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Could Gameplay Data of Games with a Purpose Assist in Training Hazardous Situations in the Industry?

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Abstract Accidents and risks in the industry pose significant challenges concerning executing critical tasks. Inadequate employee training compromises the ability to manage risks, making the environment prone to accidents. In this context, games with training purposes emerge as a promising solution, providing an interactive and immersive environment. Focusing on improved risk management, organizational managers can utilize data collected by these games as metrics for monitoring and enhancement. However, it is necessary to understand how games with a purpose can contribute to the training process for hazardous situations in the industry. With this in mind, this study investigates the topic by exploring both the literature through a systematic mapping and the perceptions of workers from an oil and gas industry through a survey. As a result of the investigations, techniques for analyzing and visualizing gameplay data obtained from training games, design elements, game genres, and primary usage contexts were identified. Additionally, it was possible to analyze workers' perceptions from the oil and gas industry of how these games and their data can add value and contribute to safety training sections within their workplaces. Therefore, there were indications that games with a purpose, combined with data analysis and visualization techniques, can offer a new perspective for conducting and evaluating training, providing information that contributes to improving work quality indices and reducing severe accident risks within the industry.

Keywords: Games With a Purpose, Safety Training, Hazard Training, Gameplay Data, Industry.

1 Introduction

Industrial activities are essential for the economic and social development of any country. In Brazil, in 2020, the sector created R$ 4.6 billion (IBGE, 2023). The whole world has faced issues related to accidents and significant human and environmental losses. For instance, in 2021, the number of work accidents in the Brazilian industrial sector reached the harmful mark of 571.800, with 506 fatal victims (Ruppenthal, 2013; BRASIL, 2021). In 2022, 612 thousand accidents were registered (EBC, 2022).

Understanding the risk context, adequately assessing scenarios, and adopting prevention measures are crucial to avoiding accidents. Nevertheless, it is not enough to only identify and analyze these situations. The correct training process for workers is essential to prevent industrial accidents (Thabit and Younus, 2018). Through continuous training, workers can recognize risk situations, adopt good safety practices, and correctly act in emergencies (Nazir *et al*., 2015; Salas and Cannon-Bowers, 2001). Therefore, it is important to invest in training sessions to guarantee a safe workplace and prevent industrial accidents (Nazir *et al*., 2015).

Games with a purpose are widely used as formative tools for learning in different domains, from the educational field to business training contexts (Von Ahn, 2006). However, independent of the context, assessing the game's efficacy is challenging. There is a real need to adopt and build methods and techniques for data analysis related to gameplay data to improve the context assessment, mainly in training contexts (Bachvarova *et al*., 2012). It is a subject that needs more attention in the field of serious game study (Haoran *et al*., 2019).

Adopting a game with a purpose in training contexts creates a large amount of data that can be used to support decision-making in an organization and assess a trained person (El-Nasr *et al*., 2016). The match with games with a purpose, data extraction techniques, and data processing and visualization methods can provide new training perspectives and innovative ways to evaluate trainees. Furthermore, games offer interactive and immersive experiences that help develop essential skills for preventing accidents and promoting the culture of safety (Nazir *et al*., 2015; Yannakakis and Togelius, 2018).

In this context, when we think about on **how games with a purpose and their gameplay data can contribute to the training of hazardous situations in the industry**, it is necessary to seek information about the state of the art both in scientific literature and professional environment. Therefore, the primary goal in this article is to look into 1) academic studies of how games with safety training purposes were used in industrial contexts, considering game genres and elements, and how their gameplay data were got and used to help training sessions; and 2) professional perceptions from people in the industry about how these games and their data can contribute to the improvement of training sessions.

The first investigation involved systematic mapping of the literature (SML). In this part of the study, we found 846 studies searching academic sources, but only 10 were accepted after a rigorous review. In the second investigation, we carried out a survey-based exploratory study, which involved the participation of 30 professionals who had participated in some training sessions on hazardous situations in the industry. At last, with SML results and survey answers, we discussed the main issue addressed in this work (how can games with a purpose and their gameplay data contribute to the training of hazardous situations in the industry?).

This article contributes to understanding how games, as innovative and interactive technology, can support training sessions in hazardous situations based on the considerations of professionals who develop and live related activities in their jobs. The research showed perspectives that help to plan, implement, and analyze training sessions, give relevant information to managers, and improve the organizational environment.

This work is organized as follows: Section 2 provides the background for the research. Section 3 explains the methodological approach. Section 4 and Section 5 detail the SML and Survey results. Section 6 presents the discussion of the results of both studies. Section 7 includes the threats to the validity and limitations of the research. Finally, Section 8, final remarks.

2 Backgrounds

2.1 Risk Situations in the Industry

The probability of an unfavorable event occurring multiplied by the severity of the potential damage resulting from that event constitutes the widely accepted definition of risk in the industry. A thorough understanding and meticulous assessment of the risks inherent in industrial activities are crucial, not only to ensure the safety and well-being of workers but also to guarantee the continuity and operational efficiency of industrial facilities (Barizon and Braga, 2020).

Risk assessment emerges as a fundamental element within the framework of an organization's safety policies, directly influencing decision-making at all managerial levels (Marhavilas and Koulouriotis, 2008; Ruppenthal, 2013). This systematic process enables identifying, analyzing, and classifying risks associated with industrial operations, providing a solid foundation for developing mitigation strategies and emergency response plans (Huang *et al*., 2020).

In addition to technical and managerial aspects, the human factor plays a crucial role in industrial risk management. Adequate training and education of workers are essential to minimize human errors, often identified as a major cause of industrial accidents (Navarro, 2022). Well-structured and continuous training programs ensure that employees can recognize potential risks, act proactively in accident prevention, and respond effectively in emergencies (Huang *et al*., 2020).

However, effective management of industrial risks goes beyond accident prevention and control. It extends to environmental protection, ensuring product quality, preserving corporate image, and ensuring the company's financial sustainability (Riazanova, 2022). Adopting an integrated and multifaceted risk management system becomes a strategic must. This will align safety practices with larger corporate goals and help the organization be more resilient and competitive in a globalized market (Salvi *et al*., 2020).

In summary, industrial risk management is a complex and multidimensional practice that requires a holistic approach involving the integration of technology, processes, and people. Understanding and effectively mitigating risks is essential not only for the safety and health of workers but also for the operational and financial sustainability of the company. By implementing robust and dynamic risk management strategies, industrial organizations can prevent losses and damages and capitalize on opportunities, driving innovation and sustainable growth.

2.2 Extraction, Treatment, Analysis, and Data Visualization

Data acquisition involves collecting raw information, while data cleaning removes inconsistencies, inaccuracies, and errors in the collected data. The quality of these processes is crucial to ensuring the accuracy and integrity of the data (El-Nasr *et al*., 2016).

