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GAMIFICATION IN OCCUPATIONAL SAFETY TRAINING: A SYSTEMATIC LITERATURE REVIEW

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Title: Gamification In Occupational Safety Training: A Systematic Literature Review

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Abstract

Gamification is a new methodology that is used mainly in education and marketing, however, in recent years it has become more relevant in the training of personnel at a professional level. The objective of this literature review was to make a synthesis and analyze the cases of gamification implementation in training both at a professional level and at a level of student practices. The following review was based on the PRISMA model, studies were delimited by inclusion criteria, and finally, after discarding articles, 39 studies remained for analysis. The results of this investigation determined that gamification is an innovative way of training that promotes growth, the development of competences and teamwork. Likewise, it was evidenced that gamification was implemented more in the field of medicine and there is a gap of knowledge of the implementation of gamification in other professional areas.

Keywords

Gamification, staff training, security, serious game, literature review.

Biographies

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1. Introduction

Despite living in an era where the mechanization of processes is observed in almost any industrial field, human resources still continue to be a key element in organizations, reflected as a competitive advantage over others (Llanos 2016). Currently, companies focus on proper personnel management, improvement of the work environment, and skills that allow autonomy in decision-making and problem-solving, as job satisfaction has been shown to be directly linked to productivity and organizational commitment (Peña et al. 2015). However, all this would not be possible without good management of the human resources area, responsible for activities such as recruitment, selection, training, or performance evaluation (Ascencio et al. 2016).

The production area of any company is related to problems such as work fatigue, monotony, pressure to meet production quotas, or work intensity (Alvarez and Noriega 2003). Additionally, according to Peña et al. (2015), operators in the production area are exposed to a higher accident rate.

To address this problem, a methodology for the implementation of gamification techniques in training is proposed. Despite being a technique that is not currently widely used, gamification is becoming more relevant in international organizations, as it has qualities to provide an improvement in the face of organizational problems (Gallego and De Pablos 2013).

Gamification consists of the implementation of mechanics or techniques based on the characteristics of a game, aimed at achieving greater use of the user's skills, the ability to absorb and retain knowledge, and improving productivity. With this, the staff can achieve objectives through recognition or incentives (Eslava Zomeño 2017). Gamification uses elements such as intrinsic or extrinsic motivation, based on theories of psychology such as the theory of operant conditioning (Wang et al. 2022).

Successful cases of gamification have been applied in large companies such as Google or L'Oréal, and it has been verified that the proper application of this technique greatly increases the performance and interest of users, promotes a mentality improvement, and generates a work environment where continuous progress and competitiveness prevail (Joy 2017). Although there are not many organizations in Peru that apply gamification, some projects in the educational field have had good results (Jugando se Aprende 2018).

This literature review aims to characterize and analyze experiences on the use of gamification in staff training, to know which were the main tools for its implementation, and to synthesize the main results obtained. The review will answer the following research questions: Which articles had the greatest impact on the scientific community? In what field was gamification implemented? What types of tools were used in the implementation? What were the results obtained?

2. Methodology

For the following study, it was decided to carry out a systematic review. This approach was chosen because, unlike a traditional literature review, it follows a scientific methodology that describes the procedure in a more specific and complete way. A systematic review provides an overview of the available studies, is impartial, and presents all the search stages in order to guarantee the reproducibility of the results obtained (Pérez 2019). To ensure the rigor of the study, the PRISMA declaration will be used as a guide for conducting the review (Page et al. 2021). Additionally, the VOSviewer tool will be used to complement the analysis of the articles obtained. This software is used to visualize bibliometric networks of the articles as a concurrency of keywords, citations, or authors.

Regarding search engines, the Scopus and Web of Science databases were used since they are the main databases of bibliographic references in different disciplines. They have a large number of quality articles, in addition to having tools that help the analysis and evaluation of the papers (Lasda 2012).

2.1 Initial search

In October 2021, a first general search was carried out using the terms “gamification” and “training” in the Scopus database to have a first overview of the articles found in the main databases. Having a large number of results, 1156 in particular, it was decided to use the Boolean operators AND and OR together with the terms “gamified system”, “serious game”, “learning”, “teaching”, “safe”, “safety” and “industrial safety” to have a more specific result.

2.2 Systematic search

After using different combinations of the terms named above with the Boolean operators, the following combination obtained the best results: (gamification OR gamified system OR serious game) AND (training OR learning OR teaching) AND (safe OR safety OR industrial safety). Likewise, the Web of Science database was added to perform the search.

