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GAMIFICATION IN COMPUTER ENGINEERING EDUCATION: A BIBLIOMETRIC REVIEW OF GLOBAL RESEARCH TRENDS

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ABSTRACT

With the impact of digitalization, innovative approaches have emerged in the field of education, making learning processes more effective and engaging through gamification and digital games. Gamification aims to enhance individuals' motivation and participation by using game design elements (points, badges, levels, leaderboards, etc.) in non-game contexts. This approach is particularly important in disciplines with technical content, such as computer engineering, to capture students' attention and increase interaction. This study aims to examine scientific publications on gamification in computer engineering education using bibliometric analysis. A total of 343 publications indexed in the Web of Science (WoS) database between 2012 and 2025 were analyzed. The analysis covers publication trends by year, most cited works, influential authors, institutions, journals, and keyword clusters. This study reveals the intellectual structure of the field, identifies research trends, collaboration networks, and potential gaps, aiming to guide future studies.

Keywords: Bibliometric Analysis, Computer Engineering, Educational Technology, Gamification.

BİLGİSAYAR MÜHENDİSLİĞİ EĞİTİMİNDE OYUNLAŞTIRMA: KÜRESEL ARAŞTIRMA EĞİLİMLERİNE YÖNELİK BİBLİYOMETRİK BİR İNCELEME

ÖZ

Dijitalleşmenin etkisiyle eğitim alanında da yenilikçi yaklaşımlar öne çıkmakta, oyunlaştırma ve dijital oyunlar öğrenme süreçlerini daha etkili ve motive edici hâle getirmektedir. Oyunlaştırma, oyun dışı bağlamlarda oyun tasarım öğeleri (puan, rozet, seviye, liderlik tablosu vb.) kullanılarak bireylerin motivasyonunu ve katılımını artırmayı hedeflemektedir. Bu yaklaşım, özellikle teknik içerikli bilgisayar mühendisliği gibi disiplinlerde öğrencilerin dikkatini çekmek ve etkileşimi artırmak açısından önemlidir. Bu çalışma, bilgisayar mühendisliği eğitiminde oyunlaştırma konusundaki bilimsel yayınları bibliyometrik analiz yöntemiyle incelemeyi amaçlamaktadır. Web of Science (WoS) veri tabanında 2012–2025 yılları arasında yayımlanmış 343 çalışma analiz edilmiştir. Analiz kapsamında yıllara göre yayın eğilimleri, en çok atıf alan çalışmalar, etkili yazarlar, kurumlar, dergiler ve anahtar kelime kümelenmeleri değerlendirilmiştir. Bu çalışma, alanın entelektüel yapısını ortaya koyarak araştırma eğilimlerini, iş birliği ağlarını ve potansiyel boşlukları tanımlamaktadır. Böylece, gelecek çalışmalara yön vermeyi amaçlamaktadır.

Anahtar kelimeler: Bibliometrik naliz, Bilgisayar Mühendisliği, Eğitim Teknolojisi, Oyunlaştırma.

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1. Introduction

The rapid advancement of technology and the pervasive influence of digitalization in all areas of life have led to profound transformations in the field of education. Alongside traditional teaching methods, innovative approaches that render learning processes more effective, motivating, and interactive have come to the forefront. In this context, gamification and digital games have emerged as prominent pedagogical tools, particularly aligned with the learning dynamics of the digital age.

Gamification is defined as the use of game design elements in non-game contexts to motivate individuals, enhance engagement, and encourage problem-solving [1, 2]. Initially adopted in the digital media industry, the concept has rapidly expanded into various domains since 2010, including healthcare [3], human resources [4], marketing [5], environmental protection [6], and most notably, education [7].

The dynamics of the digital age have transformed educational environments, necessitating the adoption of innovative methods capable of capturing learners' attention. In the educational context, gamification is an innovative approach that involves the integration of game design elements—such as points, badges, level progression, and leaderboards—into learning environments to enhance learner motivation and engagement [8-10]. Kalogiannakis et al. [10], through an analysis of 24 studies published between 2012 and 2020, highlighted the positive effects of gamification on learning outcomes, social interaction, and motivation.

Traditional instructional methods, particularly in computer engineering courses that involve technical and abstract content, often fall short in ensuring sufficient interaction and motivation, leading to a search for new pedagogical approaches [9]. As such, the gamification of educational content has become especially important in disciplines such as computer engineering, which are heavily focused on technical and abstract concepts [11]. Courses such as algorithms, programming, software testing, and data structures are often perceived by students as complex and demotivating. Therefore, gamification in computer engineering education is considered an effective pedagogical tool for increasing motivation, supporting experiential learning, and fostering critical thinking and problem-solving skills [11-13].

