

Innovating Occupational Safety Training

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Digital games have been successfully applied in different working sectors as a highly-engaging occupational safety training method. Nonetheless, they found a very limited application in agriculture. Engagement in safety training is widely acknowledged to play a pivotal role in promoting occupational safety in the agricultural sector. Based on a scoping review of 42 studies, the present entry discusses how occupational risks are addressed during game-based safety training in different productive sectors and how this can be transferred to agriculture.

agriculture

gamification

human-work system interaction

safety

serious game

training engagement

E-learning

1. Introduction

In several working environments, workers are exposed to on-site hazards which can result in fatalities and serious injuries^[1]. Despite improvements in working conditions, the high number of unintentional injuries reported in different industrial and productive working sectors continues to represent a relevant issue^[2]. Thus, the promotion of safety behaviors and the need to increase the employees' risk perception in the workplace has become one of the primary focuses. Previous studies^{[2][3]} proved that adequate safety training promotes workers' involvement in safety behaviors both at individual and group level, reduces employees' perception of work stress, and increases safety commitment and injury prevention^[2].

To deliver safety and health training, several methods are used^[4] and they can be more or less passive. The least engaging methods include lecture, adoption of videos, and written materials as pamphlets, whereas progressively more engaging training methods consist of feedback interventions, computer-based instructions associated with hands-on demonstrations, and finally behavioral simulation as the most engaging training method^[5]. As stated by^[5], a more engaging training method allows greater knowledge acquisition and more transfer of training to the work setting, thereby improving behavioral safety performance and reducing negative safety and health outcomes. Unfortunately, highly engaging safety training methods such as hands-on demonstrations are considered rather costly compared with other less engaging safety training methods. Thus, despite its low level of engagement, the most common safety training method is represented by lectures^[6].

More recently, new forms of occupational safety training are emerging and different approaches have been implemented^[1] especially with the aim to make safety training less passive and more engaging. Indeed, thanks to the use of technology, training has become more flexible in terms of time management, and it is a cost-effective

alternative to practice since it can provide realistic and effective simulations of real-life experiences^[7]. In particular, digital games are creating a more exciting, engaging, and interactive learning experience, enhancing the process of learning in terms of practice by means of simulations in a “safe” virtual environment. Often the convenience of the virtuality is to permit mistakes during training for a safety-critical system.

Several simulation tools and software applications identified with the name of “serious games” or “gamification” tools have been developed^[8] and can be differently defined. In brief, serious games represent real-world processes and events with the purpose of solving a problem, but they are more similar to classic video games; whereas gamification tool is a more recent method and refers to applying game thinking, and elements to a non-traditionally ludic context^[9], providing also rewards and incentives in forms of points, badges, and virtual goods to increase players’ motivation to find effective problem-solving strategies^[9]. Moreover, a game system is made up of specific frameworks of game design, that are game mechanics and dynamics: game mechanics represent the main elements of the game and have the power to guide the player action (e.g., points, levels, discovery, etc.), whereas game dynamics can be described as players’ interaction with mechanics and the satisfaction of their desires (e.g., achievements, competitions, rewards, etc.)^[10].

Previous studies showed that serious games and gamified learning methods have been particularly and successfully applied in different business fields [9] and in sectors where technologies and mobile applications are used, such as automotive manufacturing^[11], occupational health settings including medicine, surgery, and rehabilitation^[12], sports (e.g., baseball^[13]) and in hazardous working sectors such as firefighting^[14], construction^[1] and mining^[14].

1.1 Safety Training in Agriculture

Agriculture is worldwide recognized as one of the most hazardous productive sectors^[15]. The high risk of fatal or non-fatal injuries is due to the large variability of the tasks the operators have to perform, depending on crops, operations (seeding, weeding, harvesting, etc.), the machinery and tools adopted, the, sometimes extreme, weather and climate conditions they have to be carried out with, and the daily and seasonal exposure, as well as the lack of a strict standardization of the work in general.

Engaging workers in safety training is widely acknowledged to play a pivotal role in promoting occupational safety behaviors in the agricultural sector^[16]. Regarding this, earlier research has proved that adopting visual tools and adding visual features to the training material is appreciated and can increase the level of workers’ engagement^[16]. Nevertheless, safety training in agriculture still takes place using traditional and conventional methods such as lectures and classroom activities in which trainers use displays, pamphlets, and posters to integrate their verbal explanation^[7].