Data analysis plays a crucial role in understanding phenomena and patterns. Through analysis, it is possible to gain a deeper understanding of behaviors and patterns to enhance the system and support decision-making.

Data visualization is a powerful tool that allows the graphical representation of collected information. Tables, graphs, and other visual representations facilitate the interpretation of data, enabling the identification of trends, patterns, and discrepancies (El-Nasr *et al*., 2016; Midway, 2020).

Data analysis provides a foundation for making strategic decisions in developing and improving systems. When applied to digital games, it allows the identification of areas of interest, understanding of player behavior, and adapting the gaming experience to the preferences of the target audience (Frutos-Pascual and Zapirain, 2015; El-Nasr *et al*., 2016).

Data analysis techniques can be descriptive, predictive, or prescriptive. Descriptive analysis comprehends and summarizes data, identifying patterns, trends, and important characteristics. Predictive analysis makes forecasts and estimates based on historical patterns. Prescriptive analysis provides actionable recommendations and suggestions to optimize future outcomes (Roy *et al*., 2022).

Data extraction, cleaning, analysis, and visualization are essential for understanding and enhancing software. These processes enable obtaining valuable insights and making decisions more precisely and efficiently.

2.3 Digital Games as Innovative Systems to Safety Training

The use of digital games as a means of training in safety and security has been highlighted in various studies, pointing to their effectiveness in improving knowledge and refining the workforce's skills. Digital games as interactive tools are not only limited to educating children and adults but also promote a comprehensive understanding of the domains of safety and security (Jin *et al*., 2020; Khan *et al*., 2021). This evidence adds to the evidence that digital games are not only an innovative approach but also a powerful tool for safety training.

Furthermore, digital games' scope transcends traditional learning methods' limits, offering personalized experiences that raise awareness of critical issues such as security and cybersecurity (Jacobsen *et al*., 2022; Gasiba *et al*., 2021). The cumulative insights from these studies advocate the integration of digital games into security training paradigms, highlighting their ability to engage users and facilitate impactful learning experiences.

The strategic application of digital games in safety training, particularly in addressing cybersecurity challenges, highlights their ability to sensitize individuals to the nuances of safety standards, a crucial aspect in industrial contexts (Gasiba *et al*., 2020, 2021). In addition, construction safety training reveals the advantages of integrating virtual reality and physical simulations into training modules, thus offering a personalized and active learning environment (Jacobsen *et al*., 2022). Collectively, these studies support the notion that digital games, through their immersive and interactive nature, are a potential tool for safety training.

2.4 Related Works

In 2022, Alonso-Fernández et al. (2022) published a seminal paper titled "Game Learning Analytics: Blending Visual and Data Mining Techniques to Improve Serious Games and to Better Understand Player Learning." This paper delves into the emerging field of Game Learning Analytics (GLA) and its potential to enhance the effectiveness of serious games in training scenarios. The study explores how GLA can improve player assessment, understand player strategies, and optimize learning outcomes in game-based learning environments by analyzing player interactions with serious games. It underscores the importance of standardizing data collection formats, such as the Experience API for Serious Games (xAPI-SG) Profile, to streamline analytics processes across various game platforms and settings.

Furthermore, the research highlights the multidimensional nature of game learning analytics, encompassing both exploratory visualization tools and evidence-based assessment approaches. These methodologies offer stakeholders comprehensive insights into player actions, behaviors, and learning trajectories, empowering educators and game designers to customize interventions and instructional strategies accordingly. Their work serves as a foundational contribution to the field of game-based learning and analytics, providing practical insights and methodologies for enhancing the design, implementation, and assessment of serious games. By elucidating the interplay between visual analytics, data mining, and player learning outcomes, the research sets the stage for future advancements in GLA research and its application across diverse educational contexts and industrial settings.

In Rufino Júnior *et al*. (2022) and Runfino Júnior *et al*. (2023), a thorough examination was conducted through a Rapid Review, delving into the manifold benefits of purposeful gaming in the training of risk situations within industrial settings. Emphasizing the advantages of these digital gaming platforms' advantages in facilitating learning, enhancing engagement levels, and fostering adaptability within risk-laden environments, the studies primarily centered around critical areas such as rescue operations, cargo handling, and building evacuations. These investigations notably underscored their efficacy, particularly within sectors like electrical power and oil installations.

After reading this review, Rufino Júnior *et al*. (2023) did a full Meta-Synthesis Literature Review (MSL) to look at how purposeful gaming applications are changing in risk scenario training in industrial domains. The findings of this study pointed towards a notable surge in attention towards these gaming methodologies, particularly since 2017. These gaming platforms strive to offer an unparalleled experiential learning environment by leveraging sophisticated game design elements aimed at replicating real-world scenarios, coupled with advancements in immersive technologies such as virtual reality goggles. However, a notable challenge remains in delineating the precise costs associated with implementing these gaming solutions.

The distinctive focus of this article lies in its dedicated examination of the techniques employed for the analysis and visualization of data generated during training gameplay. Specifically, the interest lies in how this data can assist in training for dangerous situations in industries like factories or oil rigs. According to the study, these methods are carefully looked into in order to find new information that could help to understand and evaluate training programs that use purposeful gaming in a more complex way. This in-depth look tries to close the gap between theoretical frameworks and real-world applications, providing valuable insights into how to utilize gameplay data analytics as a main part of training methods designed for dangerous workplace situations.

3 Methodological Approach

Good research must follow a rigorous methodology that can be reproducible and validated for other researchers. Concerning it, the research is guided by three methodological steps: a literature review based on a systematic mapping process, an opinion survey with participants from the industry sector, and then the results were analyzed and the key findings from both the literature review and the survey. Figure 1 illustrates the three

methodological steps of this research.

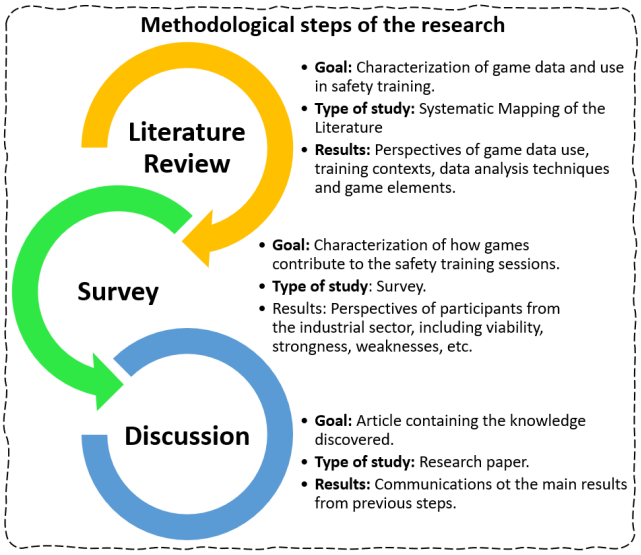

Figure 1. Research method overview.

