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Mapping of Research Trends on Didactic Games in Chemistry Learning

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ABSTRACT

The integration of didactic games in chemistry learning has gained increasing scholarly attention as an innovative pedagogical approach to enhance student engagement and conceptual understanding. Despite its growing relevance, systematic mapping of research trends in this area remains limited. This study aims to analyze the development and thematic structure of scientific publications on didactic games in chemistry education through a bibliometric approach. Data were extracted from the Google scholar database and visualized using VOSviewer to generate network, overlay, and density maps of keywords. The analysis reveals that the core terms such as "game," "chemistry," and "student" dominate the research landscape, highlighting their role as conceptual anchors. More recent trends indicate a shift toward "gamification," "learner," and broader didactic strategies, signaling the expansion of focus beyond classroom implementation. Furthermore, density visualization shows strong clustering around chemistry content and didactic tools, with opportunities for further exploration in personalized learning and the application of games in complex chemical concepts. In conclusion, this study provides a comprehensive overview of the intellectual structure and emerging directions in didactic games research within chemistry learning, offering insights for both theoretical development and practical innovation.

1. Introduction

Didactic games have gained attention as an innovative teaching method in the last decade. Didactics, as a part of teaching, is concerned with developing efficient teaching strategies. Didactic games are intended to combine instruction with fun elements with the aim of increasing student motivation and participation. Several studies have shown that integrating game elements into science learning can significantly improve cognitive, affective, and psychomotor learning outcomes (Aguilera & Perales-Palacios, 2020; Soboleva et al., 2018). The incorporation of enjoyable learning experiences has become increasingly relevant, especially in educational contexts that demand creativity, problem-solving skills, and active student involvement. As education continues to shift toward student-centered learning approaches, didactic games offer an alternative pedagogical tool that aligns with modern learning needs and fosters deeper engagement.

Chemistry teaching presents unique challenges due to the nature of the material, which requires in-depth understanding and application of concepts, as well as the ability to apply them to real-life situations. Many students struggle to grasp atoms, chemical reactions, and other concepts considered abstract (Miharti et al., 2024). These abstract concepts often require learners to visualize molecular structures or processes that are not directly observable, which can lead to cognitive overload if not supported by effective learning strategies. Didactic games with an interactive approach and hands-on practice can address these challenges by providing concrete experiences and stimulating multiple sensory modalities during learning. Several studies also report that the use of educational games in chemistry learning contributes to reducing students' cognitive load (Yuhelman et al., 2025), demonstrating that games can help simplify complex material and guide students through conceptual understanding more effectively.

Didactic games in the classroom can also facilitate cooperative learning. Group games encourage students' social skills and cooperation (Gülay et al., 2010; Wulandari & Rosdiana, 2024). Through collaborative tasks, students build communication skills, share ideas, and learn to negotiate solutions. For example, chemistry games that require students to discuss and collaborate to formulate solutions to problems encourage peer teaching. This aligns with Vygotsky's social constructivism, which emphasizes the importance of social interaction in the learning process. Other research confirms that group games can develop students' scientific communication skills (Rosiani et al., 2020), indicating that didactic games contribute not only to cognitive achievement but also to broader competencies necessary for scientific literacy.

Educational games used to teach chemistry should be carefully considered. Each game should align with instructional objectives and contain relevant and appropriate material (Ardhani et al., 2021). Without clear alignment, games may become distractions rather than supportive learning tools. Thus, teachers require proper training to effectively integrate these games, and some studies note the existence of dedicated training programs for teachers focused on utilizing these games in teaching and learning activities. Furthermore, it's crucial to assess the effectiveness of educational games to ensure they achieve their intended goals. Previous studies have indicated that games in learning enhance student discipline, reduce classroom stress, and improve learning outcomes. For example, Ariyanto's research (2020) demonstrates that mobile learning games support contextual and meaningful learning. In chemistry learning, students can use interactive games to visualize complex concepts and interact in a safe and controlled environment.

