

Building is On Fire: A Game for Fire Extinguishers Safety Training in the Construction Industry

João Pedro Gil Brandão¹, Tadeu Moreira de Classe¹,
Roberto Rufino Júnior^{1,3}, Ronney Moreira de Castro²

¹Research Group in Games to Complex Contexts (JOCCOM)
Department of Applied Informatics (DIA)
Federal University of the State of Rio de Janeiro (UNIRIO)
Rio de Janeiro – Brazil

²Department of Computer Science (DCC)
Federal University of Juiz de Fora (UFJF)
Juiz de Fora – Brazil

³Petróleo Brasileiro S.A. (PETROBRAS)
Rio de Janeiro – Brazil

{joao.brandao, tadeu.classe}@uniriotec.br
roberto.rufino@edu.unirio.br, ronney.castro@ufjf.br

Abstract. *Work accidents affect thousands of people in the industry every year, and the most efficient way to reduce them is to apply more interesting and engaging safety training sessions. Thus, developing and using games for safety training purposes is an innovative idea for this problem. In this article, using the SafetyPlay Game Design method, we create a game for fire extinguisher safety training for the construction industry. We validated the game with two civil engineers, specialists in fire training, who considered it an excellent manner to help workers in this training scenario.*

Keywords: *Fire Extinguishers, Game with a Purpose, Safety Training, Construction Industry, Games for Safety Training in Industry.*

1. Introduction

Annually, work accidents in the industrial context kill thousands of people. The International Labour Organization (ILO) measures that three million workers lose their lives in work activities every year [ILO 2023]. Between 2012 and 2021, Brazil recorded 6.2 million work accidents, with 23 thousand deaths [UN 2022].

Safety training sessions efficiently reduce work accidents, giving workers the knowledge and abilities to perform their labor activities [Venturi et al. 2021]. However, traditional safety training methods (e.g., speeches, videos, books) fail to help workers perceive and judge the best action in hazards in the work environments, increasing the odds of severe accidents [Correa and Cardoso Junior 2007].

Another problem in traditional training is the participants' lack of interest and engagement in the training sessions [Correa and Cardoso Junior 2007]. This problem is attributed to the passivity of the training process, which fails to create a sense of belonging and relevance in workers. Therefore, this problem brings opportunities to design safety training sessions that are more interactive and engaging in the industrial contexts, simulating hazard scenarios and improving workers' participation in the training process [Brown and Poulton 2018, Rufino Júnior et al. 2024, Lopes et al. 2024].

Considering it, digital games are an interesting approach to motivating workers in safety training sessions due to their capabilities to promote immersion and ludicity in learning scenarios [Rufino Júnior et al. 2023]. However, we must clarify that games for safety training sessions will not replace traditional training in the industry but will enrich the training process with interactive and motivational resources, being additional instruments for improving engagement and knowledge retention [Alyamani et al. 2023].

This paper aims to present the design and validation of the game BRBiF (BobRuff in Building is on Fire). In case of acceptance, we will change to the game's real name. We designed the game considering the safety training scenario for fire extinguishers in the construction industry. We designed the game following the SafetyPlay Game Design method (SpGD) [Rufino Júnior et al. 2023], which was specially developed to support the design of games for safety training purposes. As validation, we evaluated the game with two civil engineers, specialists in fire training, to check whether the game correctly represented the fire extinguisher rules and ways of use.

Thus, we separate this article into Section 2 approaches the SpGD method as our work methodology. Section 3, shows how we designed the game following SpGD steps. Section 4 presents the game validation with engineers. Finally, Section 5, the final remarks.

2. Work Methodology

According to the context of this article, we chose to use the SpGD method as our methodological guide for designing the safety training game, considering the context of fire extinguisher training. We chose the method once they were created specifically to support the design of this kind of game (games for training).

Rufino Junior [2023] built the SpGD to guide game development teams in creating games for safety training purposes. The method (Figure 1) starts when an industrial department demands a game to support workers in a specific safety training session.

The first task, **understanding the training context**, aims to guide the game design team, industrial managers, and workers to the same comprehension of the training context. The method uses Kirkpatrick's model for training evaluation [Kirkpatrick and Kirkpatrick 2016] to support the training understanding, considering its levels: reaction, learning, behavior, and results. Industry and organizations use Kirkpatrick's model for training in general; the SpGD adds the level of risks above the level of results once the method's purpose is to create a game for safety training.

