering professionals by adopting methodologies that promote active, critical, and situated learning. Among these approaches, gamification combined with immersive technologies such as virtual reality (VR) stands out as an educational strategy to make the learning process more dynamic, engaging, and aligned with real-world field experiences (Bontchev *et al.,* 2024; Urgo *et al.,* 2022).

This article presents a work in progress focused on the development of a serious game in virtual reality for teaching occupational safety in construction. The proposed solution aims to create an interactive, three-dimensional environment where students can simulate the inspection of a construction site, identify irregularities, and classify them according to the types of risks involved. This initiative seeks to enhance risk perception, decision-making, and knowledge retention through an immersive and gamified pedagogical experience.

1. Methodology

The serious game was developed on the Unreal Engine 5.5® platform, with support for the Meta Quest 2® device, adopting a first-person perspective to simulate the viewpoint of a safety engineer and enhance user immersion. Programming was carried

out using Blueprints, and the environment was built with both free and paid assets obtained from official libraries such as the Unreal Marketplace and FabLab.

The process is grounded in situational gamified software engineering (Morschheuser *et al*., 2018), which combines user-centered design, iterative development, and a multidisciplinary approach, fostering motivation, usability, and long-term behavioral impact (Bucchiarone, 2022; Haj-Bolori *et al*., 2024). The pedagogical design is also based on active learning principles and the Self-Determination Theory (Ryan & Deci, 2000), pursuing three main objectives: (i) to develop students' situational awareness regarding occupational risks; (ii) to stimulate preventive reasoning in proposing appropriate control measures; and (iii) to promote autonomy and critical engagement in the identification of nonconformities.

The functional prototype includes a scoring system, risk categorization menus, and real-time interactive feedback, recording players' performance for subsequent analysis. At the end of the activity, participants will complete a digital spreadsheet with preventive measures (via complementary spreadsheet access) and respond to the USE Questionnaire (via questionnaire access) (Lund, 2001), widely used for the evaluation of interactive systems.

2. Preliminary Results

At the beginning of the game, the participant is welcomed by an interactive instruction screen (Figure 1), which follows the player's head movements and presents the main mission: to inspect the construction site in search of irregularities that represent safety hazards. This introduction establishes the rules of interaction and explains the scoring dynamics, ensuring greater clarity and engagement from the very start of the experience.

Figure 1: Initial game instructions

Next, the player can freely navigate the virtual environment in first-person perspective, exploring different areas of the construction site. When approaching a safety irregularity, the player can open the risk menu by pressing the *B* button (right controller) or *Y* button (left controller). This menu presents the main risk categories (Figure 2), such as physical, chemical, biological, ergonomic, accident-related, electrical, and machinery/equipment risks. After selecting a category, a specific submenu is displayed

(Figure 3), allowing the player to classify more detailed irregularities, such as improper material storage, unprotected scaffolding, uneven flooring, lack of signage, incorrect use of PPE, and fall hazards.

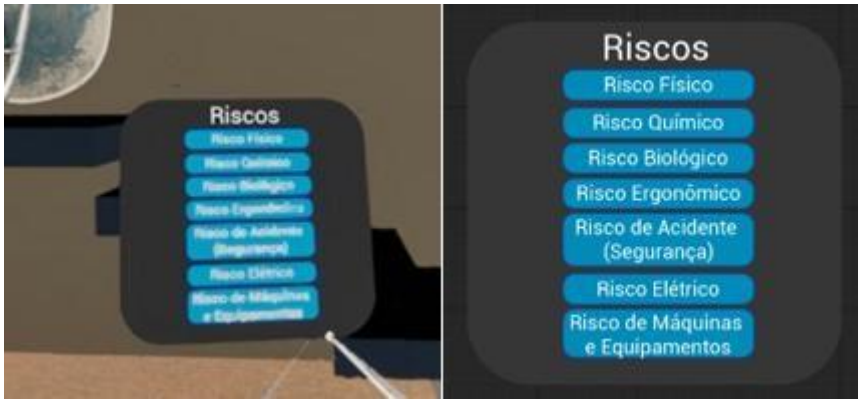

Figure 2: Risk category menu

The prototype already includes the modeling of several risk scenarios that simulate common irregularities found on construction sites. These scenarios are designed to provide students with realistic contexts in which they must exercise situational awareness and decision-making. For exemplo, portable toilets are shown in precarious conditions, with broken doors and poor maintenance. This scenario reflects the importance of proper hygiene and infrastructure for workers, as inadequate facilities may lead to health risks and violations of occupational safety standards (Figure 3).

Figure 3: Damaged and inadequate sanitary facilities

In Figure 5, a character is positioned unsafely on a scaffold, illustrating one of the most recurrent causes of severe accidents in construction: falls from height. The absence of guardrails or harnesses challenges the player to identify and classify the irregularity, reinforcing preventive measures required by safety regulations.

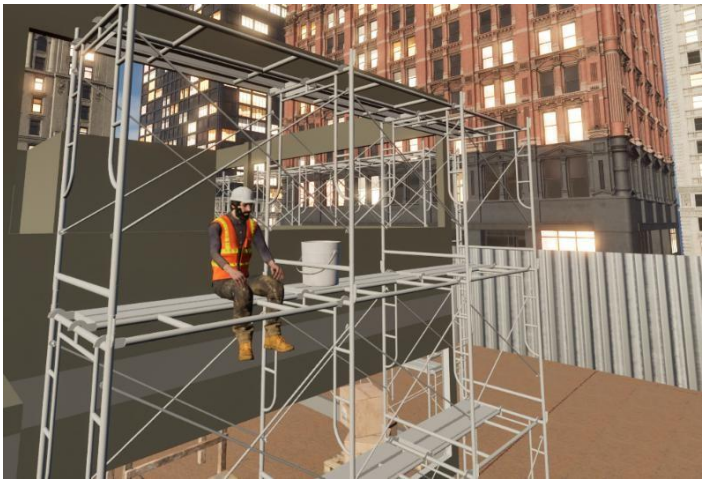

Figure 4: Worker on scaffolding without fall protection

These elements contribute to a more realistic and dynamic experience, enabling players to practice risk perception in a context close to real construction environments. The scoring system is currently under development and will reward correct classifications while allowing players to try again in case of errors, under the constraint of a limited inspection time. The next development stage will focus on finalizing this scoring logic and implementing automatic performance reports, which will serve as the basis for analyzing participants' learning outcomes.

3. Expected Results

Although the project is still a work in progress, the prototype has already reached a functional stage, with interactive scenarios and categorized risk menus. The next steps focus on consolidating the scoring system and integrating automatic performance reports.

From an educational perspective, the tool is expected to:

- Stimulate active learning through the exploration and analysis of simulated construction scenarios;
- Increase student motivation and engagement in the Occupational Safety course;
- Promote accurate hazard recognition based on visual stimuli and contextualized situations;
- Strengthen students' ability to make quick and informed decisions in a controlled and safe environment.

The experimental application will be conducted with undergraduate engineering students at the Polytechnic School of the University of Pernambuco (UPE), within the Occupational Safety course.

4. Acknowledgments

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