Bibliometric analysis is an important approach to uncover and link the development of research on didactic games used in chemistry learning with the important findings of previous studies. This method not only allows researchers to identify publication trends, influential authors, and dominant themes, but also helps map the intellectual structure and evolution of the field over time. Through such analysis, it becomes possible to determine which aspects of didactic games have been widely explored, which areas remain underdeveloped, and how scholarly attention has shifted across different periods. Consequently, researchers can more accurately describe patterns, research clusters, and opportunities for future investigations in this area. By systematically reviewing the existing literature, we will gain a more comprehensive and evidence-based understanding of the influence of interactive games on chemistry learning, including their pedagogical potential and emerging research directions. In line with this need, this study aims to analyze the development and thematic structure of scientific publications on didactic games in chemistry education through a bibliometric approach

2. Methodology

This study used a bibliometric analysis method based on metadata from the Publish or Perish application. This metadata was then mapped using VOSViewer. An overview of the software used is presented in Table 1 below.

Table 1. Information General Software

Software	Version	Year	Developer
Publish or Perish	v8.12.4612.8838	2024	Tarma Software Research Ltd
VOSviewer	v1.6.20	2023	Leiden University's

Metadata collection using PoP was conducted using the keywords didactic games and chemistry learning. The search was conducted between 2018 and 2025 to identify research updates. The search database was sourced from Google Scholar and stored in RIS format. RIS data was processed with VOSviewer using a binary counting model. Word frequencies in titles and abstracts were set three times, provided they adequately reflect the frequency of word use in titles and abstracts. VOSviewer outputs visualizations in the form of network mapping, overlay, and density. The visual network interprets the relationships between clusters, clusters, and objects. The visual overlay presents research from recent years. Visual density represents the density of research. (McAllister et al., 2022; Sood et al., 2021). In brief, the research flow is illustrated in Figure 1 below.

Figure 1. Research Flow

3. Results and Discussion

Publish or Perish

In the use of Publish or Perish, the researcher employed the keywords didactic games and chemistry learning, which then produced citation metrics that illustrate the scholarly impact of the retrieved publications. These citation metrics are presented in Table 2 to provide a clearer visualization of research productivity and influence in this field.

Table 2. Matrix Citation Game Didactics in Chemistry Learning

Criteria	Result
Publication years	2018-2025
Citation years	7 (2018-2025)
Papers	200
Citations	3322
Cites/year	474,57
Cites/paper	16,61
Cites/author	1403,72
Papers/author	93,45
Authors/paper	2,65
h-index	28
g-index	51
hI,norm	17
hI,annual	2,43
hA-index	13
Papers with ACC >= 1, 2, 5, 10, 20	124, 105, 59, 24, 6

The PoP output citation matrix shows that the number of articles captured by this application is limited to 200. The number of citations is 3,322. The average number of citations per year is 474.57, with 16.61 citations per article. The distribution of the number of articles over the past eight years is shown in Table 3.

Table 3. Total publication Game didactic chemistry

Publication Year	Number of Publications
2025	26
2024	15
2023	32
2022	28
2021	24
2020	23
2019	**27**
2018	18
Total	**474**

The highest number of publications was in 2023, with 93 articles. The lowest number of publications was in 2024, with 35 articles. The H-index is 41. A bibliometric analysis of the topic "didactic games" in chemistry learning revealed several interesting findings related to scientific publications. The study included articles published in various relevant journals and conferences in 2025. The data collected shows that the use of didactic games as a tool in chemistry learning is relatively consistent from year to year, especially at the secondary and tertiary levels. This indicates that research on didactic games remains a strong interest. In fact, in August 2025 alone, the number of articles reached 26. This number is expected to grow further, given that there are still five months to go until the end of 2025. The 10 most cited articles are presented in Table 4 to provide details of their attributes