The result of this search yielded a total of 649 studies (516 from Scopus and 133 from Web of Science). Given the large number of investigations, we proceeded to use the filtering tools of the databases. The filters of years of

publication and type of publication were used. On the one hand, studies that were published in the last 5 years were taken, that is, those that were published since 2016 and even those published up to October 2021. On the other hand, depending on the type of research, studies were excluded. Bibliographic review studies, books or book chapters were excluded. After applying these filters, only 238 items matched the specified parameters.

Subsequently, the results of each database were exported to the Mendeley Desktop program (version 1.19.8), which, thanks to its bibliographic source management functions, could detect a total of 97 duplicates. After excluding duplicate studies, a total of 154 research articles remained (135 from Scopus and 19 from Web of Science).

The articles that remained were analyzed individually by reading their titles, abstracts, and keywords, and the following criteria were taken into consideration:

- Empirical studies
- Population older than 18 years
- That use gamification techniques
- Based on a security teaching or training model

Finally, only 84 articles matched the proposed criteria, and 70 were excluded from the review. These selected articles were read in their entirety to analyze their content in more detail. After completing the reading, 44 more articles were eliminated. Twenty of them did not deal with training issues, nine evaluated a group of children on the impact of gamification in education or medical issues, nine were not oriented in training on security issues, four articles could not be accessed because payment was required to read them, two were systematic reviews, and the last one only presented a gamified model for training. Therefore, only 39 articles will be considered for the systematic review. Figure 1 shows a detailed breakdown of the articles.