Agriculture does not seem to go at the same speed as other sectors in the development and application of new technologies^[17], including innovative methods for workers’ safety training. To our knowledge, a few studies focused

on games as a safety training method: the studies conducted by^{[18][19]} deal with agricultural machinery driving training and the need to motivate operators toward changing attitudes and thinking about safety behaviors.

However, the risks in agriculture are not only linked to driving activities, but to many other factors, and the unintentional injuries that occur, share similar dynamics with other occupational sectors. A work system indeed includes “one or more workers and work equipment acting together to perform the system function, in the workspace, in the work environment, under the conditions imposed by the work tasks”^[20] (p.2) and each interaction between these components deserves attention since it may be a potential source of risk. In several workplaces, it is important to educate and train workers to identify mechanical risks (injuries of cuts and/or crushing caused by machinery use), to manage dangerous situations and follow correct procedures in case of fire or presence of dangerous substances, to use adequate personal protective equipment (PPE) and finally, to coordinate or manage rescue activities. Therefore, it is useful to understand how these risks are addressed during training where game-based interventions have been adopted in sectors other than agriculture, to understand how the difficulties and the obstacles during the training are solved, and to propose possible applications in the agricultural sector.

2. Review of evidence

A scoping review was performed on 42 studies. The results showed that literature has begun to mention the terms “gamification” and “serious games” in occupational sectors from 2007 and, afterward, a higher number of studies have been successfully conducted, especially in the last three years. Gamification has been applied to train workers in many sectors and the topics discussed concerned the main types of risks and avoidance behaviors that may also be encountered in agriculture, in the interaction with equipment and machinery, environment, work procedures, and other workers.

Overall, the capability of engaging users and the potentiality that this type of technology can offer were undoubtedly highlighted in many studies retained in the present review^{[1][21][22]}. Three main technologies were detected: computer games, virtual reality (VR), and augmented reality (AR) (which also includes mixed-reality - MR). Computer game training is recognized as being able to overcome three main limitations compared with traditional methods: “limited representation of the actual workplace situations”, “limited consideration for workers who have low literacy” and “failure in maintaining trainees’ attention”^[1] (p. 109). In research in which game-based training was compared with traditional methods (i.e., videos or power-point presentations), the digital games (using both computers or other devices) resulted to be more engaging and the participants reported higher levels of knowledge after having received the training^[23], and higher levels of satisfaction. Similarly, in those games in which the effectiveness was evaluated only through the game performance, the game training was defined as interesting, intuitive, enjoyable, able to offer a funny learning experience, and to hold the users’ attention. In some studies, when participants were asked if they were interested in playing the game again, favorable responses have always been given. However, despite the game-based training being able to recreate the working environments and the worker’s decision-making processes, in some occupational sectors such as mining, the players may be satisfied with their gameplay performance, but they also may complain about the impossibility of interacting with real materials^[23]. In addition, although participants reported stronger emotional responses when comparing the VR

technology with the computer-desktop display, some of the retained studies reported that dizziness restricted the time of the game tests, representing one of the main factors that hinder the popularity of VR technology.

When considering other factors limiting the adoption of game technologies as a training method, it should be considered that different technologies may not have the same costs^[24]. The studies analyzed in the review did not expressly mention the related costs, however, in the case of virtual and augmented reality technologies, the adoption of high-performance 3D projectors and running a cluster of computers requires high costs of purchasing and service, which cannot be borne by all types of organizations/institutions^[24]. Thus, the game platform and the respective technology must be chosen based on the availability and possibility of the training organization.

Regarding the game frameworks, the designers applied a limited number of game mechanics and interface elements. Overall, the game mechanics included, by and large, “points”, “challenges” and “levels”. Future projects could use more complex game mechanics solutions, and a wide variety of interface elements and rewards can be mixed. Moreover, it can be further investigated how the environmental features can affect and/or improve the playability and the game mechanics. Additional features such as environmental details and Non-Player Characters (NPCs), allowed keeping the training session more enjoyable and immersive^[25]. However, in the retained studies, these features were explored only in the research conducted by^[26]. Indeed, the design of NPCs, specific weather conditions, and the addition of physical elements (e.g., smoke) that are perceived as authentic by the players, is a critical success factor in the development of an engaging educational game ^[27], especially when a multiplayer game version is not yet available. Providing the player with interactive choices, the use of symbols and/or dialogue, and interactions with NPCs can establish an emotional link between the player, the other characters, and the environment^[26]. Based on this, we hypothesize also that a nonlinear-gameplay adoption, in which the game story proceeds following the player’s choices or player’s success or failure at a specific challenge and the possibility of multiple endings, can positively increase the dramatic effect and the attention of players^[26]. Concerning the agricultural sector, even though many activities are carried out by the operators alone, some other activities require the operators’ cooperation, exposing them to the risk of injuries. Therefore, it could be interesting to provide specific details of the surrounding environment and develop more NPCs to successfully complete complex tasks with them. Furthermore, NPCs may be used to simulate the mental pressure exerted by supervisors on workers: being able to experience these kinds of situations within a video game may lead to significant changes in social relationships between farm operators.