Table 4. Details of the 10 most cited articles

No	Judul Artikel	Penulis	Penerbit	Tahun	Sitasi
1	*The role of serious games, gamification and interactive simulations in chemistry education*	F Almeida, J Simoes	dergipark.org.tr	2019	484
2	*Gamification as a strategy to increase motivation and engagement in chemistry learning*	GM Chans, M Portuguez Castro	mdpi.com	2021	212
3	*Game-based learning approach on students' motivation and understanding in chemistry*	E Byusa, E Kampire, AR Mwesigye	cell.com	2022	132
4	*What effects do didactic interventions have on students' conceptual understanding in science education?*	D Aguilera, FJ Perales-Palacios	Springer	2020	109
5	*A systematic review of augmented reality game-based learning in science education*	J Yu, AR Denham, E Searight	Springer	2022	99
6	*MOL: Developing a European-style board game to teach chemistry concepts*	E Triboni, G Weber	ACS Publications	2018	96
7	*Perceptions of the use of virtual reality games in chemistry education*	C Udeozor, R Toyoda, F Russo Abegão…	Taylor & Francis	2021	81
8	*What lies behind teaching and learning green chemistry through games?*	M Chen, E Jeronen, A Wang	mdpi.com	2020	69
9	*Stereochemistry game: Creating and playing a fun learning tool for organic chemistry*	JN da Silva Júnior, DEA Uchoa…	ACS Publications	2019	63
10	*Game-based application for helping students remember chemical formulas*	MA Sousa Lima, ÁC Monteiro, AJ Melo Leite Junior…	ACS Publications	2019	61

Based on the table above, the most frequently cited article on this topic is "The role of serious games, gamification, and interactive simulations in chemistry education" by Almeida et al. This article was published in Contemporary Educational Technology and has attracted the attention of many researchers because it outlines the importance of didactic games in increasing motivation to learn chemistry among students. Serious games and gamification have the potential to increase student motivation and engagement through immersive and interactive learning experiences (Almeida & Simoes, 2019). Quantitatively, the article by Almeida & Simoes (2019) dominated citations, accounting for 14.57% of the total citations during the analysis period. This article serves as a primary reference for examining the integration of serious games and gamification in chemistry education. The top five articles cumulatively contributed approximately 31% of the total citations, indicating the presence of a highly influential core literature. This pattern supports the bibliometric principle that only a small portion of the literature forms the backbone of a research field, as demonstrated in structural analyses of the knowledge architecture of a given field.

ACS Publications, Springer, and MDPI appear to dominate these influential publications, suggesting that international publication channels with broad reach are an important factor in achieving high citations. This is consistent with the several studies who found that highly cited articles are often published in high-impact journals. Recent publications such as Byusa et al. (2022) and Yu et al. (2022) have already managed to penetrate this list, indicating that quality articles can gain significant citations in a relatively short time. This bibliometric analysis shows that didactic games are increasingly recognized as an effective tool in chemistry learning overall. The use of games not only increases student engagement but also strengthens understanding of complex chemical concepts. Previous studies have shown that game-based approaches can improve long-term retention of chemistry concepts for more than one semester (Rondon et al., 2013).

In terms of content, several articles have attracted attention. The article "Identifications: A Battle Card Game to Learn Chemical Elements" by C. Lhardy and A. Reina, published in the Journal of Chemical Education, highlights the use of card games as an interactive method for learning chemical elements (Lhardy & Reina, 2024). The results showed that this approach not only increased student interest but also strengthened their understanding of the subject matter. Another noteworthy article is "A Game-Based Approach for Learning Elements in Chemistry" by M.N.M. Naim and M. Karpudewan, published in Chemistry Education Research and Practice. This research emphasizes the importance of a game-based approach to learning chemical elements, where the games used provide career perspectives and increase student learning motivation. This research supports the idea that didactic games can be an effective tool in the context of chemistry education (Naaim & Karpudewan, 2024).

The article "Vikings: An Online Cooperative Game for Reviewing Chemical Equilibrium and Chemical Kinetics" by J.N. da Silva Júnior et al., published in the Journal of Chemical Education, introduces online games as a learning tool. This study shows that the use of online cooperative games can improve students' understanding of the concepts of chemical equilibrium and chemical kinetics

(Júnior et al., 2024). This emphasizes the importance of innovation in teaching methods to meet the learning needs of modern students. Another relevant study is "Exploring Elements: Playfulness as an Ally in Chemistry Teaching" by T.L. Lobo et al., published by Seven Publications. This article discusses the use of play approaches in chemistry teaching, demonstrating that fun and play can enhance students' learning experiences (Lobo et al., 2024). This supports the argument that didactic games not only increase student engagement but also facilitate a deeper understanding of the subject matter. Further research is needed to explore the various types of games and approaches that can be used in chemistry education to achieve optimal learning outcomes. These findings are expected to form the basis for the development of more innovative and effective learning strategies in the future.