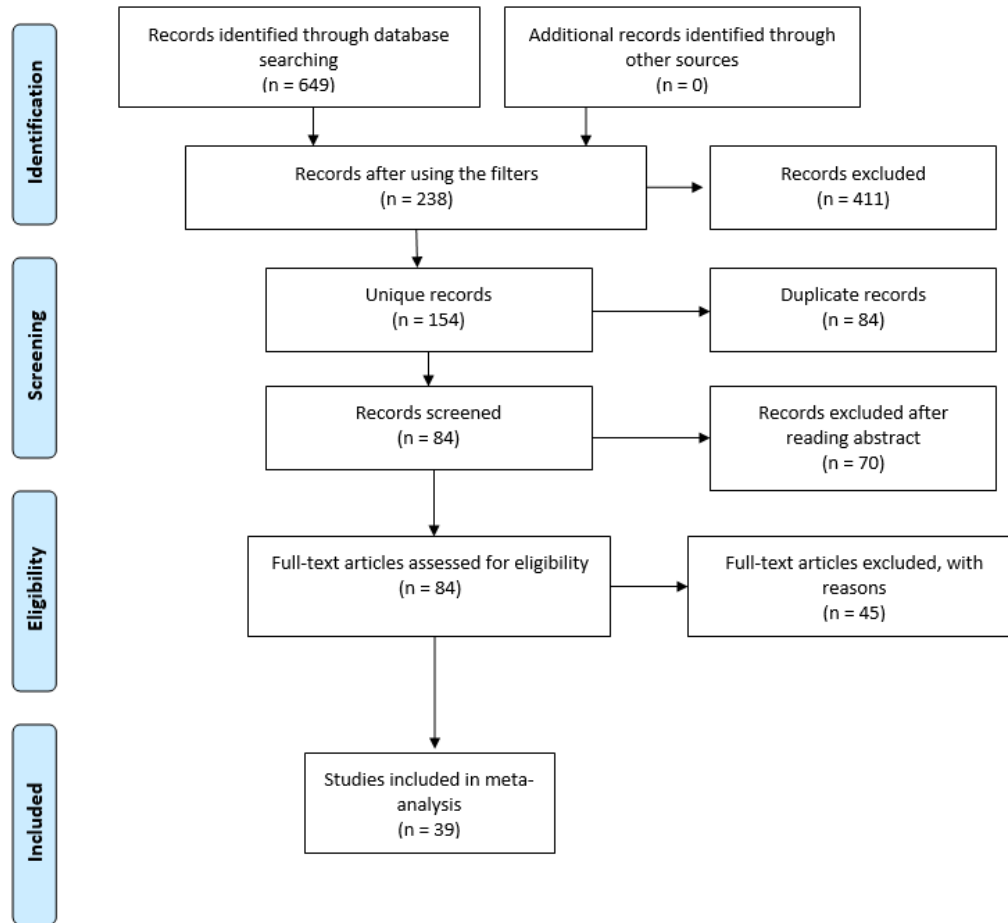


Figure 1. PRISMA methodology flowchart

In addition, to analyze the obtained articles, the elements will be classified by the year of publication. This will help us identify the trend of the gamification theme and its application in the scientific community. Likewise, we will analyze the articles that have had the greatest impact, i.e., they will be organized by the number of times they have been cited in their respective databases. We will also count how many articles have been published by a single journal. Finally, the articles will be structured by the area where the gamified model was implemented, either in a professional field (construction, laboratory, medical) or in an educational field (medical students, nursing students, engineering students), and with what tools the gamified model was implemented in the training (virtual games, face-to-face games).

3. Results

First, we began by examining the number of articles published year after year.

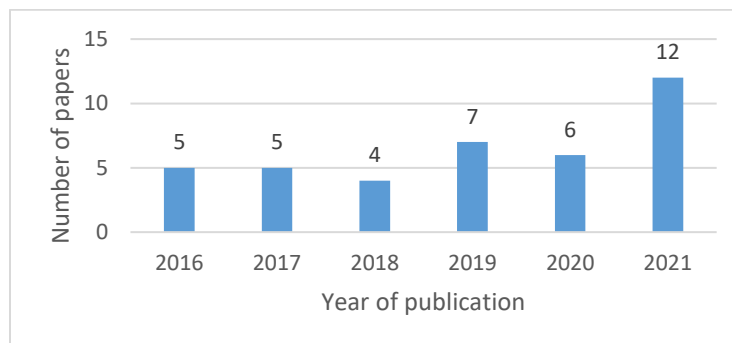


Figure 2. Distribution of articles according to year of publication

An increasing trend can be observed in the first delimited years. Currently, in 2021, slightly more than twice the number of articles written in 2016 have been identified, and 64.10% of articles were published in the last three years. Likewise, the analysis revealed that only 25% of the articles were cited 10 or more times. It can be inferred that the articles have a low number of citations because most of them were recently published. Table 1 lists the top 10 ranked articles by the number of citations.

| Authors | Title | Number of citations |
|------------------------------|---|----------------------------|
| Buttussi and Chittaro (2018) | Effects of Different Types of Virtual Reality Display on Presence and Learning in a Safety Training Scenario | 141 |
| Matsas and Vosniakos (2017) | Design of a virtual reality training system for human–robot collaboration in manufacturing tasks | 77 |
| Johnsen et al. (2016) | Teaching clinical reasoning and decision-making skills to nursing students: Design, development, and usability evaluation of a serious game | 43 |
| Edwards et al. (2019) | Haptic virtual reality and immersive learning for enhanced organic chemistry instruction | 37 |
| Kirillov et al. (2016) | Improvement in the learning environment through gamification of the educational process | 32 |
| Chittaro (2016) | Designing serious games for safety education: 'Learn to brace' versus traditional pictorials for aircraft passengers | 30 |
| Koivisto et al. (2017) | Nursing students' experiential learning processes using an online 3D simulation game | 29 |
| Dankbaar et al. (2017) | Comparative effectiveness of a serious game and an e-module to support patient safety knowledge and awareness | 28 |
| Kwon and Lee (2016) | Serious games for the job training of persons with developmental disabilities | 27 |
| Taillandier and Adam (2018) | Games Ready to Use: A Serious Game for Teaching Natural Risk Management | 26 |

Table 1. Classification of articles by number of citations.

Additionally, the journals where the articles were published were identified. It was found that all articles were published in 21 different journals. Likewise, it is observed that no journal concentrates a large number of published articles, since the maximum number of articles published by any journal was 4. Among these journals, we have BMC Medical Education, Cureus, and Nurse Education Today, and only 28.3% of journals concentrate on at least 2 items. In addition, it should be noted that 58.8% of magazines are specialized in medicine, 18.9% cover the field of computing, and 16.9% of magazines only deal with specific topics in gamification. Table 2 identifies the 7 most representative journals by the number of articles published.

| Journal | Number of papers |
|--|-------------------------|
| BMC Medical Education | 4 |
| Cureus | 4 |
| Nurse Education Today | 4 |
| IEEE Transactions on Visualization and Computer Graphics | 3 |
| MedEdPORTAL | 3 |
| Simulation & Gaming | 3 |
| Virtual Reality | 3 |

Table 2. Classification of journals by number of papers published.

