

# Game-based learning in the scientific literature: text mining analysis

## Pedagogía basada en el juego en la literatura científica: análisis de minería de textos

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### Abstract

Game-based learning has increased its influence in different fields (e.g., education or marketing) in recent years. However, it is difficult to have an overall landscape of the scientific approach that has been carried out to date around this term. The objective of this study is to identify, analyze, and provide a comprehensive map of the emerging concepts published in the scientific literature related to game-based learning, as well as to establish the most studied topics around these concepts. Method: A search was conducted in the Web of Science (WOS) database for all articles related to this topic, and they were analyzed through data mining techniques using both titles and keywords, as well as abstracts. The frequency of occurrence of unigrams, bigrams, and trigrams was calculated, as well as the investigated topics within the subject through latent Dirichlet analysis. Results: Some of the most frequent unigrams, bigrams, and trigrams were 'student', 'education', 'virtual reality', 'video

game', 'learning environment', 'autism spectrum disorder', 'design methodology approach', and 'information communication technology'. From the model based on latent Dirichlet analysis, 15 research topics related to game-based pedagogy emerged, focusing on new tools for implementing gamification in different contexts (e.g., marketing or economics), as well as the application of game-based learning in the university environment to enhance learning and motivation, which has increased their scientific presence in recent years. Conclusions: According to the results of this study, there is an overall understanding of the scientific approach that has been carried out around play-based pedagogy.

**Keywords:** games, game design, learning, students, software, motivation.

### Resumen

La pedagogía basada en el juego ha aumentado su influencia en diferentes ámbitos (p. ej. educativo o márketing) durante los últimos años sin embargo es difícil tener una visión general del abordaje científico que se ha realizado hasta la fecha alrededor de este término. El objetivo de este trabajo es identificar, analizar y proporcionar un mapa completo de los conceptos emergentes publicados en la literatura científica relacionada con la pedagogía basada en juegos, así como establecer los tópicos más estudiados alrededor de dichos conceptos. Método: se realizó una búsqueda en la base de datos Web of Science (WOS) de todos los artículos relacionados con esta temática y se analizaron utilizando tanto el título como las palabras clave y los resúmenes mediante técnicas de minería de datos. Se calcularon la frecuencia de aparición de los unigramas, bigramas y trigramas así como los tópicos investigados dentro de la materia a través del análisis latente de Dirichlet. Resultados: algunos de los unigramas, bigramas y trigramas más frecuentes son: 'student', 'education', 'virtual reality', 'video game', 'learning environment', 'autism spectrum disorder', 'design methodology approach' y 'information communication technology'. Del modelo basado en análisis latente de Dirichlet emergieron 15 tópicos de investigación relacionados con la pedagogía basada en el juego siendo aquel que se centra en nuevas herramientas para la implementación de gamificaciones en diferentes contextos (p. ej. marketing o economía) así como la aplicación de pedagogía basada en el juego en el entorno universitario para favorecer el aprendizaje y la motivación los que han aumentado su presencia científica en los últimos años. Conclusiones: gracias a los resultados de este trabajo se dispone de una visión general del abordaje científico que se ha realizado alrededor de la pedagogía basada en el juego hasta la fecha.

**Palabras clave:** juegos, diseño de juegos, aprendizaje, alumnado, software, motivación.

## Introduction

Game-based pedagogy (GBP) has recently emerged as a topic of great interest in various academic and practical fields. It seeks to integrate games or their elements into the design of learning activities, whether through digital games, adapted board games, simulations or the use of game mechanics in traditional activities (Deterding et al., 2011).

The use of GBP is intended to enhance students' intrinsic motivation, improve their engagement with content, encourage problem-solving, promote critical thinking, and provide a more meaningful and memorable learning experience (Brangier & Marache-Francisco, 2020; Nadolny et al., 2020; Osipovskaya & Miakotnikova, 2020; Tundjungsari, 2020). Furthermore, it is important to note that GBP does not simply involve the act of "playing" in the classroom; rather, it requires the careful design and appropriate integration of game elements to support the achievement of educational goals and the students' learning process (Pan et al., 2021).

