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GAMIFICATION OF SAFETY TRAINING IN CONSTRUCTION: A UK PROFESSIONAL PERSPECTIVE

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ABSTRACT

Most practitioners consider safety training in construction as a must-have but tedious and repetitive task. Novel technologies and learning approaches, such as gamification, have the potential to increase worker engagement and motivation towards safety training. This paper reports on the development of a game for safety training in construction and the game evaluation by a group of construction professionals. The study aims to evaluate the capacity of gamification to impact safety training. Based on the results, changing current practice to a more gamified approach to safety training and learning has a significant positive impact on safety awareness.

INTRODUCTION

The use of information and communication technologies (ICTs) have increased exponentially in the past decades, and educational institutions and their classrooms are no different. ICTs have been slowly but uninterruptedly introduced in the classroom to facilitate learning and acquiring knowledge, skills, and positive values. With the recent pandemic, it has become a fundamental pillar in improving students' attitudes towards learning (Lazar and Panisoara 2018; McGovern et al. 2020). Among ICTs, digital virtual platforms are revolutionizing educational experiences by providing simulated environments in which users can interact with the environment in an apparent real-time manner. These virtual environments can recreate classrooms, ensure safe experimentation of otherwise risky learning experiences, and often, a more viable and inclusive solution to overcome logistical and organizational challenges and expose learners to certain professional scenarios (Tzanavari and Tsapatsoulis 2010).

For construction education, for example, it facilitates bringing numerous students to a construction site at once, transforming the logistics and safety problems related to having students in a hazardous environment into a technological problem. From a technical aspect, virtual platforms are usually created to be accessed through various means. Hardware selection (e.g., flat screens vs. virtual reality) and the delivery method integrated into the software greatly impact the learning experience and outcomes. On that last part, an interesting approach that has been gaining popularity in the past years is serious gaming. This concept refers to a mix of gamification with an additional educational value that pushes the learner to use game mechanics in non-gaming contexts. It promotes learning, challenging performance, engagement, and personal initiative (Caponetto et al., 2014).

The rationale behind the gamification of training is, at its core, the need to change something within the learning process that is not working properly or adapt it to newer generation trainees. While health and safety in construction is a heavily regulated practice, with specific regulations at national and international levels, construction operations remain hazardous and high-risk workplaces. Gamification can be an approach to provide information at individualized levels (for operators, supervisors, technicians, etc.) an accurate and contextualized learning experiences (Benito Rodriguez et al., 2021). However, users' perspective on such games has not been recorded in literature, specifically from active professionals. This paper presents the evaluation of a safety training game by UK construction professionals, aiming to understand the benefits and drawbacks of gamified learning experiences.

LITERATURE REVIEW

Several studies have reported the success of gaming approaches for learning and skill development (Gee, 2006; Cavalcanti et al., 2021). A game environment presents an immersive environment full of stimuli that makes for an excellent sandbox to improve learning processes. Games are flexible in content and goals and can be used in a wide range of locations and engagement. This is especially important for flexible learning approaches in cases of worker availability disruptions, as occurred with the recent COVID-19 pandemic.

In a previous study, a framework for the development of games for construction activities was proposed (Le et al., 2015). Three modules are required for any game: a knowledge dissemination phase, a knowledge reflection phase, and a knowledge assessment phase. This approach has been used in the literature, and the results showed improvements in hazard identification (Bernardes et al., 2015). It also has proven applications in risk management to help learn activity interpretation and cause-consequence analysis through simulated scenarios (Barot et al., 2013).