On the other hand, these articles were classified by the topics they cover, whether in the professional or educational field.

| Field | Number of papers | Percentage |
|--------------|-------------------------|-------------------|
| Education | 27 | 69.23% |
| Professional | 12 | 30.77% |
| | 39 | 100.00% |

Table 3. Classification of articles by category of application

It is observed that 69.23% of the articles are related to implementation in the educational field for the training of professionals, and only 30.77% of them deal with implementation in a professional environment. Likewise, it should be noted that 21 of the education articles belong to the medicine category (nurses or doctors), 4 to the construction category, and 2 to the pharmaceutical category. This indicator can give us an indication of how the literature is currently focused.

To contrast the information in Table 1, the articles from the Scopus and Web of Science databases were downloaded in CSV format (Excel 2016) to be able to import them into the VOSviewer software (version 1.6.17). After importing the information from the articles, we proceeded to select the parameters for the creation of the data network. The type of analysis chosen was concurrency, the complete count method was selected, the unit of analysis was all the keywords, and the minimum number of matches, between articles, that each keyword had to have to be considered was 5, since this amount can get a considerable amount of information.

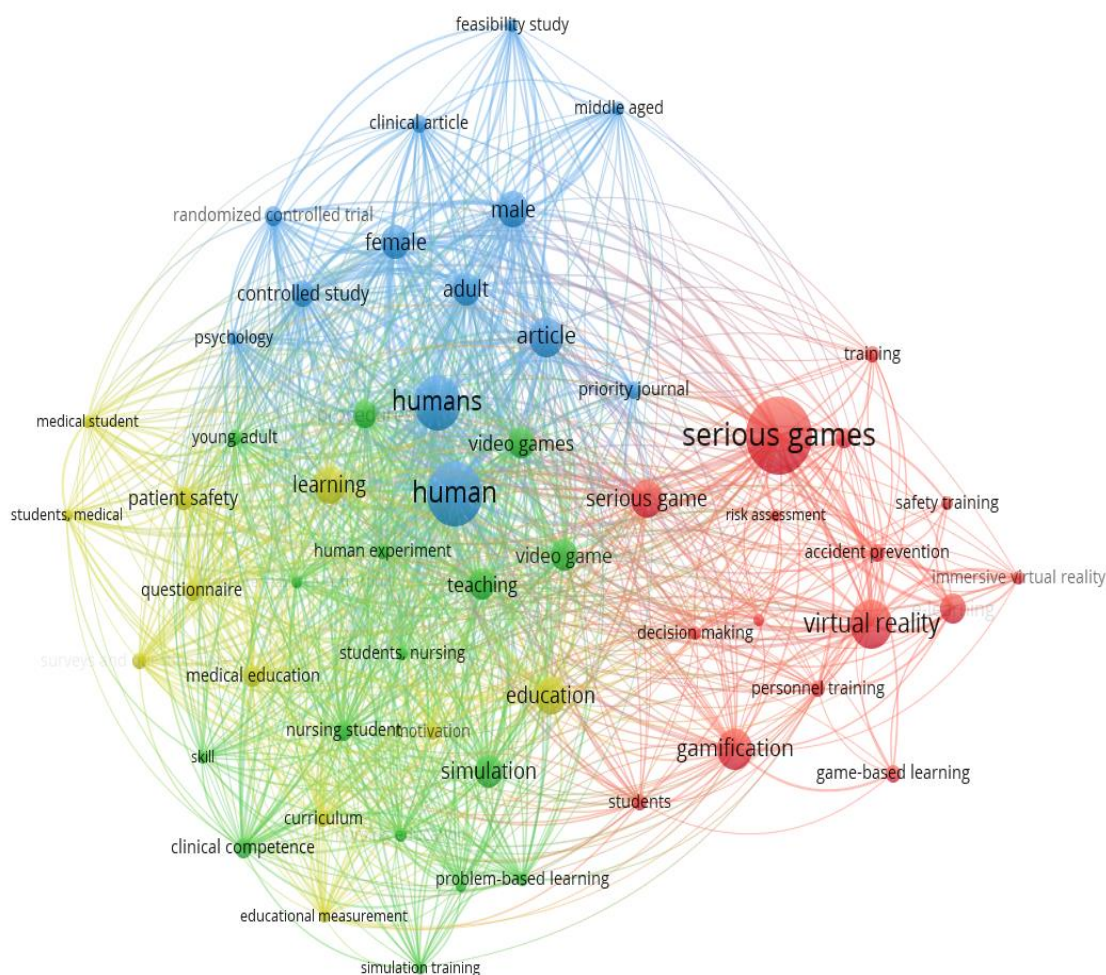


Figure 3. Network of keywords within the literature of the selected articles

To analyze this graph, we will first identify the colors of the nodes and which terms predominate. On the one hand, the yellow and green nodes are much more related to medical and educational terms, such as medical student, clinical competencies, or nursing students. On the other hand, the blue nodes include psychology terms and keywords related to people, which indicates the population or sample with which we worked, as they are experimental articles. Finally, the red nodes reflect those terms that are most closely related in a more industrial field, which deals with issues of safety, accident prevention, and risk assessment.

After making these dimensions, we can say that what was described in Table 3 is reaffirmed, since there is greater concurrence between the green and yellow terms compared to the red nodes. This means that these terms related to medicine cover the selected articles to a greater extent.

On the other hand, the articles were classified by the tool used in each study to implement gamification. In this case, two modalities were considered: virtually or face-to-face in classrooms. Table 4 details the main tools used.