GBP can be implemented through a combination of different strategies, including gamification and serious games. Gamification is the process of applying game elements and mechanics in nongame contexts (Deterding et al., 2011), such as education, work or marketing. It involves the use of game-like techniques and dynamics to motivate and engage people in activities that might otherwise be less appealing. Elements such as rewards, challenges, competition and progression are employed to encourage participation and engagement (Toda et al., 2019). For instance, the *Kahoot!* tool (<http://kahoot.com/>) permits assessment processes in the classroom (it is not a game) while implementing game-like elements such as progress bars, rankings or immediate feedback. In contrast, serious games are interactive applications designed with a primary purpose beyond entertainment (Apt, 1970). Although they are games in themselves, their main purpose is to provide learning, training, simulation or problem-solving in specific areas (Ritterfeld et al., 2009). These games are often used in fields such as education, health, business training or research (Pan et al., 2021). One example of such a game is *Foldit* (<https://fold.it/>). This is a protein folding game in which players attempt to solve online puzzles to determine the three-dimensional structure of proteins.

Both gamification and serious games have recently emerged as topics of great interest in various academic and practical fields. This innovative

approach has captured the attention of researchers, practitioners and educators seeking to harness the potential of games to foster engagement and learning in different contexts. Its application in areas such as education (İlhan, 2021; Pando Cerra et al., 2022), marketing (Korn & Schmidt, 2015; Rodrigues et al., 2016), health (Edwards et al., 2016; Sardi et al., 2017) and personal development (Gaonkar et al., 2022) has generated a growing body of research and a wide variety of theoretical and practical approaches.

The objective of this article is to conduct a comprehensive review of the literature on GBP and then perform a text mining analysis. This will enable a comprehensive understanding and interpretation of how GBP is being approached, developed and implemented. It will also facilitate the establishment of key terms and relationships between them, as well as the most studied topics to date related to this pedagogy and its evolution over the years. This can provide valuable guidance for future research on gamification and offer a comprehensive and up-to-date understanding of the key areas of interest concerning GBP.

To date, several papers have been published that have conducted a text mining analysis on articles related to gamification in different contexts. Rodrigues et al., (2019) conducted their analysis on a selection of papers (i.e., 50 articles) related to gamification. Furthermore, in this paper, they analyzed only the conclusions and future lines of research in their text mining. In their conclusions, they identify eight topics of interest related to this term: gamification, games, use, users, business, points, engagement and learning. Martí-Parreño et al., (2016) conducted a study based on social networks and text mining of 139 articles published between 2010 and 2014. These authors found that interest in GBP at the scientific level increased progressively during those five years. Moreover, the researchers identified four themes that have been investigated to date: effectiveness, acceptance, social interactions and engagement. However, it should be noted that the majority of these papers only analyze a small proportion of the available literature on GBP. Likewise, a significant period of time has elapsed since the completion of these works, and a current analysis could provide an updated and present overview of the state of the art.

The objective of this paper is therefore to identify, analyze and provide a comprehensive mapping of the emerging concepts published

in the scientific literature related to GBP, as well as to establish the most studied topics around these concepts. To achieve this objective, a search was conducted in the *Web of Science* (WOS) database of all articles related to this topic. These were then analyzed using both the title and the keywords and abstracts through the application of text mining techniques.

## Method

### Data Recovery

This study focuses on the analysis of titles, abstracts, and keywords published in the WOS database. A group of experts in Physical Education convened to define the study's topic and design a structured search.

The search was conducted in the *Web of Science database (Advanced Search Query Builder)*, utilizing the title, abstract, and author keywords fields. The following search equation was employed, considering the theme and the keywords of interest for the present special issue: “*gamif\**” OR “*gameful des\**” OR “*gam\* bas\* learn\**” OR “*serious gam\**”. No document type filters were applied, and multiple databases within the WOS main collection were considered, such as SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC.

The search had no time or language restrictions and was conducted on May 19, 2023. A total of 23,603 documents were downloaded. For each obtained record, the title, abstract, author keywords, publication year, and DOI were collected and stored in a CSV file for further analysis.