2.1. Recommendations for the design of gamified safety training in agriculture

In light of the results discussed, some insights are provided to develop an effective, satisfying, and engaging safety game-based training for workers employed in agriculture:

- even though different technological supports (computer, VR and AR) have proved to be effective and satisfactory^{[26][27]}, the computer game technology can be detected as the most used and “practicable” one, in terms of ease of use, play rules (e.g., the game could be downloaded and can be played on one’s own personal computer) and costs;

- the game may allow the players to look around to become aware of their environment and has to be able to recreate the decision-making processes that operators encounter in different hazardous situations, with the aim to improve operators' capability to react to hazards in real situations^{[28][29]};
- games should be developed with multiple levels and should be structured with different and increasing levels of difficulty to be more appreciated^[21];
- the game scene needs to be well contextualized within a suitably designed work environment allowing the player to identify specific hazards^{[26][28]};
- simulated characters (NPCs) should be present since they motivate trainees by being credible, trusting, and helpful ^{[18][26]};
- the game should have simple gameplay with few core activities and a limited set of core game mechanics, but with some variations in tasks, since introducing new little elements allows to enhance the challenge and sustains the motivation during the game^[30];
- the game could be based on rewards to increase players' engagement^[31];
- the game should give the players the possibility to practice their skills, through a "trial and error" approach, and ultimately win, to increase motivation and engagement^[32];
- players must be allowed to retry as many times as necessary to complete the game; however, the total playing time for the computer-game must not exceed one hour, in order not to be boring or frustrating^[33].

Some research questions for future studies in agriculture but also in the other occupational sectors can be identified based on the reviewed literature. In particular, which is the role played by individual variability in terms of gender, age, nationality, and level of working experience (i.e., novice or expert) when assessing game usability and/or satisfaction and/or effectiveness? Indeed, previous studies showed that all these variables can affect attitudes toward technology adoption and how people interact with technologies.

In addition, considering the growing interest in this innovative training and the existence of different technologies that can be used for such purposes, future studies may perform a comparison between these technologies. For instance, previous literature on gaming confirms that no differences can be found in players' performance and game usability between immersive and non-immersive games^[34]. Whereas, in contrast, other results reported that better performance was achieved using computer-desktop digital games rather than VR methods^[35]. It would be relevant to understand whether certain types of skills can be better acquired by adopting a simple computer game or by using a more complex augmented reality or virtual reality equipment.

Regarding the insights provided here for the development of game-based training in agriculture, we acknowledge that they are only a starting point, and future studies may be developed to adapt different game mechanics to specific farm characteristics and operations, in specific environmental conditions (e.g., adverse climatic and weather conditions, presence of slopes or different kinds of terrain). In addition, it should be considered that training can solve many safety issues, helping workers to recognize hazards and risks in the workplace and to avoid them. However, there are other sources of stress in agriculture—as working alone for farmers^[36] or pressure from supervisors in the case of farmworkers, pressure from governmental regulations, financial and management issues and lack of control^[37], poor safety attitudes—that can contribute to unintentional injuries occurrence and should be tackled not only through training but through targeted multi-level interventions.

In conclusion, the present review showed that digital games can represent an effective and satisfying alternative to hands-on demonstrations, and gamified safety training in agriculture may be developed starting from previous experiences in other sectors since gamification has been adopted to address risks and behaviors which correspond to safety needs in agriculture.

In today's scenario, learning methods have become increasingly digitalized and e-learning, in particular, is becoming much more appreciated for its flexibility, availability without space and time constraints, and cost-effectiveness. Due to the dynamics developed during the COVID-19 pandemic period, the use of digital platforms has doubled and prove to be an effective instrument to train workers. The general perception of the usefulness of games to support learning will certainly improve over the next few years; we believe that research should no longer focus on whether games may be used for learning, but instead should investigate how games can be best used for learning.

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