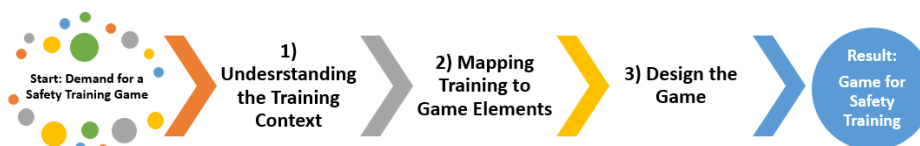


Figure 1. SpGD method (Adapted from Rufino Júnior and Classe [2024]).

The goal of the second activity, **mapping training to game elements**, is to translate the training elements allocated to each Kirkpatrick's level into game elements. This translation suggests using game design frameworks or methods to associate training elements. In this article, we used the elements of the MDA framework [Hunicke et al. 2004] (mechanics, dynamics, and aesthetics), associating them to Kirkpatrick's levels. This step is also performed by game designers, organizational managers, and workers to maintain the same understanding and avoid misconceptions related to the training context.

Lastly, **the design of the game**, the game design team (designers, artists, programmers, etc.) builds the game considering the previous steps. Even though the game design team is responsible for performing the step, managers and workers must observe the process for the best training representation in the game world.

3. Building is on Fire

3.1. Understanding the Training Context

For this work, we choose the scenario of fire extinguisher safety training in the construction industry. For this context, we followed all rules and norms of the ISO 7165-2017¹ that guides the types of extinguishers and what of them should be used for each type of fire source. Also, we hear from the managers and workers about what they expect in this specific training. Although this is a simple context, they illustrate all the steps of designing the game for this purpose.

As defined in SpGD, we filled all Kirkpatrick's levels regarding the fire extinguisher training (Table 1). Also, considering managers' and workers' answers about the training, we could describe the most important aspects they expect in fire extinguisher training. For instance, we can observe that workers must know the types of fire and what kind of extinguisher must be used for each case (learning); what metrics organizations observe to evaluate whether the workers concluded the training with success (results); and the most important, what are the risk involved in fire situations.

Table 1. Understanding the training contex

Kirkpatrick's level	Expeted result
5 - Risks	Explosion risk
	Burns risk
	Life risk
	Environmental risk
	Financial risk
4 - Results	We measure the fire extinguishing rate.
	We measure from the rate of identified fire focus.
	We measure from explosions of accidents rate.
3 - Behavior	We expect that participants could make the best decisions.
	We expect participants to think about situations.
	We expect that participants be calm and safe to fight against the fire.
2 - Learning	They must know the type of fire extinguishers (type A - whater, B - carbon dioxide or C - chemical dust).
	They must know the type of fire source (solids, flammable, electrical)
	They must use the correct type of extinguisher for each type of fire source (A: solids; B and C: carbon dioxide; A, B and C: chemical dust)
1 - Reaction	Participants must be alert about the type of fire source.
	We expect that participants will be interested in training, immersed in the situation, and react quickly to the fire. We expected the participants to be engaged and satisfied with their actions to solve the problem.

3.2. Mapping Training to Game Elements

Secondly, we performed the mapping training elements with managers and workers. As we mentioned, we aligned Kirkpatrick's level to MDA elements. As suggested by Rufino Júnior and Classe [2024], we also considered mapping (Figure 2(A)): 1) Reaction to Aesthetics; 2) Learning to Mechanics; 3) Behavior to Aesthetics and Dynamics; 4) Results to Aesthetics; and 5) Risks to Aesthetics and Mechanics.

3.3. Designing the Game

After the element mapping, the game design team worked on the game. Our first game decision was to represent the construction scenario using 3D space. This choice is because we wanted to approximate the game world to a real construction environment. We developed