### Data pre-processing

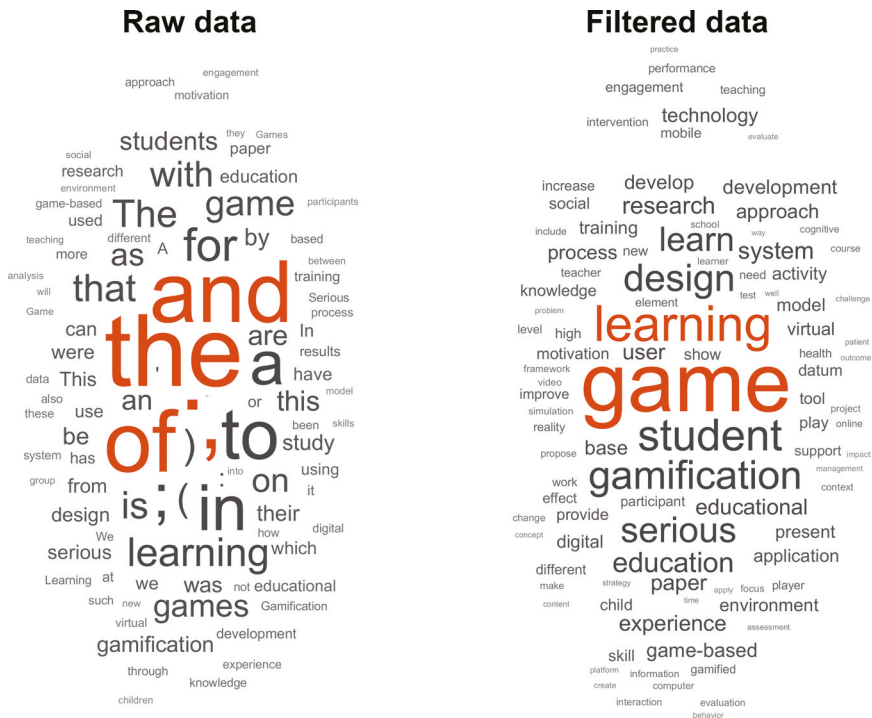
To prepare the text of the documents for further analysis, we followed the standard recommendations used in similar studies (Rajman & Besançon, 1998). As a first step, duplicate documents, in our case 138, were removed, leaving a total of 23,465 documents. These documents were converted into tokens (tokenisation) and the following actions were performed in the following order:

- All hyperlinks ('http://url') were removed.
- Punctuation marks and special characters were also removed.
- All characters were converted to lowercase.
- Words that did not contribute significant content to the documents and could introduce noise in the text (e.g. 'a', 'and', 'to') were removed, using a list of stopwords provided by the Matlab text analysis toolbox.
- As the abstracts of articles sometimes include copyright information and the name of the publisher and sometimes not meaningful content (e.g. 'aim' or 'methods'), these parts were removed as they do not provide relevant information about the content of the articles.
- The words were standardised through a process of lemmatisation, which involves analysing the morphology of the words and reducing them to their roots using a predefined dictionary. In addition, details were added about the grammatical function of the words, such as whether they were nouns, verbs, adjectives, etc.
- Finally, words that were less than two characters or more than 20 characters in length, as well as words that appeared less than two times in the corpus of documents, were removed. This procedure has been employed by research applying this same methodology (Pans et al., 2021). Figure I shows the effect of preprocessing on the most repeated words in the analyzed bibliography. The resulting tokens were then grouped into sets of words (unigrams), as well as two sets of frames (bigrams and trigrams).

## Descriptive analysis of the documents

The document analysis commenced with a description of the retrieved documents, using only the text and the date of creation. The number of articles per year was counted, and a frequency analysis of the principal n-grams was performed. An n-gram is defined as a contiguous sequence of  $n$  elements within a given sequence of words. The frequency values of the principal unigrams, bigrams and trigrams are presented in frequency tables.

FIGURE I. The principal terms identified in the documents prior to and subsequent to data processing



Source: own elaboration.

## LDA Topic Analysis

To identify the present topics in our data corpus (i.e., the collection of papers), we applied a latent Dirichlet assignment (LDA) model. This model assumes that there are a fixed number of latent topics appearing in various documents (in our case, the 23,465 papers). Each paper is characterized by a mixture of topics, and each topic is characterized by a probability distribution of words. The presence of a word in a document indicates the potential presence of a latent topic.

The LDA model serves two functions: first, it extracts the main topics from the corpus studied by different research groups over the years; second, it serves as a method for selecting documents related to topics of interest.

The analysis was performed using the 'filtlda.m' function from the MATLAB text analysis toolbox, utilizing the previously preprocessed unigrams. Before proceeding, it was essential to determine the optimal number of subjects. To assess the quality of the LDA model, the perplexity was calculated, which indicates the model's ability to describe a set of documents. A lower perplexity value indicates a superior fit. A total of 5, 10, 15, 20, 30, 40, 50, and 60 topics were tested, with the lowest perplexity value obtained with 15 topics. Once the appropriate number of topics was fixed, an LDA model based on a Gibbs sampling algorithm was implemented.