| Modality | Tool | Number of papers |
|-----------------|---------------------------------|-------------------------|
| Presential | Board game | 1 |
| | Team games in classroom | 2 |
| | Escape room | 4 |
| | Face-to-face simulation | 3 |
| Virtual | Role playing games | 7 |
| | Virtual simulation | 19 |
| | Interactive videos with quizzes | 3 |
| | | 39 |

Table 4. Classification of articles by implementation tool

It is observed that in the implementation of gamification, researchers tend to use virtual resources more often, such as games created in computer software or dynamic tools like interactive videos.

Lastly, a synthesis of the results of the most relevant studies chosen by the methodology (virtual reality, prototype, application, etc.) can be found in the following table. The analysis that follows is categorized according to each theme for better understanding and integration of the results.

| Paper / Author | Sample Size | Methodology | Results |
|--|--|--|---|
| The Mystery Dinner RCA: Using Gamification and Simulation to Teach Root Cause Analysis (Smeraglio et al. 2021) | 134 students | The gamified system consisted of a virtual reality game where the participants were in a simulation with patients with characteristics of real past events to train in RCA. | 96% of the participants recognized that they felt better trained in security methods. They also stated that at the end of the training program, they had sufficient skills to participate in an RCA. |
| Gamification and BIM Teaching the BIM Method through a Gamified, Collaborative Approach (Pütza et al. 2020) | 50 participants | Participants are placed in scenarios where real project schedules are simulated as a competition. The evaluation method was based on multiple choice questionnaires and scales. | 76% of the participants affirmed that they acquired a new vision with the BIM system. Likewise, 90% of them evaluated the system positively since they had fun and felt motivated to continue participating because of the idea of competing. |
| Boss fights in lectures! – A longitudinal study on a gamified application for testing factual knowledge (Wesseloh et al. 2020) | 2 groups of 153 students and 65 students | The problem was identified with the current literature, a gamified prototype was implemented and sessions with the game were held for the 2 groups of participants in order to test factual knowledge. | The students were surveyed and it was perceived that the utility they feel about the game is greater. Likewise, those who were in the top 10 places were much more satisfied than others with respect to their performance. |