Also, current literature highlights the dynamic presentation capabilities of gamified learning processes for safety training as a key element that supports higher immersion and learning outcomes. This is in line with learning theory regarding attention and visual cues. In fact, when delivered using virtual reality methods, games provide an additional level of dynamism and an improved learning experience (Harichandran et al., 2021). In this line, a large number of studies have been done over several learning training processes to address construction education. For instance, Kazar et al. (2021) developed a serious game for safety training and assessed its effectiveness with senior civil engineering students. Their results showed that the serious game is an effective training approach, and its effectiveness is not influenced

by the game experience of the learners. In another study, Gallerati et al. (2017) assessed students' learning retention and the cost associated with training activities through serious gaming and VR. In their experiment, students used a simulated immersive VR that emulated a drilling land rig, the results showed improvement in learning retention and a reduction in safety risks and training costs. For flood safety training in the urban built environment, D'Amico et al. (2023) developed a non-immersive VR game, which could make a significant improvement in the self-efficacy and safety knowledge of the learners. The use of digital twin, which can dynamically update the digital models with real-time data, was studied by Harichandran et al. (2021) for developing dynamic VR games. They developed a framework for creating safety training scenarios from the project intent information, project status knowledge, safety regulations, and historical knowledge provided by the digital twin. Despite the novelty of the proposed approach, manual creation of the scenarios is reported as its drawback to be addressed in future.

This literature review has highlighted that the current implementation of serious gaming in AEC education has a lot of potential for education and training. Safety training has been identified as a key area for gamification. However, most of the existing studies focused on experiential learning for students, disregarding professionals who may have a more pragmatic approach to learning approaches (Abotaleb et al., 2023).

This paper explores how industry professionals perceive the introduction of serious gaming for safety training and how it compares to their current approaches. The population is a sample of AEC professionals who are actively involved in the construction industry, not necessarily around safety. Based on this, the following research questions are proposed:

1. What is the opinion of industry professionals regarding the gamification of safety training?
2. How does gamification compare to current approaches for safety training?

METHODOLOGY & GAME DESCRIPTION

The research is based on a quasi-experiment due to the lack of randomization in the testing group. The professionals involved in this experiment were selected based on experience and availability. A total of 28 professionals participated in the experiment in four different sessions due to space and availability constraints. However, a single group is created to check and evaluate the methods and learning outcomes presented through the experiment (see Figure 1). The learning activity is designed to introduce the population to two different concepts: site traffic safety from a trucker perspective, and crane safety from the crane operator and ground safety personnel. The first activity uses serious gaming to present different hazard profiles and safety procedures of driving across a congested and operational construction site while driving a loaded truck. Similarly, the second activity focuses on crane operations from two points of view, one while performing a module lifting operation from the cabin and the other one while doing a routine ground inspection around the crane lifting area. After the experiment, lasting around 40-45 minutes, a post-assessment point is given to allow the population to provide feedback and assess their learning experience.

Figure 1. Serious gaming for safety training activity.

To kickstart the learning activity, the participants are given a small tutorial prior to immersion in the game. The tutorial lasts about 20 minutes and covers the basics of the game experience regarding controls, main menu, and game structure and goals. This phase is meant to facilitate navigation within the game to all participants. Any participants who had difficulty with navigation or any game-related issue were provided with support and additional training.

After that, the participants start the game. They are thrown in first person on a construction site environment where they can interact with the main menu of the game (see Figure 2). This menu allows players to select the different levels available in the game. Each training topic/theme is structured as a set of levels, starting with a tutorial phase where participants are taught using visual cues and written statements regarding safety rules on specific scenarios that the participants walk into.

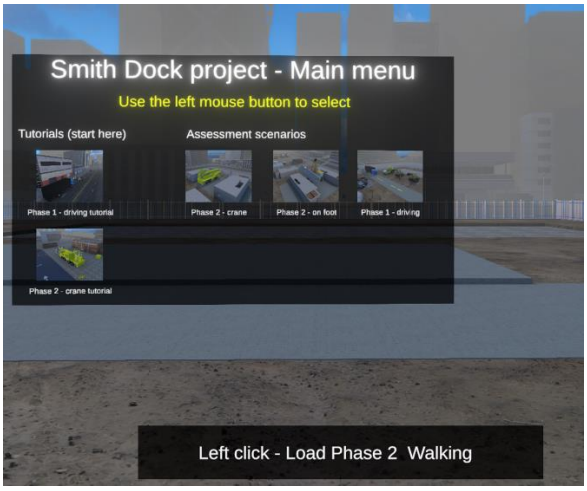

Figure 2. Screenshot of the main menu of the serious game.