It is recurrently stated in the serious games literature that the speech of games produces a large amount of data during gameplay, and it can be used for several analysis purposes (Nazir *et al.*, 2015; El-Nasr *et al.*, 2016). When we think about safety training in the industry, gameplay data could be used as an informational source for decision-making and improvement of training processes and to assess whether a worker performed well. Thus, this data could avoid work accidents and provide parameters for improving organizational processes.

Considering this, a **literature review** proves beneficial as it enables the investigation of how games and their gameplay data are obtained, processed, and used for support training sessions. This kind of study also enables meeting application contexts, data analysis techniques, and game elements associated with the training sessions.

With regard to the research objective, it is still essential to explore the opinions of workers in an oil and gas industry industry and their perceptions. To do so, a **survey** was conducted, which included answers from 30 participants from the industrial sector and aimed to look into their perceptions of games as training sessions and the use of their gameplay data for industrial purposes.

Finally, in the **discussion** step, we organized the studies and communicated to the research and professional community. This step aimed to discuss the SML and survey findings and the essential relationship between both studies (literature and practical perceptions). In this step, limitations and possible threats to the studies also emerge.

3.1 SML Planning

Considering the literature review, this study part followed the SML steps proposed by (Kitchenham, 2004): 1) Planning; 2) Execution e; 3) Presentation (Figure 2). Thus, performing a deeper review of preliminary studies in a focal area is possible using these steps. It allowed an examination of research studies, identifying and evaluating relevant research within a specific field or research topic.

An SML plan is determined by considering a research protocol, which must be followed rigorously in study execution. Therefore, we planned and were guided by the following steps: i) goal definition, ii) composition of research questions, iii) choice of the research bases, iv) definition of the search string, and v) definition of inclusion, exclusion, and quality criteria.

The **goal** was defined with basis on the main research question (**How can games with purpose and their gameplay data contribute to the training of hazardous situations in the industry?**). Thus, the study protocol was organized with the support of the GQM (*Goal Question Metrics*) approach, which we describe as: **analyzing** the existence of primary studies; **with the purpose of** identifying games with a purpose that uses gameplay data and data visualization; **related to** training in hazardous situations; **from the perspective of** researchers; **in the context of** industries.

Based on this goal, it was defined **six secondary research questions** which will help to answer the main question:

- **Q1:** In which safety training situations were the games used?
- **Q2:** How was the game data collected, processed, and analyzed?
- **Q3:** How was the game data used?
- **Q4:** What methods/techniques of data analysis were used?
- **Q5:** What game elements were present in those games?
- **Q6:** What were game genres identified in the studies?

As the **research bases**, the primary databases in computer science were used, as well as those indexing research papers in the field of gaming. Therefore, the following sources were considered: *ACM Digital Library*[1], *EI Compendex*[2], *IEEE Digital Library*[3], *ScienceDirect*[4], *Scopus*[5], *ISI Web of Science*[6], *Springer*[7], and *Wiley*[8].

Each research database employed its search methodology. Nonetheless, it was essential to develop a search strategy guided by a specific search string. The PICOC (Population, Intervention, Comparison, Outcomes, and Context) approach was employed to support the composition of this search string. The main research terms deemed relevant to the research objective are presented in Table 1. The "Comparison" component was omitted because the focus in Systematic Literature Review (SLR) research was on exploring a context without intending to compare interventions. Additionally, a column for Portuguese terms was included, considering the possibility of finding studies in Portuguese, though none were found.

After defining the search strategy, the research string was increased using synonyms and keywords. Accordingly, the final research string was:

[1] https://dl.acm.org/
[2] http://www.engineeringvillage.com
[3] http://ieeexplore.ieee.org
[4] http://www.sciencedirect.com
[5] http://www.scopus.com
[6] http://www.isiknowledge.com
[7] http://link.springer.com
[8] http://www.wiley.com

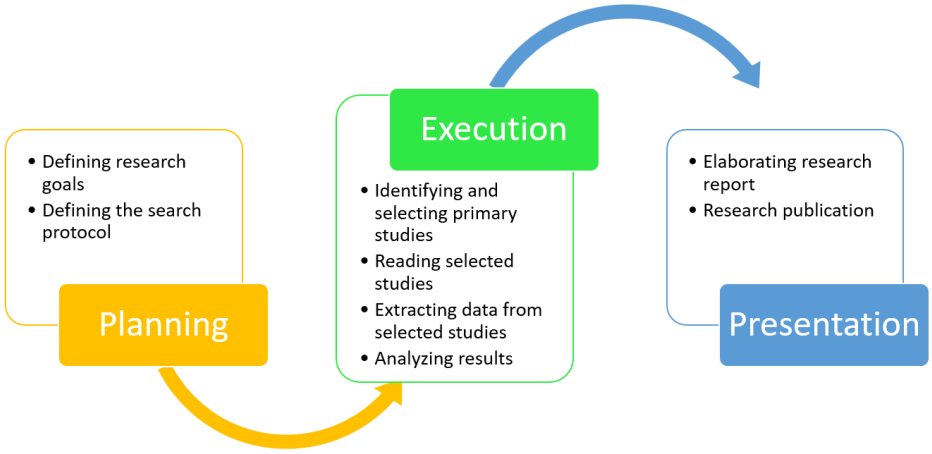

Figure 2. SML steps.

Table 1. PICOC - Terms and Synonyms

Dimension	Term in Portuguese	Term in English
Population (P)	Risco	*Risk OR Hazard*
Intervention (I)	Jogos com propósito	*Game with a purpose OR Serious Game*
Comparison (C)	-	-
Outcomes (O)	*Analytics* OR Visualização	*Analytics OR Visualization*
Context (C)	Indústria	*Industry*

("risk" OR "hazard")
AND
("game with a purpose" OR "game with purpose" OR "serious game")
AND
("industry")
AND
("analytics" OR "data visualization")

Given the vast volume of results typically returned by research databases, it is imperative to establish exclusion and inclusion criteria for systematic mapping literature (SML) reviews (Table 2). This procedure enables the selection of studies based on their titles, abstracts, and keywords during the selection phase and their full texts during the acceptance step, according to predefined inclusion criteria (CI). Studies manifesting any exclusion criteria are consequently eliminated.

Table 2. Inclusion and exclusion criteria

Code	Description
CI-1	Study addresses the use of serious games aimed at risk situation training in the industry that got and analyzed data.
CI-2	Study addresses the use of serious games aimed at risk situation training in industry.
CE-1	Study with no access for complete visualization in scientific databases.
CE-2	Study with less than 4 pages.
CE-3	Duplicated study
CE-4	Study does not address the use of serious games aimed at risk situation training.
CE-5	Non-primary study (reject systematic literature reviews or systematic mapping studies).
CE-6	Study is not written in Portuguese or English.
CE-7	Study is a preface, book, editorial, abstract, poster, panel, lecture, round table, workshop, keynotes, tutorial, or demonstration.