¹https://webstore.ansi.org/preview-pages/ISO/preview_ISO+7165-2017.pdf

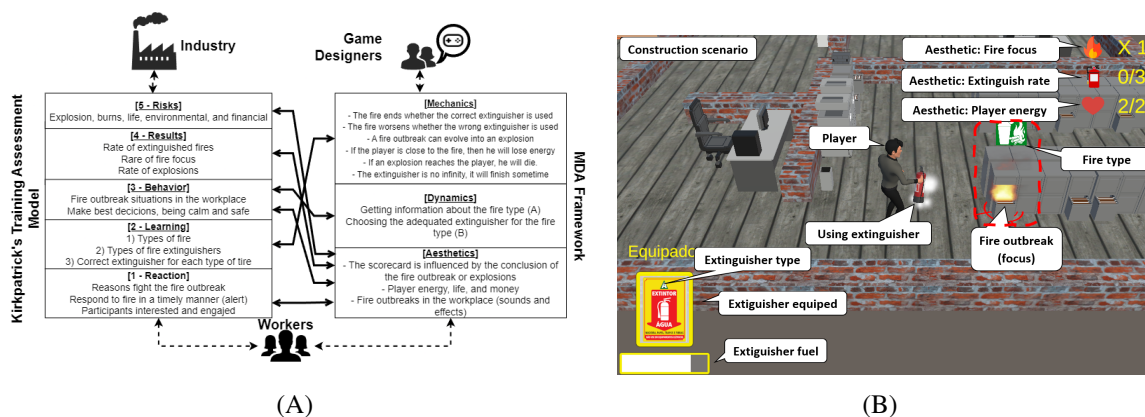


Figure 2. BRBiF Game: A) Mapping Elements (Design). B) Gameplay

the game in Unity 3D², choosing the game build settings as HTML5 (Web) because it is the easiest way for workers to play it in a browser from any computer with the Internet.

Figure 2(B) shows an example of the BRBiF's game screen³. In the figure, it is possible to observe elements that were described in the mapping elements (Figure 2(A)), such as aesthetics elements (fire rates and play energy), type of fire, fire extinguishers, and its type and fuel, the player grabbing the fire extinguisher and using it, and the scenario of the construction industry as the game world.

4. Validation with Managers

Validation with organization managers is essential to guarantee that the training information is in the game and presented correctly. Game designers, managers, and workers work together using the SpGD method. However, only with the game validation can it bring trust to run it in training sessions, ensuring that workers/trainers will not misconception training information.

We validated the game based on two civil engineers' perceptions (a man and a woman), specialists in fire training in construction, regarding their knowledge and skills in training sessions for fire extinguishers. We selected them by convenience because they were available to participate. They played the game and answered a survey based on MEEGA+ [Petri and von Wangenheim 2019], giving answers based on a Likert scale of 5 items that ranged from -2 (totally disagree) to 2 (totally agree). Thus, we could analyze their perceptions of the game in terms of usability, trust, challenge, satisfaction, fun, focused attention, relevance, and learning.

Figure 3 shows the engineers' perceptions. We had to summarize their answers in each dimension by calculating the statistical average. We also calculated the general perception using each dimension's average of engineers' answers.

As we can observe, engineers generally agreed with several affirmations about the game (average above 1– partially agree) in the dimensions of fun, satisfaction, focused attention, relevance, and learning. This result indicates that the game covered the main aspects of Kirkpatrick's level that we analyzed in the first step of SpGD, considering reaction level – engagement and immersion (focused attention and fun), satisfaction; learning level: learning and relevance perception; and behavior and risks levels: relevance.

²<https://unity.com>

³The game is available at: <https://jocom.uniriotec.br/games/buildfire/>

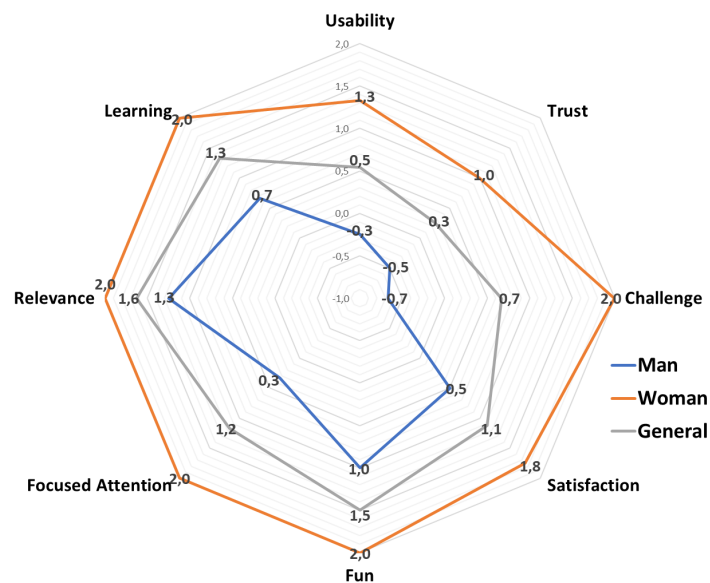


Figure 3. Validation with civil engineers.