Upon completion of the tutorial, an assessment level on the theme just covered is unlocked. This assessment level is similar to the tutorial level in terms of tasks and environment; however, no cues or support is given. A scoring system is introduced to automatically assess the results of the participant over their behavior and motion

across the level. Participants receive their scores and feedback on how to improve the sections in which they lose points. The level structure is illustrated in Figure 3. Participants are free to navigate through the different tutorial levels at any given time, as there is no order to those levels.

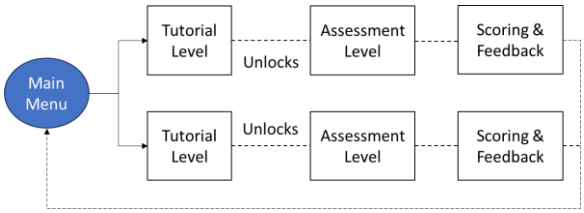

Figure 3. Game flow and level structure used.

The game brings the participants across different situations where safety training can be taught and tested. Within the same construction environment, that can be exported directly from BIM for additional user immersion, a large variety of scenarios can be proposed to imitate even the less plausible hazard profiles. While the safety training focused on traffic and crane operations, additional safety training elements of more generic nature can be added. For example, as shown in Figure 4, signage awareness or construction debris removal can be incorporated.

After the completion of an assessment phase, the participants are scored based on their performance, behavior, and interactions with the built environment. Performance is scored based on timing, behavior is scored around whether a set of safety tasks are done or not, and the interactions with the built environment are built as penalties (i.e., ignoring signage results in a loss of points). A final score is provided to the participant, with some feedback regarding potential improvement or where the participant was penalized. Then, the score is uploaded onto the leaderboard.

Once the participants are done playing with the game, about 40 to 45 minutes, a post-test questionnaire is given to each participant to fill. This questionnaire focuses not just on the learning experience, the game development, or the effectiveness and drawbacks of using serious gaming for safety training but also on prior engagement with safety training methods and current practice.

Figure 5. Signage included in the construction scenario for safety training.

RESULTS

This study and its protocol have received full ethical approval from the Northumbria University ethics online system (project ID: 5567). All participants gave permission to use the collected data. Initially, a personal assessment of the participants' professional experience and prior experience with safety training is provided. It allows us to showcase a better understanding of the participants and potential biases introduced by the population subconsciously. Figure 5 illustrates those results (left to right) for work experience, participant professional active field or background, and their prior experience with video games and safety training methods respectively. Note that the population is slightly biased towards early career professionals, with a current role in architecture or engineering. This will be addressed in

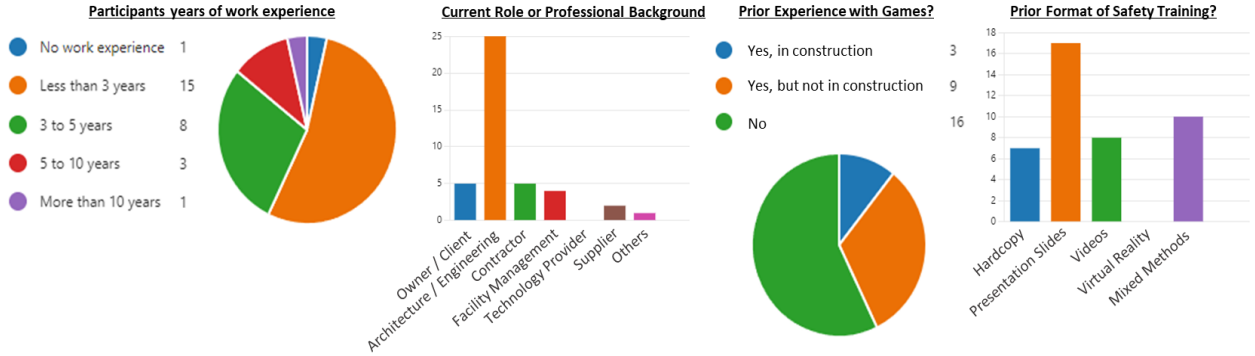

Figure 4. Experiment population data.