In the acceptance phase, six quality criteria were delineated for evaluating the data extracted from the accepted studies (Table 3). Each criterion was assigned a score ranging from 0 to 1, reflecting the extent to which a study satisfied the specified quality benchmarks. It is important to note that although quality criteria are often utilized as a threshold for study selection in literature reviews, no study was excluded based on these criteria due to the exploratory nature of systematic mapping. Instead, the quality criteria served as statistical indicators of the studies' relevance and alignment with the research objectives.

Table 3. Criteria of quality

Code	Description
CQ1	Does the study answer any research questions?
CQ2	Is the study goal clear?
CQ3	Is there a related works section comparing the research proposal to other research?
CQ4	Is the research methodology defined and presented clearly?
CQ5	Are the results presented clearly?
CQ6	Does the study present the training context for the game?

3.2 Survey Planning

The survey aimed to investigate this article's main question: **How can games with purpose and their gameplay data contribute to the training of hazardous situations in the industry?** To address the primary question, sub-questions were formulated to aid in comprehending the current state of evaluating training sessions within the industry, the viewpoints regarding the utilization of games in training sessions, and the insights on how data derived from gameplay in training games could facilitate organizational decision-making.

- **Q1:** How does your organization assess its safety training sessions?
- **Q2:** Regarding the safety training context, do you think using games for safety training purposes is viable?
- **Q3:** How do you imagine gameplay data collection and analysis can contribute to your organization's safety training?

The questionnaire used as survey instrumentation was divided into three sections: 1)A concise overview of the research objectives was provided, along with the free and informed consent form (Bispo Jr *et al.*, 2021); 2) Participants were requested to provide profile information,

including age, gender, education, and profession. This information facilitated the characterization of the audience and the delineation of the research scope.; and 3) Questions designed to address the survey's sub-questions were presented. All questions in the third section were open-ended, allowing for discursive responses.

A pilot study was conducted with a training manager experienced in safety training sessions to validate the questionnaire. This step was crucial to ensure the reliability of the research instrument by adhering to quality standards and enhancing the clarity and objectivity of each question (Manzato and Santos, 2012). The feedback from the pilot study led to improvements in the presentation of the questionnaire, including a more logical sequence of questions and refined terminology to clarify the questions.

4 SML Results: The Use of Gameplay Data in Hazard Situations in the Industry

After the systematic mapping literature (SML) protocol was defined, searches were conducted in data sources from May to July 2023[9]. The tool *Parsif.al*[10] was utilized to facilitate the planning and organization of all study references. The execution process comprised four steps: searches, exclusion of duplicated studies (step 1), selection of studies (step 2), and acceptance of studies (step 3). These steps are depicted in Figure 3.

Figure 3. SML steps and amount of study by steps.

In total, A total of 846 studies were identified through the search process. From these studies, 38 (4%) were removed by duplicity. In the selection step, 808 studies remained from the previous step, and 786 (94%) were removed because they did not meet any inclusion criteria[11]. Lastly, 10 studies passed to the acceptance step, and all of the **10 were accepted** (1.2% of studies), as shown in Table 4.

Table 4. SML steps and amount of studies by each source.

Source	Search	Step 1 Duplicated		Step 2 Selection		Step 3 Acceptance	
		Removed	Remaining	Removed	Selected	Removed	Accepted
ACM Digital Library	53	0	52	53	1	0	1
El Compendex	1	0	1	1	0	0	0
IEEE Digital Library	0	0	0	0	0	0	0
Science@Direct	204	16	185	186	3	0	3
Scopus	495	13	486	472	6	0	6
Web of Science	0	0	0	0	0	0	0
Springer	58	1	57	57	0	0	0
Willey	35	8	27	27	0	0	0
Total	**846**	**38**	**808**	**796**	**10**	**0**	**10**

[9]On January 15th, 2024, another research round was performed using the research string, and no new results were found.

[10]Parsif.al: `https://parsif.al/`

[11]Removed studies: 38 by CE-3 (4.49%), 674 by CE-4 (79.67%), 56 by CE-5 (6.62%) e 30 by CE-7 (3.55%).

Preliminary Analysis of Accepted Studies

Table 5 shows all of the 10 accepted studies, presenting the columns: ID as study code, responsible for the study identification across all this article; Year of publication; title of the study; and study quality points.

As a preliminary analysis, considering the studies' years distribution (Figure 4), it is possible to observe that from 2010, there was a significant increase in studies. It's impossible to say the reason for that increase, but it matches the COVID-19 pandemic. At that time, the concern about safety protocols in the health context was the priority of the whole world, which could influence the research work numbers. On the other hand, perhaps this increase could also represent a growing interest from the industry in improvements to safety training in general. Nevertheless, Figure 4 shows a decrease from 2023; it is necessary as future work to rerun the SML protocol until nowadays to look into whether the decrease was kept or not.

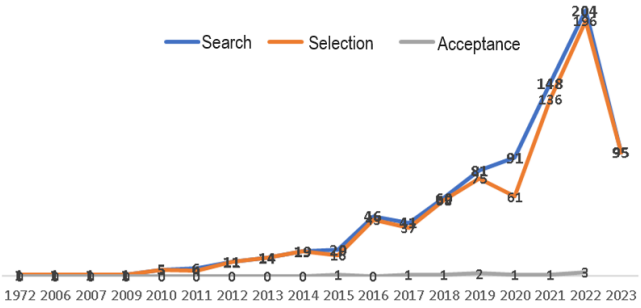

Figure 4. Distribution of studies by publication year.

Regarding the study country, we observed a more considerable concentration of studies in Germany, Greece, and the United States, two studies each (representing 60% of studies). Australia, Brazil, China, and Denmark published one study each (40% of studies). Such concentration of studies in these countries could emphasize specialized fields, academic collaborations, or interest of the industrial sector in approaches to applying games to training purposes.

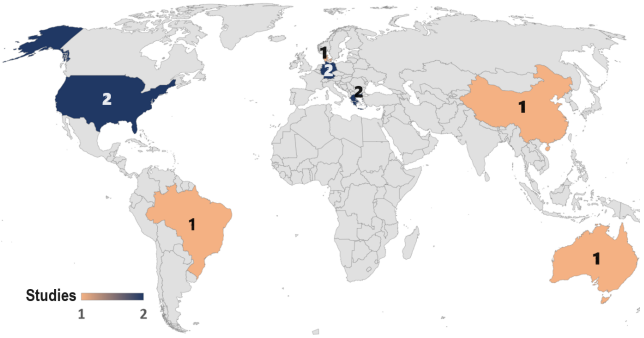

Figure 5. Geographic distribution of accepted studies.