The 15 topics were then subjected to further analysis, with the most representative words being selected based on their highest probabilities of occurrence in the topic. Additionally, topic mixtures were calculated for each document, and the most representative documents for each selected topic were identified.

Finally, an analysis of the dynamics of the topics was conducted. To this end, the words that belonged to each topic were searched year by year, and the frequency of occurrence in the documents published was calculated. With the frequency values for each year, Z scores were calculated for each of the topics. The Z score, also known as the Z score, is a statistical measure that indicates the number of standard deviations a particular data point is above or below the mean in a normal distribution. A positive Z score indicates that the value is above the mean, while a negative Z score indicates that it is below the mean. The Z score is used to standardize and compare different datasets.

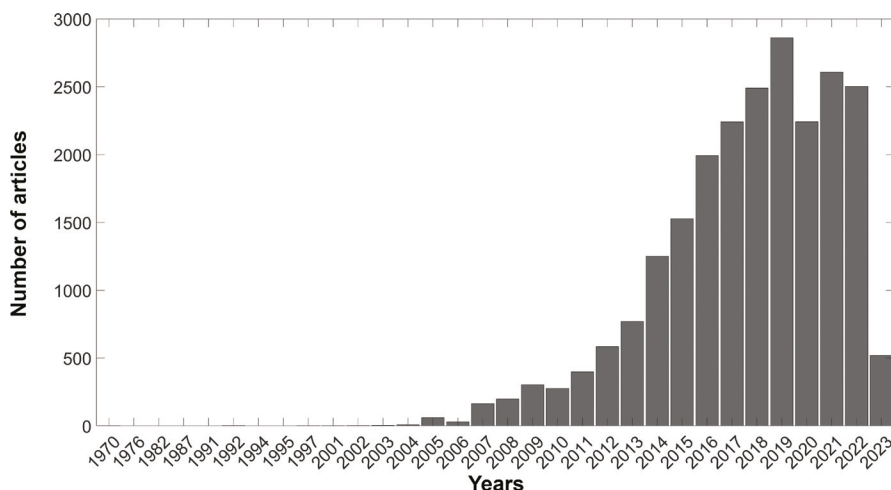
## Results and Discussion

This study represents a pioneering effort to analyze all articles published to date and indexed in WOS that explore different applications, effects, or conceptualizations of GBP-related terms. The results derived from these text mining analyzes are presented in the following sections.

### General Data of Published Articles

Before preprocessing, a total of 23,465 documents published in WOS were included once duplicates were removed. Figure II presents a

FIGURE II. Frequency of published articles indexed in WOS related to game-based pedagogy



Source: Compiled by the authors.

histogram of the frequency of publication of the articles included in the study over the years. There was an increase that followed a practically linear trend from 2012 to 2019. The number of journals and, therefore, the number of articles published each year are increasing (Peset et al., 2020). Nevertheless, it is evident that the research topic is garnering increasing attention from the scientific community, as previously posited by certain authors (Martí-Parreño et al., 2016). However, since 2019, the number of publications has remained relatively constant. It is possible that this was due to the impact of the COVID-19 pandemic for two different reasons. The first is that following the pandemic, restrictions were imposed that included educational institutions, which hindered the possibility of conducting research studies in classrooms, in our case, related to GBP. Second, the emergence of the pandemic prompted a shift in focus among researchers, with an increased emphasis on analysing the effects of the pandemic on various aspects, including educational aspects (Cretu & Ho, 2023). This shift in focus resulted in a reduction in the number of GBP-based studies conducted.

## Description of the Most Frequently Used N-Grams

A total of 21,791 words emerged independently from all the documents analyzed. Table I shows the twenty most repeated unigrams, bigrams, and trigrams in the documents used. As expected, those combinations that were used as a search strategy appear at the top of this list (e.g., 'serious game' or 'game-based learning').

Upon examination of the most frequently occurring unigrams, excluding those explicitly included in the search strategy, it becomes evident that 'student' and 'education' are the two most prevalent terms. This suggests that despite the multitude of contexts in which GBP-related strategies have been employed and investigated, the educational setting has received the greatest degree of attention.

Concerning the most frequently occurring bigrams (again, with the exclusion of those directly included in the search), we find the terms '*video game*', '*virtual reality*', '*educational game*', or '*learning environment*'. Upon examination of these bigrams, two primary trends related to GBP can be identified. The first, as with unigrams, is the application of this pedagogical strategy in the educational environment to promote learning. The second trend is related to the use of technological means (virtual reality or video games) to implement this type of pedagogy.