VOS viewer

The visualization of bibliometric networks through VOSviewer provides a comprehensive overview of the intellectual structure within a research field. By mapping the relationships among keywords, authors, or references, this visualization allows researchers to identify thematic clusters, core concepts, and the connections that link them. Such graphical representation not only facilitates the interpretation of complex bibliometric data but also offers an intuitive understanding of how concepts interrelate and form distinct research clusters. The network visualization of didactic games in chemistry learning is presented in Figure 2.

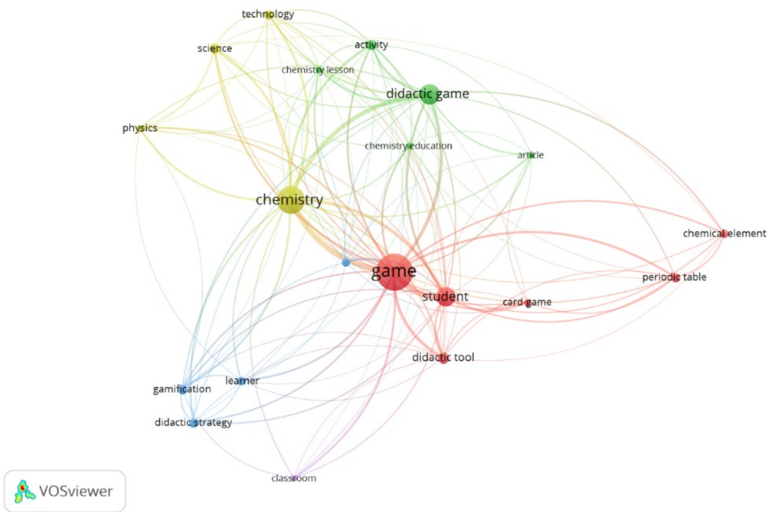

Figure 2. Network Visualization *Didactic Game, Chemsitry Learning*

The term network map shown above is the result of a bibliometric analysis depicting the relationships between various terms related to "didactic games" in chemistry education. This map was generated using the VOSviewer application, which retrieves data from RIS files containing these keywords. In this visualization, each node represents a term, and the connecting lines between nodes indicate the relationships or connections between these terms in the scientific literature. Different colors indicate different clusters, depicting interrelated themes or subtopics (Samsara, 2022). A more detailed explanation of this visual mapping follows:

The network map generated from the bibliometric analysis shows that the term "game" occupies the most dominant position, serving as the center of all interconnections between terms. This confirms that the theme of games is central to the literature reviewed. The term "chemistry" also appears as a large node with close connections to "didactic games," "student," and several other terms representing the scope of science learning. Thus, it can be said that the main focus of research in this domain is the use of didactic games in chemistry learning, whether in the form of card games, gamification, or other didactic strategies.

A closer look at this network reveals several thematic clusters, each with its own characteristics. The red cluster focuses on the implementation of games as didactic tools directly used in chemistry learning. Linked terms such as "student," "didactic tool," "card game," "periodic table," and "chemical element" demonstrate that these studies emphasize how games, particularly card-based ones, can help students understand abstract concepts like the periodic table or chemical elements. The green cluster emphasizes the pedagogical aspect, with links between "didactic game," "chemistry education," "chemistry lesson," "activity," and "article." This connection demonstrates how didactic games are integrated as part of broader learning activities and are the focus of numerous scientific articles discussing their role as teaching strategies.