Figure 6 presents the quality points of the studies, where we can perceive a good quality in general. Nine studies reached the max score (90%), and only one had 5 points. This indicates that all studies provided reliable and robust data for analysis in relation to the research questions.

Table 5. Accepted studies

ID	Year	Title	Quality
E01	2022	Active personalized construction safety training using run-time data collection in physical and virtual reality work environments (Jacobsen *et al*., 2022)	6
E02	2018	Serious games & human reliability. The use of game-engine-based simulator data for studies of evacuation under toxic cloud scenario (Andrade *et al*., 2018).	6
E03	2019	Developing a virtual reality environment for mining research (Bellanca *et al*., 2019)	6
E04	2019	Development of Virtual Reality Serious Game for Underground Rock-Related Hazards Safety Training (Liang *et al*., 2019)	6
E05	2021	Towards design guidelines for virtual reality training for the chemical industry (Fracaro *et al*., 2021)	5
E06	2017	RiSKi: A Framework for Modeling Cyber Threats to Estimate Risk for Data Breach Insurance (Panou *et al*., 2017)	6
E07	2020	A serious gaming framework for decision support on hydrological hazards (Sermet *et al*., 2020)	6
E08	2015	A structured war-gaming framework for managing extreme risks (Liu *et al*., 2015)	6
E09	2022	Investigating hazard recognition in augmented virtuality for personalized feedback in construction safety education and training (Wolf *et al*., 2022)	6
E10	2022	Design, Development, and Evaluation of a Virtual Reality Serious Game for School Fire Preparedness Training (Mystakidis *et al*., 2022)	6

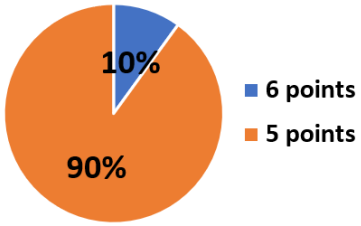

Figure 6. Study quality.

Q1: In which safety training situations were the games used?

In this question, we aimed to explore environments that used games as approaches to support safety training for hazardous situations. Figure 7 shows that in 8 studies (20% each), games were used in the fields of construction (E1 and E9), chemistry (E2 and E5), mining (E3 and E4) and environment (E7 and E8). Also, 2 studies considered cybernetics (E6) and education (E10).

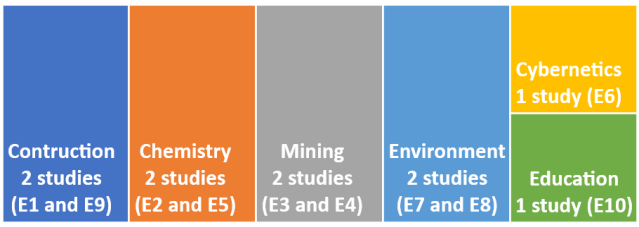

Figure 7. Identified contexts.

Q2: How was the game data collected, processed, and analyzed?

This question analyzed methods and techniques for data collection, processing, and analysis during a gameplay session. Figure 8 pointed out that all studies collected data in run-time. For data processing, only study E1 cited the removal of the duplicity in data. The analysis studies E1, E2, E4, E5, E7, E9, and E10 (70%) indicated using graphs, considering the exhibition of variables such as accuracy, points, time, and levels.

Q3: How was the game data used?

In this question, we aimed to observe the importance of getting and analyzing game data for the training processes, considering their use in the organizational processes. All

Figure 8. Collect, process, and analysis types.

studies pointed out the significance of game data for risk management, decision-making, and accident responses. Only one study (E6) highlighted the opportunity to use game data to decrease costs in insurance, but it did not provide any details on how it could work.

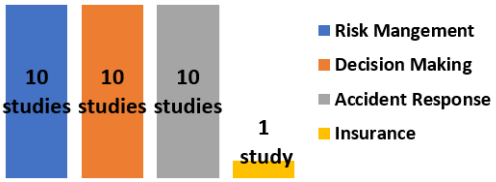

Figure 9. Situations of use of game data.

Q4: What methods/techniques of data analysis were used?

With this question, we aimed to identify which methods or data analysis techniques were used in gameplay data of games with a purpose (Figure 10). We observed 9 studies (90%) mentioning descriptive analysis (E1, E2, E3, E4, E5, E6, E8, E9 and E10) to describe trends, patterns, and correlations. On the other hand, predictive analysis was applied in 4 studies (40% - E1, E2, E6 and E8), considering algorithms to predict future events based on historical data. Finally, prescriptive analysis was present in 2 studies (20% - E6 and E8) to suggest actions to optimize future results. Such different approaches allowed organizations to get valuable data about participants' performance in training sessions.

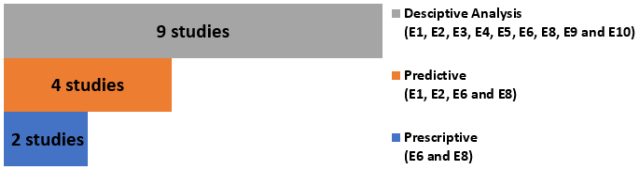

Figure 10. Data analysis techniques.

Q5: What game elements were present in those games?

This question aimed to discover what game design elements are being applied and associated with gameplay data. All studies (E1, E2, E3, E4, E5, E6, E7, E8, E9 and E10) highlighted real environment elements such as simulation, for instance, with the essential game design element for these games. Other elements, such as virtual reality (E3, E4, E5, and E10) and augmented reality (E1 and E9), also were mentioned in studies.

Other game elements also were presented in studies associated with gameplay data (Figure 11): Studies E1, E2, E3, E5 and E9, looked into the element of time expended by players; Accuracy (E1, E3, E5 and E9) and Score (E2, E4 and E7) to follow players' performance; Levels (E1, E2, E4, E6, E7, E9 e E10) to observe players' progress; Awards (E1, E2, E7, E8 and E10) to encourage players' participation; Feedback (E1, E3, E4, E5, E7, E8, E9 and E10) to get data from players' experience; Aesthetics (E1, E2, E3, E4, E5, E7, E8 e E9) used to influence the player experience.

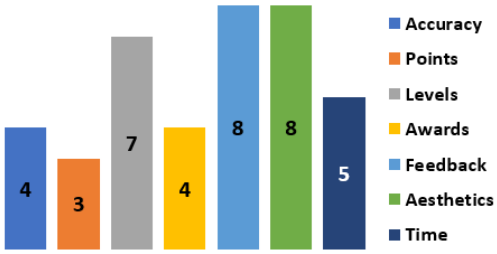

Figure 11. Game elements.

Q6: What were game genres identified in the studies?