Finally, concerning the trigrams, the most representative terms in the field of study could be '*autism spectrum disorder*', '*design methodology approach*', and '*information communication technology*'. In some ways, the trends identified in the bigrams are reinforced, both in terms of technological media (e.g., '*information communication technology*' or '*immersive virtual reality*') and in terms of the application of this pedagogy in the educational environment (e.g., '*autism spectrum disorder*' or '*high school student*'). Nevertheless, a novel line of concepts emerges that can be related to the design of methodologies and games to implement this pedagogy in different environments (e.g., '*design methodology approach*').

## Main topics found in the LDA model

The identified words were classified into fifteen broad topic groups according to the LDA model. These topics are ordered from most to least

TABLE I. Unigrams, bigrams and trigrams most frequently repeated in the analyzed documents

| Unigram      | Count  | Bigram      |             | Count | Trigram      |               |             | Count |
|--------------|--------|-------------|-------------|-------|--------------|---------------|-------------|-------|
|              |        | serious     | game        |       | game         | base          | learning    |       |
| game         | 82.773 |             |             | 20093 |              |               |             | 1401  |
| learning     | 36.884 | game-based  | learning    | 7429  | serious      | game          | design      | 1133  |
| student      | 30.906 | game        | design      | 4569  | game         | serious       | game        | 1017  |
| gamification | 26.703 | video       | game        | 3678  | digital      | game-based    | learning    | 859   |
| design       | 24.775 | virtual     | reality     | 3584  | gamification | serious       | game        | 540   |
| serious      | 22793  | educational | game        | 3019  | game-based   | learning      | environment | 504   |
| learn        | 20283  | paper       | present     | 2606  | information  | communication | technology  | 409   |
| education    | 16523  | play        | game        | 2483  | game         | design        | element     | 409   |
| research     | 13382  | learning    | environment | 2390  | autism       | spectrum      | disorder    | 379   |
| system       | 12569  | digital     | game        | 2374  | development  | serious       | game        | 348   |
| educational  | 12214  | high        | education   | 2227  | learning     | serious       | game        | 325   |
| paper        | 12022  | game        | base        | 1847  | develop      | serious       | game        | 322   |
| user         | 11805  | computer    | game        | 1784  | design       | methodology   | approach    | 314   |
| experience   | 11561  | game        | element     | 1738  | high         | school        | student     | 312   |
| approach     | 11165  | physical    | activity    | 1595  | serious      | game          | virtual     | 304   |
| process      | 10572  | learning    | process     | 1497  | reality      | serious       | game        | 304   |
| base         | 10537  | learning    | experience  | 1286  | virtual      | learning      | environment | 265   |
| game-based   | 10443  | base        | learning    | 1275  | educational  | video         | game        | 261   |
| develop      | 10442  | user        | experience  | 1204  | immersive    | virtual       | reality     | 246   |
| technology   | 10386  | virtual     | environment | 1118  | game         | virtual       | reality     | 233   |

Source: Compiled by the authors.

likely to appear in the complete body of knowledge. That is, topic 1 is more likely to appear in articles published about GBP than topic 8 or 15. Additionally, the model provides a percentage of probability that the concepts are part of a given topic and ranks them from most to least important for the topic according to that percentage. This approach enables the determination of the significance of individual topics and the occurrence of combinations of key concepts. The number of topics identified differs from the four proposed by Martí-Parreño et al., (2016) and the eight proposed by Rodrigues et al., (2019). It is important to note that by including a larger number of papers in this study than in the two previously published studies (i.e., 23,603 versus 50 and 139 of the previous studies), it is to be expected that the number of topics that emerge from text mining will be greater and that they will cover different aspects.

Although it may be somewhat complex to express this concept, visualizing Figure III and proposing illustrative examples will facilitate a clear understanding of this analysis and the results it provides. The first topic is represented by terms such as *'game'*, *'serious'*, *'player'*, *'design'*, *'video'*, and *'educational'*. Therefore, this topic appears to pertain to documents that have focused on the design of serious games, which are likely to be applied, above all, in the educational context. Upon examination of the literature on this topic, it becomes evident that several authors have advocated the inclusion of user enjoyment as a crucial element in the design of serious games. For instance, Read, (2016) proposed that user engagement should be a primary consideration in the development of these games. Similarly, Fiadotau et al., (2022) recommended striking a balance between player preferences and design considerations, such as the educational value or practicality of the game, when designing serious games. Additionally, Dormann & Biddle, (2009) proposed that humor should be incorporated into the design of serious games, as it influences social, emotional, and cognitive aspects of player behavior. These works collectively provide a framework for the design of serious games, with a focus on the educational environment.