Meanwhile, the yellow cluster illustrates the interdisciplinary dimension of this research. The term "chemistry" is linked to "science," "physics," and "technology," indicating that the application of didactic games is not limited to chemistry but also has the potential to be adopted in other scientific fields such as physics, further enhanced by the use of digital technology to support learning. The blue cluster emphasizes modern pedagogical strategies through terms such as "gamification," "learner," "didactic strategy," and "classroom." This cluster demonstrates how games are not merely a medium but also a gamification strategy that positions students as active actors in the learning process, emphasizing a paradigm shift toward more participatory and learner-centered learning.

The network of terms in this map demonstrates how interconnected the various aspects of didactic games are in chemistry education. Terms such as "classroom," "activity," and "implementation" in the blue cluster indicate that didactic games are an integral part of classroom activities. The connection between "element" and "periodic table" in the green cluster indicates that games are used to teach basic chemistry concepts. The red cluster indicates that strategy and evaluation are essential components of the use of didactic games, while the yellow cluster demonstrates the integration of advanced technologies such as augmented reality into learning.

In the map, "game" is the central node with numerous, thick connecting lines, particularly with the terms "student," "chemistry," and "didactic tool." This indicates that in the literature, the topic of games is most often discussed in relation to students and their use as didactic tools to support chemistry learning. The "game-student" relationship, for example, shows that research tends to focus on students as the primary actors in game use. Meanwhile, the "game-chemistry" relationship indicates that game applications are often directed towards chemistry, supported by more specific terms such as "periodic table" and "chemical element."

Furthermore, the relationships between terms also form bridges between clusters. For example, "didactic game" in the green cluster is strongly connected to "chemistry education" and "chemistry lesson," then crosses over to the yellow cluster through the terms "technology" and "science." This indicates that didactic games are not only positioned as pedagogical activities but are also studied in interdisciplinary contexts, such as their integration with other sciences and the use of learning technology. On the other hand, the term “gamification” from the blue cluster is related to “learner” and “didactic strategy”, but still has a connection to “game” at the center of the network, indicating that the gamification approach is seen as an extension of the concept of games itself.

This visual mapping of the term network provides a comprehensive overview of how didactic games are used in chemistry education. By examining the relationships between these terms, we can understand how didactic games not only increase student engagement and motivation but also aid in teaching complex chemistry concepts (Hugerat et al., 2020). The map also shows that there is a wealth of research focusing on the use of games in various educational contexts, from the classroom to higher education, and from basic concepts to advanced technologies such as augmented reality. This demonstrates that didactic games are a flexible and effective tool in chemistry education, which continues to evolve with technological advances and pedagogical innovations (Martínez et al., 2020).

The overlay visualization in VOSviewer provides dynamic information about the development of a research field over time. By utilizing color gradients on terms or nodes, this visualization enables researchers to understand the chronology of topic emergence, identify new trends, and observe how the focus of studies shifts toward more contemporary themes. This representation is particularly useful in highlighting emerging topics while distinguishing them from well-established concepts. The overlay visualization of didactic games in chemistry learning is presented in Figure 3.