Lastly, this question aimed to explore what game genres were considered in studies for training games (Figure 12). The study E7 focused on competition and tournament games. Meanwhile, study E9 concentrated on the war-game genre. Seven studies presented simulations in 3D (E1, E2, E3, E4, E5, E9 and E10) and 2D (E7 and E8) environments. We did not find any genre in the study E6. Considering all studies, we identify the predominance of 3 dimension graphs that use geometry to represent the depth of scenarios, objects, and characters.

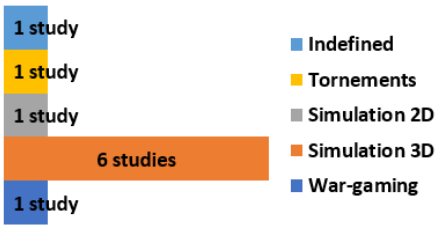

Figure 12. Identified game genres

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5 Survey Results: Possibility of Using Games in Training Sessions of Hazard Situations

Studies based on surveys provide opportunities to gather information by systematically arguing a group of people within a specific context, allowing researchers to discover relevant knowledge from the respondents quickly and at low cost (Creswell and Creswell, 2017). In this research, the survey sought a perception of safety training sessions in the industry from the perspective of training managers.

Inspired by the research of Pfleeger and Kitchenham (2001), the study guided the survey following the steps: i) *planning*, describing goal setting, research questions, and instrumentation; ii) **execution**, considering the choice of participants and the questionnaire distribution; and iii) **results**, presenting data analysis and reporting research findings.

After adjustments to the questionnaire from the pilot study, it was distributed to training managers of a company in the gas and oil sector via an online platform, where participation invitations were sent individually. The survey was accessible from January 9th, 2024, to January 19th, 2024. During this period, a total of **30 answers** were received.

We applied qualitative techniques to analyze the data collected[12]. Their profiles were explored and summarized from the demographic questions posed to participants. For this purpose, descriptive statistics techniques were utilized alongside graphs and tables.

To analyze the descriptive answers obtained in the third section of the questionnaire (research questions), the analysis was based on the principles of grounded theory (Strauss and Corbin, 1990). The qualitative analysis was adapted to include two main steps: i) open coding, wherein data is separated and categorized into codes; and ii) axial coding, wherein relationships among codes and categories can emerge, facilitating the definition of new knowledge and theories. Given that the study involves a small group of training managers (30 participants) relative to the potential sample universe across the industry, the selective coding process (Strauss and Corbin, 1990) may not be applicable. This is because selective coding is utilized to identify broad and theoretical patterns in data that may represent a significant portion of the population under observation. Therefore, only open and axial coding were applied in this study's qualitative analysis.

With the support of Atlas.ti 23 software, two researchers organized concepts identified in the open coding into categories and explored relations among them to create conceptual models that can help to explain sub-questions. It is important to say that the coding process performed by those researchers was validated by themselves for each new code created to keep the coding consistent and research reliable.

[12] Survey data (in Portuguese): `https://doi.org/10.5281/zenodo.10697073`

Participants' Profile

From the 30 participants, 28 (93%) were men, while 2 (7%) were female (Table 6). 47% aged between 40 and 50 years (14 participants), all male. The other participants were aged 30% over 50 years old (9 participants), 20% between 30 and 39, and 1 participant from 18 to 29 years old.

Table 6. Analysis of participants' profile

Age group	Male	Female	Total
below 18 years old	0 (0%)	0 (0%)	0 (0%)
18 to 29 years old	0 (0%)	1 (3%)	1 (3%)
30 to 39 years old	5 (17%)	1 (3%)	6 (20%)
40 to 50 years old	14 (47%)	0 (0%)	14 (47%)
over 50 years old	9 (30%)	0 (0%)	9 (30%)
Education level			
Incomplete fundamental school	0 (0%)	0 (0%)	0 (0%)
Complete fundamental school	0 (0%)	0 (0%)	0 (0%)
Complete high school	8 (27%)	1 (3%)	9 (30%)
Complete graduate	16 (53%)	1 (3%)	17 (57%)
Specialization or MBA	3 (10%)	0 (0%)	3 (10%)
Complete postgraduate (master of Ph.D.)	1 (3%)	0 (0%)	1 (3%)
Professions			
Teacher	0 (0%)	1 (3%)	1 (3%)
Operation technician	5 (17%)	1 (3%)	6 (20%)
Vessel coordinator	1 (3%)	0 (0%)	1 (3%)
Engineer	1 (3%)	0 (0%)	1 (3%)
Manager	3 (10%)	0 (0%)	3 (10%)
Operator	4 (13%)	0 (0%)	4 (13%)
Occupational safety technician	1 (3%)	0 (0%)	1 (3%)
Electrical technician	4 (13%)	0 (0%)	4 (13%)
Stability Technician	2 (7%)	0 (0%)	2 (7%)
Maintenance technician	3 (10%)	0 (0%)	3 (10%)
Mechanical technician	2 (7%)	0 (0%)	2 (7%)
Chemical technician	1 (3%)	0 (0%)	1 (3%)
Retired	1 (3%)	0 (0%)	1 (3%)
Summary	**28 (93%)**	**2 (7%)**	**30 (100%)**

Regarding the participants' education level, 57% (17 participants) reported completing the graduate level. 4 participants (13%) informed having some postgraduate level (specialization, MBA, master, or Ph.D.). And 30% of them (9 participants) reported having completed high school.

Finally, 100% of them already had training sessions in their jobs, and around 37% (11 participants) already had ministered a training session. Most of the participants' professional activities focused on operation technicians (20%), operators (13%), electrical technicians (13%), 3 participants (10%) figured in managers positions, and others. It is essential to highlight that 63% (19 participants) are technicians. It means that, by law, all of them must participate in safety training sessions. However, the survey had only 1 participant who works in occupational safety.

Q1: How does your organization assess its safety training sessions?

Based on answers to question Q1, the diagram in Figure 13 was built concerning about how training sessions are assessed. Organizations assess their safety training sessions through various evaluations focusing on dropout rates, the form of training (presumably the format or method), empirical evidence of effectiveness, scores achieved by participants, specific questions to gauge understanding, practical exercises, engagement levels, and self-assessment by participants. We could perceive these findings in participants' answers, for instance:

"Usually a test with written questions and multiple-choice." [Participant 5]

"By mastery and ability to convey content, use of objective language, and interaction dynamics between student/instructor." [Participant 7]

"Evaluation of the course and also of the instructor." [Participant 11]

All these aspects contribute to an overall evaluation of the training's effectiveness, highlighting a multifaceted approach to ensure comprehensive learning and engagement.