The following section describes those topics that are most relevant to the learning environment and learning. In particular, we selected topics 2, 6, 9 and 10 for an in-depth description and discussion. However, if readers would like to know which documents are most closely associated with each of the topics and to read them, they can consult the supplementary material.

FIGURE III. Topics included in the documents analyzed using the LDA model



Source: Compiled by the authors.

Topic 2 is composed of terms such as *'learning'*, *'game-based'*, *'teacher'*, *'language'*, *'digital'* or *'school'*. This suggests that this theme is based on the use of serious games in teaching-learning processes for students at early levels of schooling. Furthermore, it seems that language teaching may have a special relevance to this topic. To elaborate on this in more detail, let us look at the main contributions made in this area. Hsu et al., (2008) propose a system for analysing GBPs and digital GBPs and raise questions about the design of these strategies for use in the classroom. Fu et al., (2022) conducted a study in which they applied a proposal for collaborative digital game design by students. They found that students who designed collaboratively performed the task more effectively and from a more constructivist point of view. Another study on this topic applied an intervention for teaching mathematics at the primary school stage using serious games in a digital context. They found that children who completed sessions using this methodology increased their

mathematics knowledge to a greater extent than did those in a traditional teaching group (Hwa, 2018). School teachers believe that educational games such as Minecraft can help foster collaboration among students, encourage creativity, and foster active learning and can be useful in fostering inclusive education (Slattery et al., 2023). Finally, Hayak & Avidov-Ungar, (2023) conducted a qualitative study in which they reported that primary schoolteachers use four types of knowledge to integrate digital GBPs in the classroom. These four categories were knowledge of games (e.g., type of game, difficulty levels), technological knowledge associated with games (e.g., familiarity with digital systems and technical skills to operate them), pedagogical knowledge associated with games (e.g., how to use digital games to contribute to teaching-learning objectives) and pedagogical knowledge of content associated with games (e.g., ability to integrate knowledge of using games to implement teaching methods for any content and learning-centred pedagogy). As previously stated, this topic concerns the implementation and design of GBP (especially serious games) in primary and secondary education and the analysis of its effects on variables of educational interest. It also includes works that analyze strategies for incorporating this pedagogy into the educational environment. This topic is related to the theme identified by Martí-Parreño et al., (2016) on the effectiveness of gamification in the educational process and to the themes of ‘gamification’ and ‘game’ identified by Rodrigues et al., (2019).

Topic 6 encompasses words such as ‘gamification’, ‘element’, ‘engagement’, ‘design’, ‘motivation’, ‘reward’, ‘online’ or ‘system’. This suggests that the topic is focused on gamification, its design and implementation through various systems and elements, and its effect on user motivation and engagement. One of the most representative works on this topic is that published by Chan et al., (2018), in which the influence of gamification based on different elements (e.g., points and rankings) on intrinsic motivation is determined. The results of this study indicated that students who are already motivated do not require gamified environments. Furthermore, the authors suggest that the use of gamification decreases intrinsic motivation, particularly in cases where the point system is not proposed as a way of providing feedback. However, Kim et al., (2020) found that the application of gamification to engineering students led to improvements in intrinsic and extrinsic motivation while simultaneously reducing demotivation. Hamari et al., (2014) suggest that gamification