Although various studies have examined the effects of gamification in computer engineering education, these studies have predominantly focused on pedagogical outcomes or practical implementations [10, 13]. However, there is a notable lack of studies that systematically analyze the gamification literature through bibliometric criteria such as publication trends, author network relationships, citation analyses, and thematic intensities. This gap hinders the structural mapping of the knowledge base and the generation of guiding insights for future research.

In this context, the aim of the present study is to systematically examine gamification-based research in computer engineering education by uncovering the intellectual structure, thematic development, collaborative networks, and citation hotspots within the field. Accordingly, this study seeks not only to describe the current state of the literature but also to provide guidance for future academic inquiries. In line with these objectives, the following research questions will be addressed:

1. What is the annual distribution of publications on gamification in computer engineering education?
2. Which studies on gamification in the context of computer engineering have received the highest number of citations, and what is their intellectual impact within the literature?
3. Who are the most prolific authors in the field of gamification in computer engineering education, and what is the level of their citation impact?
4. Which institutions have published the highest number of studies on this theme?
5. Which academic journals publish the most research on gamification in computer engineering education?
6. Based on keyword frequencies and word cloud analysis, which conceptual trends and thematic clusters stand out in the gamification literature?
7. During which periods has research on gamification in computer engineering education become more prominent?

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2. Methodology

In this study, the quantitative research method of bibliometric analysis was employed to identify the publications and research trends related to the concept of gamification in computer engineering education. The bibliometric method is particularly suitable for evaluating the number and significance of empirical contributions in a given field, identifying similarities and differences within the literature, and constructing a research map [14]. In the study, descriptive bibliometrics was used to measure the productivity of the identified publications, while evaluative bibliometrics was utilized to assess the use of literature.

Bibliometric analysis is a method that reveals the relationships among publications and different authors. This approach allows researchers to base their work on the bibliographic contributions of other scholars and to express their ideas through writing and collaboration. When such data are collected and analyzed, insights into social networks, current areas of interest, and the structural characteristics of the field can be obtained [15]. The bibliometric method can be both descriptive and evaluative in nature. Common data sources are widely used in most bibliometric analyses. While Web of Science (WoS) and Scopus databases are widely preferred in bibliometric analyses [16], the results of bibliometric analyses may vary depending on the database used [17]. WoS and Scopus handle bibliographic metadata differently. WoS processes and reformats references to include details such as first author, year, journal, issue, and DOI. Whereas Scopus retains all APA-style citations provided by authors [14]. This means that although the tools have been perfected, limitations still prevent some analyses from being performed by merging WoS and Scopus data [18]. Therefore, considering the problems related to the merging of the data presented in different cell formats and the ease of classification of information retrieved from WoS in a research database, in this study, bibliometric data in WoS (including all indexes) core collection were included in the review. Another reason to choose WoS over SCOPUS was that WoS is a collection of databases that index the world's most authoritative scholarly literature in the social sciences, arts, and humanities [19].

Table 1. The dataset

Main Information About Data	
Timespan	2012-2025
Sources (Journals, Books, etc.)	178
Documents	343
Annual Growth Rate %	24,9
Document Average Age	4,13
Average citations per doc	27,62
References	15989
Document Contents	
Keywords Plus (ID)	523
Author's Keywords (DE)	1243
Authors	
Authors	1276
Authors of single-authored docs	33
Authors Collaboration	
Single-authored docs	33
Co-Authors per Doc	3,93
International co-authorships %	21,87
Document Types	
article	343

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2.1. Creating Dataset

Articles related to gamification in computer engineering education were examined by accessing the Web of Science (WoS) Core Collection databases. Following a comprehensive literature review on publications in this field, relevant keywords were identified, and the final search query was formulated through consultations with experts in bibliometric research. The information about the dataset is presented in Table 1.

Table 1 above shows general information about 343 studies obtained with the topic Gamıfıcatıon In Computer Engıneerıng Educatıon. Within the scope of WoS, studies between 2012 and 2025 were analyzed. These studies have an average citation rate of 27,62 per publication. We understand that the number of single-author studies, n=33, is significantly lower than the total number of studies.

In this study, bibliometric analyses were conducted using biblioshiny, a web-based application built on the R package bibliometrix (Aria & Cuccurullo, 2017). Biblioshiny is a shiny app that provides an interactive graphical interface for performing bibliometric analysis, facilitating user-friendly and comprehensive exploration of bibliographic data.

2.2. Planning, Selection, Extraction and Execution Process in Bibliometric Analysis

This section covers the planning, selection, data extraction, and implementation stages of the analysis process. During the inclusion/exclusion phase, as illustrated in Figure 1, the articles retrieved through the search query were assessed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards.