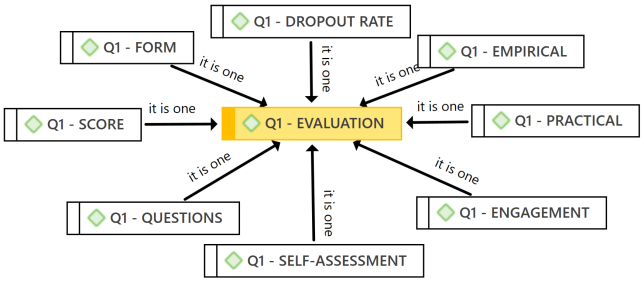

Figure 13. How does your organization assess its safety training sessions?

Q2: Regarding the safety training context, do you think using games with safety training purposes is viable?

Regarding this question, Figure 14 summarizes and organizes the knowledge we got from participants' answers. The viability of using games for safety training is seen through both positive and negative lenses. On the negative side, concerns are raised about the misuse of artificial intelligence and the lack of privacy. For example, it is possible to identify some negative aspects in participants' answers:

"Depending on what is collected, there is a tenure-line between what is acceptable and what is a violation of privacy or organizational data protection." [Participant 17]

"I believe that it is necessary to avoid getting sensitive data from trainees to avoid the leak of information." [Participant 21]

"It's necessary to take care of the LGPD [brazillian data protection law]." [Participant 24]

However, the positive aspects far outweigh these concerns, with games being recognized for their innovation, attractiveness, engagement, ease of learning, accessibility, fun, increased risk perception, versatility, and dynamic nature. These positive points underscore the potential of games to enhance safety training by making it more appealing and effective for participants. We can perceive some positive aspects in participants' answers in the following:

"Digital games are an alternative to attract young people to participate more in the presented topic." [Participant 1]

"Risk analyses within the company are an example where game practices can be applied to develop risk perception. And games capture the student's attention. We live in the digital age." [Participant 7]

"I believe they have the potential to add value, but not to replace conventional training. For some professional profiles, certain approaches use infantilized methods as a way of communicating with the trainee. Like teaching through cartoon videos." [Participant 17]

"I think it would bring a different dynamic, involving the trainees more." [Participant 21]

Q3: How do you imagine gameplay data collection and analysis can contribute to your organization's safety training?

Gameplay data collection and analysis are highly valued for their contribution to safety training, offering both general and specific benefits, as we can see in Figure 15. It enables analysis through reports and dashboards, providing good indicators and metrics for evaluating training outcomes. Despite concerns over the potential for superficial analysis if relied upon as a single source, the positive aspects include making training fun, supporting decision-making, simplifying visualization, efficient learning, improved analysis capabilities, real-time monitoring, encouraging good practice, presenting key indicators, and interactive learning experiences.

To illustrate the findings, examples of how gameplay data could contribute to safety training are presented based on participants' responses:

"Safety practices on board (offshore), safety working with electricity at height, crane operator, safety in the use of cutting equipment (chainsaw, grinder, sanders)." [Participant 7]

"Security." [Participant 20]

"Safety, environmental and health training" [Participant 26]

6 Discussion

This research paper aimed to investigate **how games with a purpose and their gameplay data could contribute to the training of hazardous situations in the industry**. Drawing on systematic mapping literature (SML) and survey research, the main findings are discussed considering: i) "How viable is the use of games for training in hazardous situations?"; ii) "How can gameplay data contribute to training in hazardous situations?";and iii) "How can games with purpose and their gameplay data contribute to the training of hazardous situations in the industry?".

6.1 How viable is the use of games for training in hazardous situations?

Based on survey findings, it was possible to highlight the significant benefits of using games in safety training that strongly support the viability of games for training in hazardous situations. These benefits, including innovation, engagement, and ease of learning, make training more dynamic, versatile, and effective, particularly in enhancing risk perception and retention of safety practices. The SML study results in high-risk fields like construction (E1, E9), chemistry (E2, E5), and the environment (E7, E8) show that games can be used and are effective in a lot of different areas. Despite concerns regarding artificial intelligence and privacy, the overwhelmingly positive sentiment from a demographically diverse group of 30 training participants affirms the strong endorsement of gamified learning approaches for hazardous situations.

6.2 How can gameplay data contribute to training in hazardous situations?

Both survey results and the analysis of gameplay data across studies E1, E2, E4, E5, E7, E9, and E10 in SML highlight the crucial role of gameplay data in refining safety training methodologies. Through sophisticated analysis, this data provides deep insights into learners' performance and progress, enabling a tailored, engaging, and responsive training approach. The survey emphasizes the utility of real-time feedback and the potential for gameplay data to support decision-making, enhance learning experiences, and foster best practices. Despite some reservations about analysis depth if used in isolation, the broad applicability of gameplay data across diverse professional backgrounds indicates its possible contribution to improving training methodologies and outcomes.

6.3 How can games with a purpose and their gameplay data contribute to the training of hazardous situations in the industry?

Therefore, to answer the research question, both SML analysis and survey research findings, purpose-designed games, in combination with gameplay analytics, have a tremendous potential to revolutionize safety training in industrial settings. These games offer safe, simulated environments for practicing responses to hazardous situations, significantly enhancing risk awareness and decision-making skills. Using real-time data collection and analysis, like in studies E1, E2, E3, E4, E6, E7, E8, E9, and E10, lets changes be made quickly based on how each learner is doing. Including game design elements like simulation, virtual reality (E3, E4, E5, E10), and augmented reality (E1, E9) highlights the adaptability of these games to meet specific training needs. The diverse professional backgrounds of participants, reflected in the survey responses, underscore the effectiveness and relevance of purposeful games in enhancing safety training outcomes across various sectors.

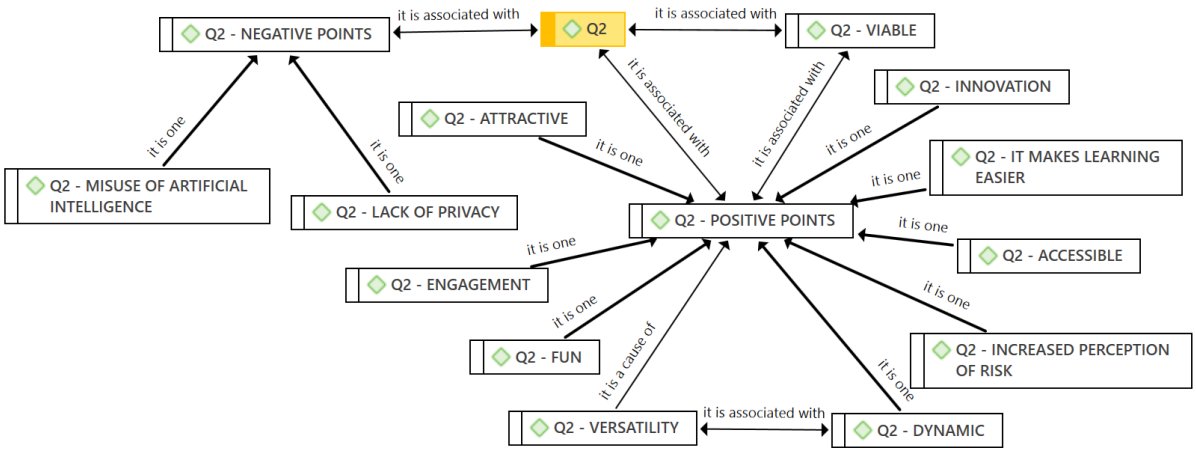

Figure 14. Do you think using games with safety training purposes is viable?