has the potential to promote positive effects on motivation, although these effects depend on the context in which it is implemented and the users who participate in the experience. In a similar vein, Mekler et al., (2017) examined the impact of points, rankings and levels on intrinsic motivation. Their findings indicate that none of the three elements of the games resulted in greater intrinsic motivation compared to a control group. However, they elicited a greater number of positive responses in the task, which may be attributed to the increase in extrinsic motivation. Another study on this topic has also been interested in analysing the differential effects of certain elements included in gamification. This review concluded that elements such as stories or narratives and badges are useful for increasing students' cognitive engagement with lessons (Abu-Dawood, 2016). It seems that a key aspect to consider when developing educational programmes is the elements that are included in gamification, as different groups of elements can generate specific changes in student motivation and other educational variables. This research topic is still ongoing today, and there is a need for further articles to be published to establish which types of elements are the most suitable for creating gamification in educational environments. Upon examination of the works included in this topic, it becomes evident that a significant proportion of them are not from the educational field and instead belong to the domains of marketing and economics (e.g., Eisingerich et al., 2019; Morschheuser et al., 2016). Upon attempting to correlate this topic with those previously identified by other researchers, a degree of concurrence was observed with the theme of 'engagement' proposed by Martí-Parreño et al., (2016), which encompasses terms such as enjoyment and task retention. Additionally, it is also related to the themes '*engagement*' (e.g., *context*, *mechanics*), '*game*' (e.g., *elements*, *design*), and '*gamification*' found by Rodrigues et al., (2019).

Topic 9 encompasses terms such as '*student*', '*university*', '*learning*', '*course*', or '*education*'. Consequently, it appears to be more oriented towards the application of this pedagogical approach to university students, with the objective of facilitating learning. A further investigation of this topic revealed works such as that of Sánchez-Martín et al., (2020), who demonstrated the efficacy of escape game experiences in science, technology, engineering and mathematics (STEM) subjects in enhancing student motivation. These experiences were well received by students, irrespective of their degree or gender, and the experiences they had were

predominantly positive. Gómez-Urquiza et al., (2022) conducted a study to assess the opinions of nursing students regarding educational escape games. The findings indicated that the students perceived these games as fun, dynamic, and motivating strategies for studying and learning. In contrast, Martínez-Jiménez et al., (2021) conducted a study demonstrating that the utilization of *Kahoot!* in student assessment is conducive to enhancing learning efficiency and reducing the number of students who fail the subject. Additionally, numerous papers in this field have examined the utilization of this assessment tool in university settings (e.g., Cruz et al., 2021; Esteves et al., 2018; Pertegal-Felices et al., 2020). Other works present compendiums of applications that can be used for gamification and propose the creation of different resources, such as role-playing games (RPGs), to be applied in the educational environment (Batista & Vaz de Carvalho, 2008; Mikic-Fonte et al., 2020; Rocha et al., 2020). Consequently, this topic is linked to the application of GBP in the university environment. Among the most commonly employed strategies are educational escape games and the utilization of *Kahoot!* in assessment processes.

Finally, topic 10 included words such as '*student*', '*learning*', '*game-based*', '*performance*' or '*motivation*'. When contrasting some of the papers associated with this topic, we found works such as Lei et al., (2022). These authors conducted a meta-analysis to determine the effects of GBP on the academic performance of students from primary school to university in science fields. Their results showed that GBP helps students achieve educational goals to a greater extent than more traditional forms of instruction. Lin et al., (2017) conducted a study comparing the effectiveness of digital GBP on student learning and motivation when used in a competitive or cooperative manner. Their findings indicate that both strategies yielded comparable results in terms of effectiveness and motivation. However, they observed that participants in the competitive mode exhibited greater levels of satisfaction than did those in the cooperative mode. In a study conducted by Hung et al., (2014), the application of GBP in primary school mathematics was found to have a positive impact on students' performance, self-efficacy and motivation towards the subject. Consequently, the focus of this topic is on the effects that GBP has on the outcome (in terms of efficiency) of the educational process. Additionally, different proposals, competitive or cooperative, and their impact on the variables of educational interest are analyzed. It is important to