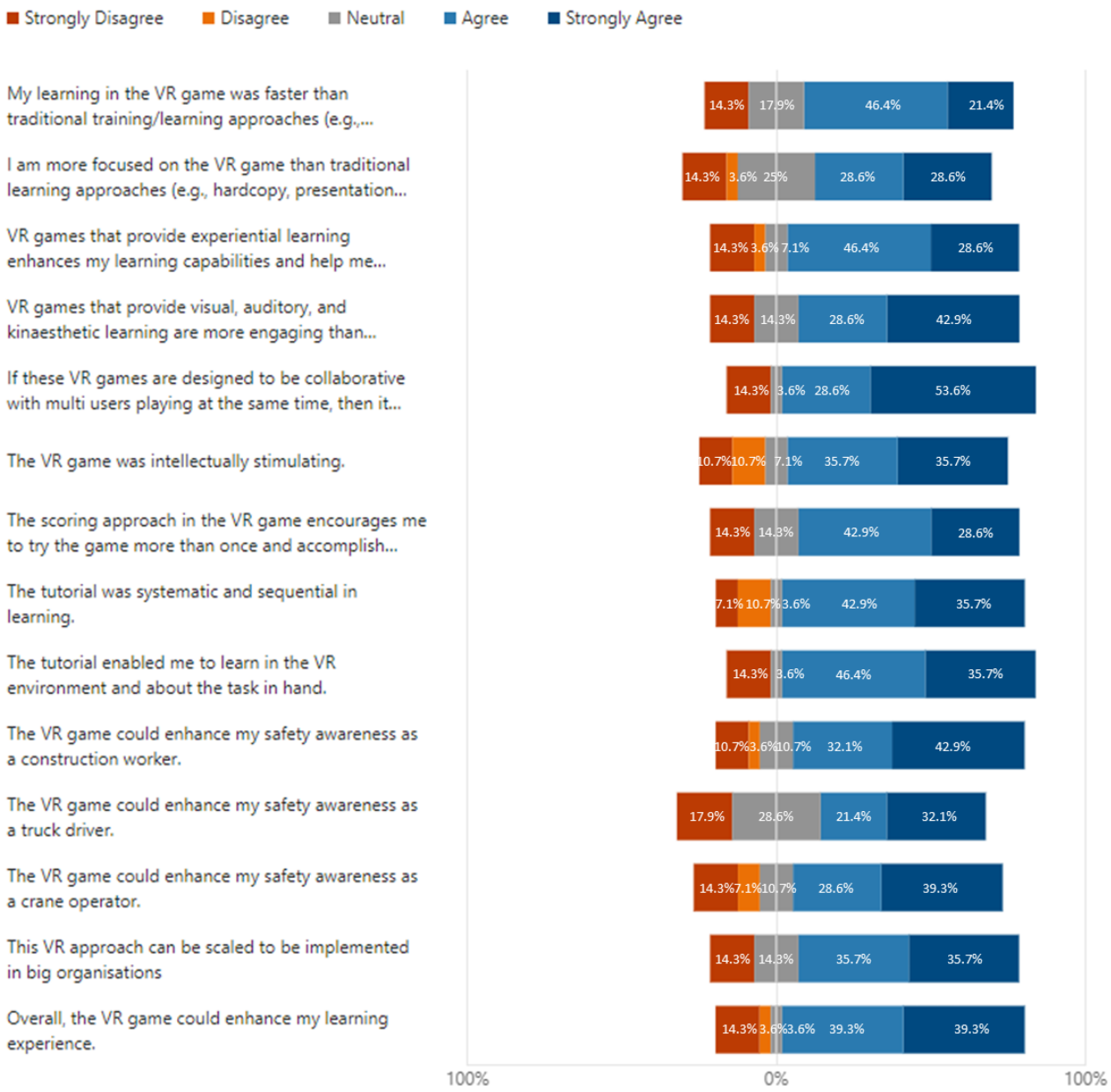

Figure 6. Participants' answers to the final questionnaire.

further experimental testing to provide a more homogenous population.