7 Threats to Validity and Limitations of the Study

Normally, utilizing an SML method introduces limitations and potential threats to its validity (Zhou *et al*., 2016). Initially, a sole researcher carried out the selection process, escalating the risk of bias in article selection. Despite diligent efforts in conducting the analysis and discussion, the subjectivity inherent in the process suggests that other researchers may attain more comprehensive results by thoroughly examining the findings.

In surveys, challenges and limitations affecting reliability may arise from the involvement of external entities (Nascimento *et al*., 2018). The survey, distributed to training managers via email, introduces the possibility of response bias, given the potential for participants to answer together. Another limitation pertains to the brevity of responses, with numerous participants providing concise answers, thereby complicating the extraction of more nuanced interpretations. As highlighted by Pinto and Santos (2012), researchers immersed in a specific scientific inquiry may inadvertently inject personal biases into their interpretations, posing a potential threat to the study. This bias could have been introduced during the coding phase, contingent upon the researchers' understanding. However, the researchers' validation process alleviates bias in this regard.

Additionally, as per Wagner *et al*. (2020), surveys initiated through open invitations may introduce self-selection biases, wherein individuals with a keen interest in the research topic are more inclined to participate, potentially resulting in a skewed sample. This approach lacks control over the sample size, thereby risking non-generalizable results. Furthermore, a threat exists concerning verifying participants' identities, potentially allowing individuals who do not meet the study's inclusion criteria to participate. To address these concerns, efforts were made during the response analysis stage to consider contextual factors and filter out potential non-representative participants to mitigate these threats.

In conclusion, the survey study faces threats to internal and external validity. Internal validity is at risk due to participant engagement and the potential influence of specific training content. On the other hand, difficulties in

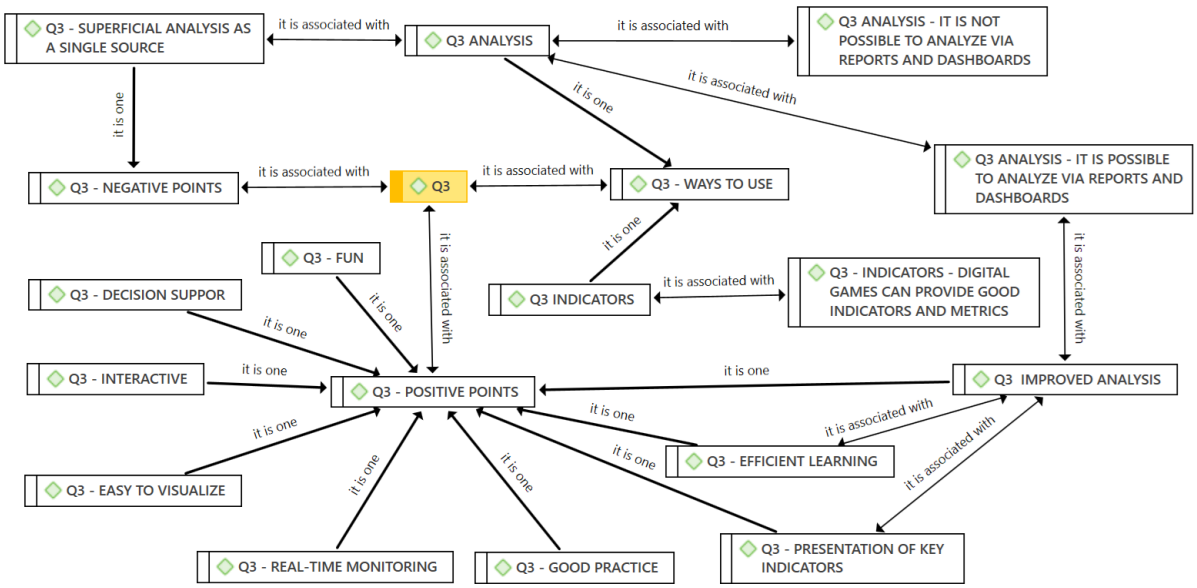

Figure 15. How do you imagine gameplay data collection and analysis can contribute to your organization's safety training?

generalizing results to various contexts and worries about the representativeness of participants may compromise external validity. Future studies should carefully consider and address specific contextual limitations to enhance the validity of the results.

8 Final Remarks and Future Works

This study embarked on a comprehensive journey, conducting a Systematic Mapping Literature (SML) review and survey research to delve into how purpose-designed games leverage data extraction, analysis, and visualization techniques for enhancing risk situation training in the industry and how it contributes to training sessions. The investigation, which benefited from the survey results' insights, evidence that this novel approach has the potential to improve training effectiveness and promote more memorable learning opportunities.

Fundamental discoveries made through the analysis and survey responses highlight the common application domains — namely, the chemical, construction, and environmental industries — where combining game design elements with solid data analysis methods can make a big difference. The survey, in particular, shed light on the enthusiastic reception and perceived benefits of gamification in training scenarios, underscoring the importance of engaging, dynamic, and immersive learning environments enabled by real-time data processing and immersive technologies.

These technologies not only furnish profound insights into participants' performance but also facilitate the detection of behaviors that could precipitate risks, thereby enhancing the safety and efficacy of training programs. The survey's emphasis on the utility of descriptive, predictive, and prescriptive data analyses illuminates the pathway to understanding historical trends, anticipating future occurrences, and crafting strategies to refine training outcomes.

While strides have been made, avenues for further exploration beckon—particularly in pinpointing specific game genres that resonate most effectively within training contexts, innovating within the realm of game design, and harnessing sophisticated data treatment techniques. The survey findings underscore the critical need for ongoing inquiry and development in this domain to not only advance training methodologies but also unlock novel applications for purpose-designed games.

Besides, as future work, we need to be concerned about players' data privacy issues and the precision of simulation related to real training. We understand those issues as essential investigations to the success of the research.

Conclusively, the fusion of purpose-designed games with cutting-edge data analysis and visualization tools emerges as a formidable strategy for revolutionizing risk prevention training in the industrial sector. This approach promises not only to enhance the effectiveness and safety of training initiatives but also to boost engagement and participation rates significantly. Anticipated future research and technological advancements hold the promise of broader adoption, poised to redefine safety protocols and efficiency standards across the industrial landscape.

Acknowledgements

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