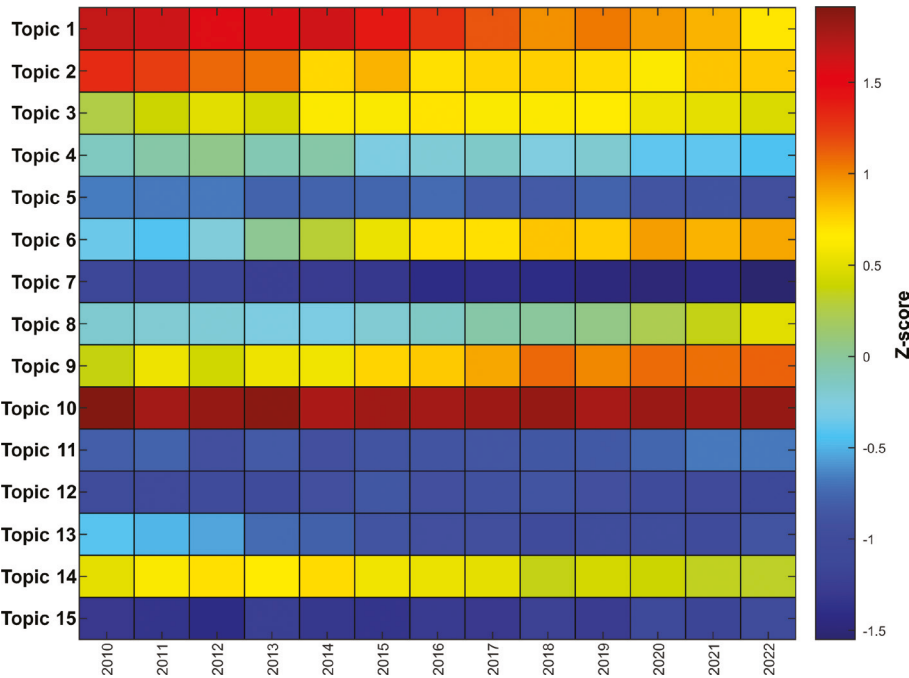
note that the cooperative or competitive orientation of GBP may be related to the differentiated effects that gamification elements may have on motivation. This is because the character of the game is dependent on the elements that predominate in the game. Therefore, both topics 9 and 10 seem to focus on how GBP can promote learning in the educational environment. These findings may be related to the 'learning' theme identified by Rodrigues et al., (2019) or the 'effectiveness' theme identified by Martí-Parreño et al., (2016).

To conclude, this section, Figure IV illustrates the evolution of the various topics in terms of the number of related papers published over time. Upon analysis of this figure, it becomes evident that there has been a notable increase in interest in topics 6 and 9 in recent years. Consequently, over recent years, there has been a surge in interest among the scientific community in developing novel systems to implement gamification in diverse settings with the aim of enhancing motivation and user engagement. Similarly, there has been a notable increase in the application of GBP in the university environment, with the objective of facilitating learning and boosting student motivation. Conversely, topics 1 and 2 have experienced a decline in relevance over the same period. It is important to recall that the first topic is focused on the design of serious games for application, above all, in the educational context. The second topic is based on the use of serious games in teaching-learning processes for students at the initial levels of schooling and the analysis of their effects on variables of educational interest (e.g., motivation or effectiveness).

## Limitations and future lines of research

This work is subject to certain limitations pertaining to the type of analysis employed. While text mining enables the analysis of a significantly larger corpus of texts than would be possible through manual means, it does have certain limitations in terms of the depth of analysis that can be conducted on the texts themselves. Consequently, the methodology employed yields results that provide a valuable overview of the research conducted thus far in the field of GBP. To gain a deeper understanding of the texts and to present the current knowledge of each topic in a narrative form, it would be necessary to carry out a qualitative and manual

FIGURE IV. Dynamics of the topics found in the LDA model over the years



Source: Compiled by the authors.

review of the complete texts. As a second limitation, it would have been beneficial to include more databases. However, due to the large number of papers available, we considered that using WOS (the database with the greatest impact at present) was sufficient.

This work paves the way for comprehensive narrative reviews of the topics under consideration, which will enable us to ascertain the current state of knowledge about each topic with precision. This will result in a comprehensive description of the current knowledge about GBP in all areas of application. Furthermore, while there are some topics that seem to have lost interest in specialist journals, it is recommended that researchers continue to carry out studies proposing new systems that allow the implementation of gamification in various environments to increase user motivation and engagement, as well as the application of GBP in the university environment to promote learning and increase

student motivation. This is because the number of papers published on these topics in recent years has been increasing.

## Conclusions

In recent years, the number of published works on GBP has increased significantly. An overview of the existing knowledge on this subject is therefore essential. This work makes a significant contribution to this overview by identifying the unigrams, bigrams and trigrams most closely related to GBP. The most relevant terms identified as the most common topics covered in GBP-related research are ‘*student*’, ‘*education*’, ‘*virtual reality*’, ‘*video game*’, ‘*learning environment*’, ‘*autism spectrum disorder*’, ‘*design methodology approach*’ and ‘*information communication technology*’. Nevertheless, for a more comprehensive analysis, the 15 most pertinent research topics related to this subject have been provided. These include the investigation of novel tools for the implementation of gamification in diverse settings, as well as the utilization of GBP to enhance learning and increase the motivation of university students. Additionally, the research topics that have witnessed a surge in scientific prominence in recent years have been included.

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