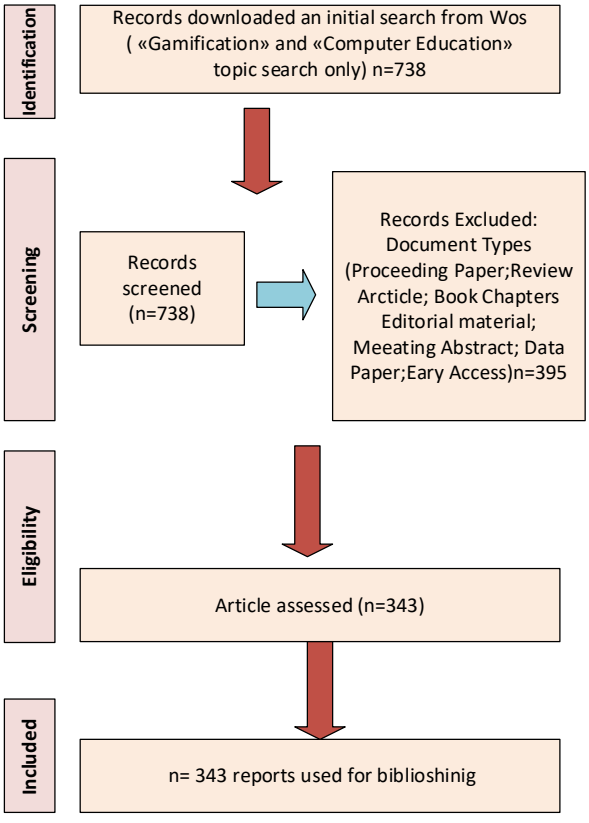

Figure 1. PRISMA flow chart of the article screening process

In the first stage, the selection of internationally recognized scientific databases was carried out during the planning phase. The Web of Science (WoS) database was chosen for this study due to its broad indexing of scientific journals and its distinction from other databases. The second stage involved the identification of keywords related to the research topic or question. This stage is a cornerstone of any successful bibliometric study. The search query was limited to articles containing the terms "computer

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education" and "gamification" in the topic field. As for document type, only journal articles were selected. In the third stage, inclusion criteria were applied. No time restrictions were imposed in order to include the most recent and relevant studies. Only peer-reviewed articles were included in the analysis, as they undergo rigorous review processes and meet established quality standards. In the fourth and final stage, the analysis process was carried out based on the records of 343 potentially relevant studies. At this point, a detailed evaluation was conducted to determine whether these studies were truly related to the topic of interest. Ultimately, 343 studies were thoroughly analyzed.

3. Research Findings

This section first presents the publication outputs related to gamification in computer engineering education, followed by an analysis of the sources, the most prolific researchers in the field, the most relevant institutions, and the most highly cited publications. Additionally, co-citation analysis of the articles, examination of the source journals, keyword trends, and the evolution of publications and citations are explored to reveal overall research trends.

3.1. Annual Number of Publications

As part of the annual literature output, the average yearly number of publications related to the keyword gamification in computer engineering education indexed in the Web of Science (WoS) is presented in Figure 2.

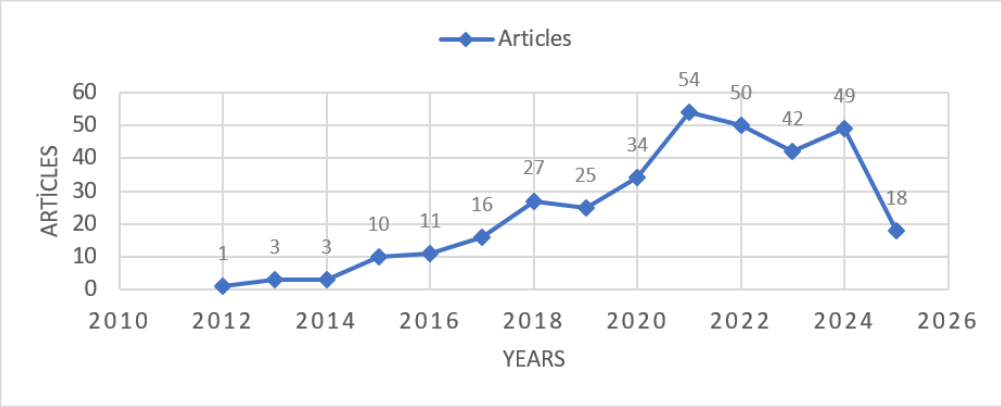

Figure 2. Average annual number of publications

The annual distribution of the articles examined within the scope of the bibliometric analysis is presented in Table 2. Between 2012 and 2015, the number of publications on gamification in computer engineering education remained quite limited, with only 1 to 3 articles published per year during this period. From 2016 onwards, a steady increase in publication output was observed, with a notable surge in 2018, reaching 27 articles. The most significant rise occurred in 2021, when the number of publications peaked at 54, marking the highest point in the literature.