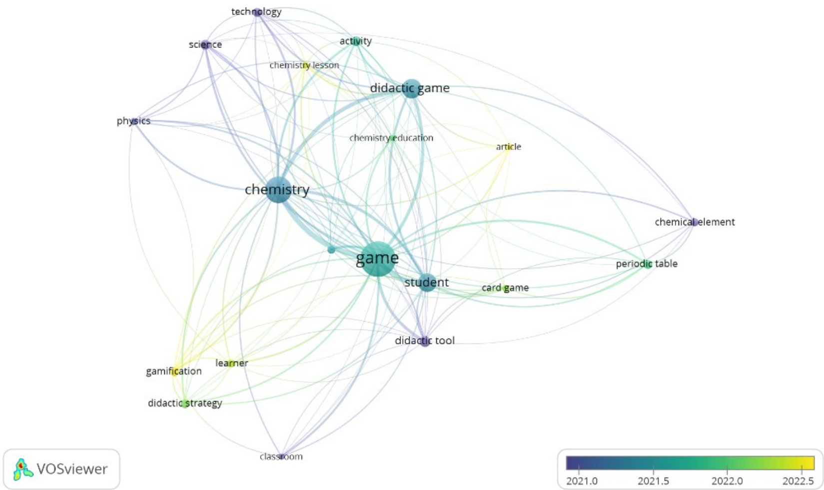

Figure 3. Overlay Visualization Didactic Game Chemistry Learning

This visual mapping generated by VOSviewer illustrates the relationships between various terms related to didactic game chemistry learning based on research conducted over the past few years. The diagram uses color to indicate the research period from 2020 to 2022, with blue indicating older research and yellow indicating more recent research. It can be seen that core terms such as "game," "chemistry," and "student" tend to be bluish-green, indicating that this topic has been a center of attention since the beginning of the observation period, around 2021. This is understandable, considering that studies on the use of games in chemistry learning, focusing on students, have been conducted since early 2021, and even earlier (Putri et al., 2022). These terms serve as conceptual anchors that then connect to various research development directions.

More recent terms, highlighted in yellow, such as "article," "learner," and "gamification," indicate a shift or expansion of research toward a more contemporary direction. This trend demonstrates that research is shifting beyond the implementation of games in chemistry learning to how scientific publications highlight gamification as a broader pedagogical strategy. The presence of "learner" emphasizes a new perspective that emphasizes the role of individuals in game-based learning, not just students in general. This aligns with findings that gamification approaches in science education can increase enthusiasm, engagement, and create a more learner-centered learning experience (Shaheen et al., 2022).

Meanwhile, other terms such as "periodic table," "chemical element," and "didactic tool" tend to be colored blue to green, indicating that research on the use of games to understand basic chemistry concepts such as the periodic table and chemical elements has been conducted for a long time, although they remain relevant today. Their proximity to the core terms indicates that this area represents a concrete application of the use of didactic games. Previous research has also confirmed that chemistry-based educational games, particularly those focusing on the periodic table and elements, can improve students' academic performance (Alejandria et al., 2023). This research on didactic games is not limited to chemistry education but also encompasses science education in general, demonstrating the broad potential of this innovative teaching method (Anderson & Barnett, 2013; Bevc et al., 2023).

The density visualization in VOSviewer illustrates the intensity of research within a field based on the frequency of term occurrences in the literature. Areas with brighter colors indicate topics that have been studied more extensively, while darker areas suggest limited attention to those areas. In this way, researchers can easily identify the core topics that are most frequently explored while also uncovering research gaps that remain underexplored. The density visualization of didactic games in chemistry learning is presented in Figure 4.