The results from the quasi-experiment can be found in Figure 6. Participants answered a series of questions using a 5-step Likert scale (1 – Strongly Disagree; 2 – Disagree; 3 – Neutral; 4 – Agree; 5 – Strongly Agree). Overall, the participants reacted positively to safety training through gaming instead of more traditional learning methods. Table 1 showcases the statistical analysis of the results obtained per question, in the order shown in Figure 6.

Table 1. Statistics of the questionnaire results.

	Questionnaire Results	
	Median	**Std. Deviation**
Question 1	4	1.235
Question 2	4	1.322
Question 3	4	1.305
Question 4	4	1.355
Question 5	5	1.361
Question 6	4	1.326
Question 7	4	1.278
Question 8	4	1.205
Question 9	4	1.291
Question 10	4	1.280
Question 11	4	1.402
Question 12	4	1.411
Question 13	4	1.319
Question 14	4	1.82

Based on the results obtained, on average, the learning experience of the professionals questioned is positive. The

gamification approach is seen as an improvement of current approaches and can potentially increase safety awareness and training capabilities for operators/workers. The questionnaire results highlight the value given by the users of the collaborative aspect of the game (question 5), the immersion (question 4), and the increase in safety awareness when compared to traditional training delivery (question 10). Note that most professionals agree that the technology is scalable to an organization level.

However, more divisive results are obtained for certain questions: a more average neutral stance is given towards the efficacy of engagement and focus during the training of the game users compared to current approaches and the overall view of the game from a learning perspective is relatively neutral. Regarding those points, the participants could further elaborate on. Their feedback on possible improvements is listed below:

- Considering adding a story mode that simulates certification.
- Incorporating multiplayer.
- Improved tutorials for a broader range of users (especially non-gamers).
- Clearer instructions and transparency on the scoring system.
- Providing different camera angles instead of only first-person point of view.
- Better details and graphics for additional immersion, especially sound.

Separating the comments on improved technical performance, some of the desired improvements are of a complex nature. Developing certifications or learning assessments in a multiplayer environment would be an interesting challenge. While it challenges the idea of individual knowledge testing, it would probably be a more realistic representation of safety considerations and efforts on construction sites. As safety on sites is not an individual responsibility, could training be more effective in collaborative environments? Further research to explore feedback provided and perform more extensive evaluations on the potential of gamification will be pursued.

STUDY LIMITATIONS

The showcased study is a preliminary work to understand the impact of serious gaming on safety perceptions and training around hazards on construction sites, however the results obtained have to taken with the consideration of certain limitations in the scope and untested biases that can be accounted for.

For example, how the novelty of the serious gaming experience is affecting the perception of the usefulness of the approach by the users is uncertain. Or how the safety perception given by the gaming experience is translate onto the physical world. In the end, even the gaming optics of the criteria used to develop the training scenarios or even the scenarios themselves may had an impact on the experience outcomes that is uncertain.

Overall, multiple variables that would need to be accounted for are not considered in this study and should definitely be included in the experiment planning and posterior analysis to come up to more decisive conclusions.

CONCLUSIONS

The study's investigation into the use of serious gaming for construction safety training presents innovative findings. It demonstrates that gamification significantly enhances professionals' engagement, motivation, and safety awareness, offering a novel approach to addressing the complexities and hazards inherent in construction environments. The positive reception of the game's immersive and interactive features encourages a pivotal shift towards more dynamic training methodologies. This research enriches the academic discourse on educational technology by applying gamification within a novel context. It also provides evidence of its potential to revolutionize traditional safety training practices in construction. It underscores the efficacy of serious gaming in improving learning outcomes, thereby advocating for its integration into standard training protocols to better meet the evolving demands of the construction industry. The study outlines several pathways for future research, including enhancing game functionalities, exploring gamification's long-term impact on safety practices, and its scalability and cost-effectiveness. These potential avenues demonstrate further the role of serious gaming in professional education and its potential to transform safety training in construction and other sectors.

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