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| Training Competences in Industrial Risk Prevention with Lego® Serious Play®: A Case Study (Cerezo et al. 2019) | 172 students | The participants took practical workshops to implement LSP methodologies and work by competencies. They propose scenarios where they discuss ideas, suggest models and use Lego to make decisions and exchange experiences. | At the end of the intervention, self-assessment surveys were carried out and yielded results such as that the level of skills they believe they possess increased by 268% compared to before the intervention. Likewise, the utility they give to the content and the interest they show increases by 77% and 89% respectively. |
| Escape into patient safety: bringing human factors to life for medical students (Backhouse and Malik 2019) | 19 students in a group of 6 and 7. | An escape room game was designed, a game where teamwork is reinforced and clues are sought to find a way out (in this case, the objective was to diagnose and treat the patient in a maximum time of 30 minutes). It was carried out 3 times in a period of 1 year and was attended in order of arrival. | It was shown that an educational intervention for medical students provides them with greater knowledge and helps them gain more confidence, being successful and fulfilling its objective. |
| A system for immersive medical and engineering training based on serious games. (Mondragón 2020) | The group with the first application consisted of 20 students and 8 adults. The group with the second application was 11 students. | 2 applications were used: the first uses information modeling and focuses on security risk training. The second is a tool that develops skills to be able to read medical images. | According to the perception of the users, a game used for training would be interesting, considering that the virtual environment is realistic. The tool is most useful for people who have not had preparation or any training with VR or gaming, but on the other hand, people with knowledge of VR or gaming understand the realism of the game. |
| Finding the ‘QR’ to Patient Safety: Applying Gamification to Incorporate Patient Safety Priorities Through a Simulated ‘Escape Room’ Experience (Zhang et al. 2019) | 130 internal doctors divided into 16 groups. | A simulated escape room game was designed where the objective was to identify threats to patient safety in a maximum time of 20 minutes. | The results showed that the simulator was well accepted by the participants. In addition, the experience changed the way they view threats to patient safety and they were able to easily identify mistakes they can make in a real situation. |

| Paper / Author | Sample Size | Methodology | Results |
|--|---|---|---|
| Formative, multimethod case studies of learn to quit, an acceptance and commitment therapy smoking cessation app designed for people with serious mental illness (Vilardaga et al. 2019) | 38 participants passed the eligibility process for the study. Only 14 made it through the in-person interview screen, 9 passed the in-person interview screen, and 7 completed the study. | Two applications were implemented: LTQ, an app for people with mental illnesses that helps them quit smoking, and QG, the app designed for the general population. | The indicators indicate that there is a high level of comprehension and retention of the LTQ content, which is consistent with their tests and could indicate that the application is having a positive influence on its users. Based on the results, LTQ would appear to be a good use option for people with mental illness. |
| The Zoom Picture Book Game: A Creative Way to Promote Teamwork in Undergraduate Medical Education (Zhang et al. 2020) | 260 first-year medical students signed up for this activity. | This game is based on the picture book "Zoom". The members play with 30 images and they will organize them only by looking at the image that each one has (they will be able to describe the image to the rest of their team). They have a maximum time of 30 minutes | The results shown on a scale from 1 to 4, with 1 being a great acceptance and 4 rejection of the idea or conclusion, that the game promotes interactions between the participants, respect, trust and other good attitudes. |
| The Sound Games: Introducing Gamification into Stanford's Orientation on Emergency Ultrasound (Lobo et al. 2017) | 16 residents (interns) of the Stanford Emergency program. According to their knowledge, they were divided into 8 teams of 2 people each. | The game is made up of 3 rounds of questions and a practice session using simulation. Questions were selected from reading materials and included general, technical, diagnostic, and driving knowledge. In the case of the simulation, this represented one of the seven possible diagnoses. | 13 of the 16 participants stated that the game helped them improve their knowledge of ultrasound. Similarly, 13 of 16 participants stated that the competition helped them better understand the reading material. The results suggest, additionally, that adding the game to the compulsory course has a benefit in the students and their acceptance. |
| Expect the Unexpected: Simulation Games as a Teaching Strategy (Ambrosio and Ford 2016) | A first group of 7 students and a second group of 11 students. They came together in groups of 2-3 students. | 3 gamified simulation scenarios regarding patient safety and the care environment. | 100% of the participants feel that this experience was beneficial and their fear of the unexpected decreased. All students expressed an improvement in the clinical aspect and 98% are better prepared for what may occur in their work. 95% were able to identify areas where they needed to improve and were motivated to improve them. |

| Paper / Author | Sample Size | Methodology | Results |
|---|---|--|---|
| Enhancing Surgical Team Performance with Game-Based Training (Kreutzer et al. 2013) | 141 participants (36 women and 105 men) | Game called Safe Surgery Trainer, which trains medical staff in virtual scenarios designed to improve group skills, responses and control. | The results show that a game-based approach can be effective in improving knowledge and behavior that facilitate team communication. The development and feedback given by the SST has the potential to facilitate team skills that would improve patient safety in the operating room. The participants showed an improvement in knowledge about effective communication behaviors, being able to apply them to situations and showed an improvement in the level of training. |

Table 5. Methodology and results of the main articles.