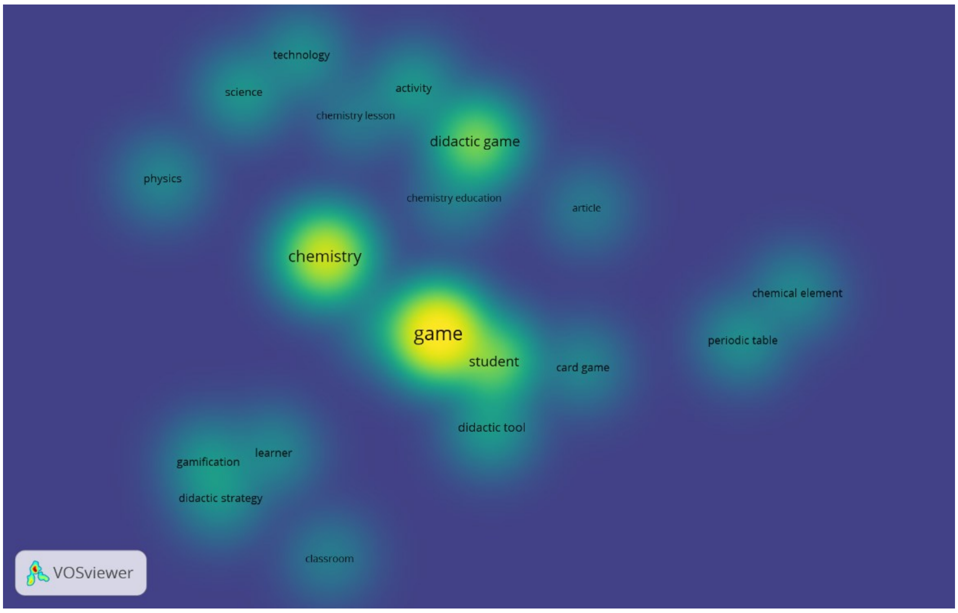

Figure 4. Density Visualization Didactic Games Chemistry Learning

This visual term density mapping generated by VOSviewer shows how frequently certain terms appear in a body of research focused on "didactic game chemistry learning." The map uses color to indicate term frequency, with yellow indicating high frequency and blue indicating low frequency. Below is a detailed explanation of some of the key elements in this map: This density map shows that the terms "game" and "chemistry" appear with the highest density, indicated by the bright yellow color in the center of the visualization. This indicates that the literature on didactic games in chemistry learning focuses on two main pillars: the use of games as a pedagogical strategy and the scientific context of chemistry as its application. This focus on these two core terms is understandable, as didactic games have long been considered an effective medium for making chemistry learning more engaging and improving student learning outcomes (Lutfi et al., 2023).

Around the core, the terms "student" and "didactic game" also show a fairly high density, colored green-yellow. This position emphasizes that the role of students as beneficiaries and the presence of didactic games as a core strategy are crucial elements consistently researched. This trend aligns with research emphasizing how the use of didactic games can improve student motivation, engagement, and learning outcomes, particularly in science subjects (Vlachopoulos & Makri, 2017). Thus, the literature places students and game strategies within an interconnected pedagogical ecosystem.

Other terms such as "periodic table," "chemical element," and "card game" are seen with medium density, colored bluish-green. This indicates that research on didactic games is also directed toward practical applications, particularly in supporting the understanding of basic chemistry concepts often considered difficult and abstract. For example, the use of card games to learn the periodic table has been shown to support active learning, concentration, and the use of trial and error (Rastegarpour & Marashi, 2012). Thus, this density map confirms that didactic games are not only a methodological concept, but are also translated into concrete media in chemistry learning.

Areas with lower density, such as "gamification," "didactic strategy," and "learner," are located on the periphery of the map. The blue color indicates that these terms are still relatively infrequently used but have the potential to grow in the future. For example, the focus on gamification is gaining ground as a broader approach than just games, namely the integration of game mechanics into various aspects of learning to shape students' character more positively (Rahayu et al., 2025). Therefore, these blue areas indicate opportunities for new research development that could enrich the landscape of didactic game-based chemistry learning.

This term density mapping provides an overview of how frequently various terms appear in the literature focusing on didactic games in chemistry education. From this map, we can see that research focuses not only on the development and implementation of didactic games, but also on evaluating their effectiveness and exploring the use of new technologies. This research spans multiple disciplines, demonstrating the broad potential of this innovative teaching method. The map also highlights areas that may require further research, such as the integration of new technologies and more in-depth evaluation approaches.

4. Conclusion

This bibliometric analysis of didactic games in chemistry learning reveals that the field has developed around core concepts such as "game," "chemistry," and "student," which consistently act as anchors in the research landscape and reflect the central aim of enhancing engagement and conceptual understanding. The overlay visualization demonstrates a gradual shift toward broader themes such as gamification and learner-centered approaches, indicating that recent research has begun to explore didactic games not only as classroom tools but also as part of wider pedagogical frameworks. Meanwhile, density mapping confirms a strong research focus on chemistry-specific content and didactic tools, while also highlighting potential opportunities for future studies in areas like personalized learning and the application of games to more complex chemical concepts. The dominance of influential publishers such as ACS Publications, Springer, and MDPI further underlines how global dissemination contributes to the visibility and citation impact of these works. Importantly, the concentration of citations in a small number of highly influential publications demonstrates the presence of a core literature that significantly shapes subsequent studies. Altogether, these findings not only provide a comprehensive map of the intellectual structure in this field but also suggest promising directions for advancing both theory and practice, particularly through the integration of gamification strategies, digital innovations, and learner diversity in chemistry education.

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