On the other hand, they had a borderline perception (near to 0 – I do not agree nor disagree) related to usability, trust, and challenge. In terms of usability, they indicate that the game is unattractive and that text and font colors should be improved. This affirmation makes sense for us once the game is still a prototype. Regarding trust, it seems like the first impression did not let the perception that the game could help the participant learn, which is not valid if we observe the learning dimension. Lastly, regarding the challenge dimension, the male engineer considered the game pretty hard and did not present new challenges, considering the rhythm of the player learning new skills.

Even though we recognize that the game needs improvements in those dimensions for future versions, we also understand that the civil engineering specialists validated the game. The game could approach several aspects related to the training context that we identified with SpGD, and we also think that it is a good manner to innovate training sessions, considering the context of fire extinguishers training.

5. Final Remarks

In this article, we presented and validated the game BRBiF, designed for fire extinguisher safety training in the construction industry. We created the game using the SpGD framework, which considers understanding the training context, aligning training aspects to game elements, and programming the game. In the end, we performed the game validation with two civil engineers, asking for their perception of the game and its purpose.

As a result, although the game was a prototype, engineers had good perceptions of it as a training tool for fire extinguishers. However, the new versions need usability, trust, and challenges improvements. As a limitation, we understand that we must assess the game with more people (engineers and workers) in the construction industry. We intend to perform this in future steps of this research.

Apart from limitations and improvements, we observed evidence that games with safety training can help several industries that need to innovate their training processes. Therefore, we believe this article could help researchers as an application sample and collaborate with them on ideas for new games for training purposes in the industry.

References

- Alyamani, H., Alharbi, N., Roboey, A., and Kavakli, M. (2023). The impact of gamifications and serious games on driving under unfamiliar traffic regulations. *Applied Sciences*, 13(5):3262.
- Brown, L. D. and Poulton, M. M. (2018). Improving safety training through gamification: An analysis of gaming attributes and design prototypes. In *International Conference on Applied Human Factors and Ergonomics*, pages 392–403, Orlando. Springer, Springer.
- Correa, C. R. P. and Cardoso Junior, M. M. (2007). Análise e classificação dos fatores humanos nos acidentes industriais. *Production*, 17:186–198.
- Hunicke, R., LeBlanc, M., Zubek, R., et al. (2004). Mda: A formal approach to game design and game research. In *Proceedings of the AAAI Workshop on Challenges in Game AI*, volume 4, page 1722. San Jose, CA.
- ILO (2023). Ilo - quase 3 milhões de pessoas morrem devido a acidentes e doenças relacionados ao trabalho. ilo, 2023. Available at: <https://bit.ly/438xK3A>. Accessed: March 06 2024.
- Kirkpatrick, J. D. and Kirkpatrick, W. K. (2016). *Kirkpatrick's four levels of training evaluation*. Association for Talent Development.
- Lopes, T. N., Araujo, R. M. d., Classe, T. M. d., and Sant'Anna, F. d. S. (2024). Pyp4training: designing digital games for business process training. *Business Process Management Journal*, 1(1).
- Petri, G. and von Wangenheim, C. G. (2019). Meega+: A method for the evaluation of the quality of games for computing education. *Proceedings of the SBGames, Rio de Janeiro, Brazil*, pages 28–31.
- Rufino Júnior, R., Classe, T., and Lima, C. (2023). Safetyplay game design - projetando jogos com propósito de treinamentos de segurança na indústria. In *Anais Estendidos do XXII Simpósio Brasileiro de Jogos e Entretenimento Digital*, pages 1161–1172. SBC.
- Rufino Júnior, R. and Classe, T. M. d. (2024). Safetyplay game design: Método para o design de jogos de treinamento de risco. *RelaTe-DIA*, 17(1).
- Rufino Júnior, R., Classe, T. M. d., and Lima, C. d. C. (2024). Games with safety training purposes in the industry: Game design method and its demonstration. *Journal on Interactive Systems*, 15(1).
- UN (2022). Un - acidentes de trabalho e mortes acidentais crescem no brasil em 2021. un news, 2022. Available at: <https://news.un.org/pt/story/2022/04/1787092#>. Accessed: June 02 2024.
- Venturi, D., Konell, A. E., and Giovanela, A. (2021). Treinamento: importância e benefícios da disponibilização de treinamento nas organizações. *REVISTA CIENTÍFICA FAMAP*, 1(01).