4. Discussion

After analyzing the results of the articles selected for the bibliographic review, it is evident that studies are becoming more relevant in recent years in areas of a professional nature or professional training to test and apply learned theory. Studies such as Ambrosio and Ford (2013) show that engaging nursing students in the early stages of their education with gamified simulation promoted motivation related to the importance of improving the safety of patient outcomes. Also, it is a creative innovation to increase students' enthusiasm for learning, encourage collaboration and enhance learning.

On the other hand, due to technological advancements and modernization, gamification techniques are easier to implement as there are technological tools and software that facilitate their development, design, and adaptation (García et al. 2019).

Furthermore, there is a significant use of virtual tools in gamification implementation in studies, particularly those related to medical education. Results from authors such as Blakely et al. (2009) show that game-based simulation has the potential to be an effective learning method, but games must be able to replicate clinical reality. Today's students are familiar with the virtual world and visually realistic gaming environments, so the standard required for educational games is high. In general, the findings are consistent with previous research, which suggests that computer-based simulations engage students in the learning process.

In contrast, investigations conducted by Jackson et al. (2020) did not report any significant findings in their studies. Games are effective for engaging clinicians and provoking reflection, but they are not necessarily a superior teaching tool. Patient transfers in simulations are not straightforward since there is no certainty of having more specialists available. Similarly, results obtained by Weyrich et al. (2021) did not demonstrate significant differences between learning conditions. Although there were problems in implementation, such as images not being helpful, difficult interpretation, and minimal video animation, participants in the serious game condition had higher levels of participation.

Studies like Mondragón (2020) suggest that a game used for training would be interesting, considering that the virtual environment is realistic. The tool is most useful for people without preparation or training in VR or gaming. However, people with knowledge of VR or gaming understand the realism of the game. In other studies such as Wong et al. (2020), participants were able to learn complex scientific concepts through active exploration, and the inclusion and development of these games will be useful for public communication of science.

Backhouse and Malik (2019) verified that participants acquired greater knowledge on the subject through an "escape room" and had an increase in their self-confidence. This was also observed in the article presented by Zhang et al. (2019), where the "escape room" not only promoted trust but also a different learning environment, developed

communication skills, teamwork, and gave a new perspective on learned theory.

Lobo et al. (2017) demonstrated that gamification, especially the "sound game," provides a new perspective when viewing theory, and participants feel that they better process theoretical concepts in a more practical or experiential way during the game. Additionally, the competition brought by gamification provides an additional educational value that contributes to learning.

After investigation, this study is considered to contain some limitations that could delimit future research and should be considered when interpreting the results. The first limitation identified is the use of only two databases, Scopus and Web of Science, which only considered articles with an experimental design. Although these two databases were used due to the quality and quantity of research available, the search could be expanded by including other types of articles such as literature reviews, theoretical articles, or articles where a prototype is developed or results in, and other databases such as SciELO and Science Direct.

Another limitation identified is that an age limit was set for publications, only considering articles published in the 5 years prior to the research. The search could be broadened by expanding the range of publication years to 10 or 15 years prior to the research. Additionally, an increase in research on the topic of gamification was observed, indicating that for future research and literature reviews, there may be a greater number of sources to analyze.

Finally, the lack of resources to pay for journal subscriptions limited the number of studies that could be covered.

5. Conclusions

In conclusion, the proposed methodology allowed for the most relevant studies to be analyzed with the VOSviewer bibliometric manager. The analysis of key terms and their occurrence through bibliometric visualization enabled initial conclusions to be made on the main topics being addressed by research, such as nursing and medical practitioners. Conversely, it also revealed a knowledge gap in the area of industrial safety and risk at work that could be explored in future empirical research.

Moreover, this study highlights the main tools currently used in the implementation of security gamification, indicating that virtual tools such as computer software or the use of virtual reality instruments predominate.

Finally, the synthesis of the context and results of the literature determined which topics are currently covered by gamification. The study showed that gamification offers a new teaching modality that is more interactive and entertaining, encouraging the improvement and development of job skills through games and rewards. However, it was also noted that gamification does not always produce a good result and further research is needed. Studies suggest that gamification is a more attractive learning method that guarantees at least the same results as traditional training, but it is necessary to identify the staff to be tested, determine the most motivating incentives for this population, and design a plot that is didactic and intuitive.

Overall, this research can serve as a basis for future studies on the implementation of gamification, its benefits, and limitations in personnel training.

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