In the following two years, 2022 and 2023, 50 and 42 articles were published, respectively. In 2024, the number increased again to 49. However, in 2025, a sharp decline was observed, with the publication count dropping to 18. This drop may be attributed to the fact that data for 2025 were collected before the year had concluded.

This trend indicates that academic interest in gamification-related studies has significantly increased, particularly after 2018, highlighting gamification as an emerging research theme in the field. At the same time, sudden declines in publication counts may not only reflect limitations in data coverage but also suggest temporary saturation or shifts in research focus within the academic community.

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3.2. Most Globally Cited Publications

Citations to studies can be analyzed using bibliometric methods at both local and global levels [14]. When examining publications related to gamification in computer engineering education, Figure 3 presents the ten most globally cited studies on gamification in computer engineering education

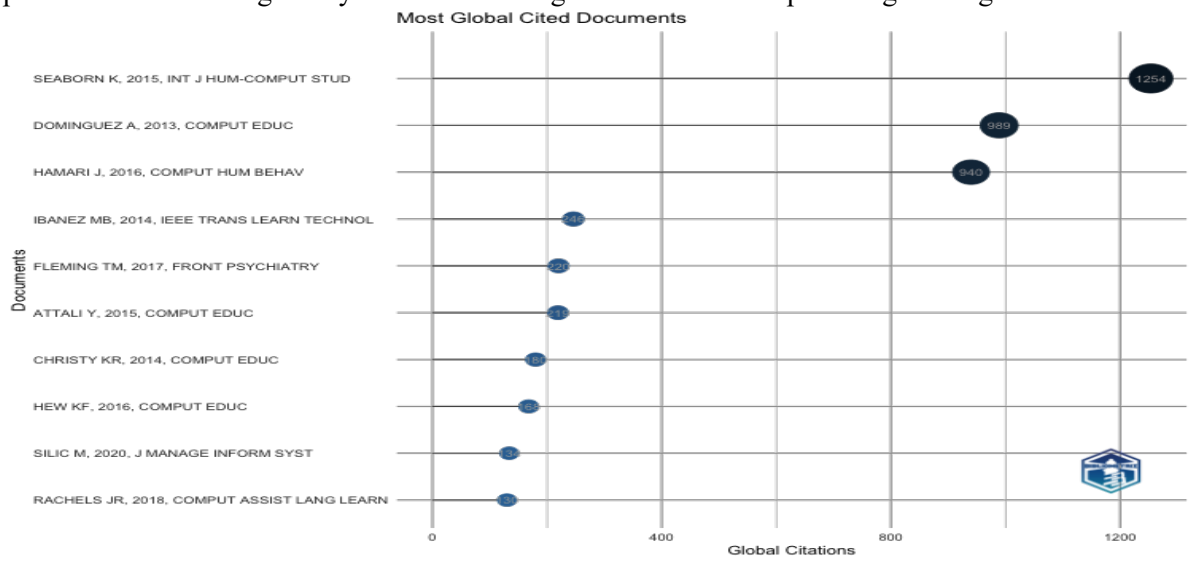

Figure 3. Top ten most globally cited publications

As shown in Figure 3, the most cited publications on gamification in the context of computer engineering education represent the foundational and influential works in the literature. The most highly cited document is the conceptual review by Seaborn et al. [8], which has received a total of 1,254 citations. This study provides a comprehensive conceptual framework for understanding gamification and has had a significant impact on subsequent literature.

The second most cited work is an experimental study by Domínguez et al. [20], published in Computers & Education, with 980 citations. This article is notable for empirically demonstrating the effects of gamification on learning outcomes. The third most cited publication is by Hamari et al. [21], published in Computers in Human Behavior, which received 940 citations. This study offers systematic findings on the effects of gamification on user behavior and is frequently cited in both educational and digital media research.

The remaining publications on the list generally contribute to the fields of educational technology, computer-assisted learning, and cognitive sciences. Noteworthy contributions include studies by Banerjee et al. [22], Fleming et al. [23], and Attali et al. [24], among others. These documents, due to their high citation counts and publication across various disciplines, reflect the interdisciplinary nature of research on gamification.

This analysis reveals that the most influential studies on gamification were predominantly published between 2013 and 2015, a period during which the theoretical and empirical foundations of the field were solidified. These publications continue to serve as key citation hubs and knowledge clusters for researchers in this domain.

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3.3. Analysis of the Source Journals

Journals that have published articles on gamification in computer engineering education were examined, and based on the number of publications, the top ten sources are presented below.

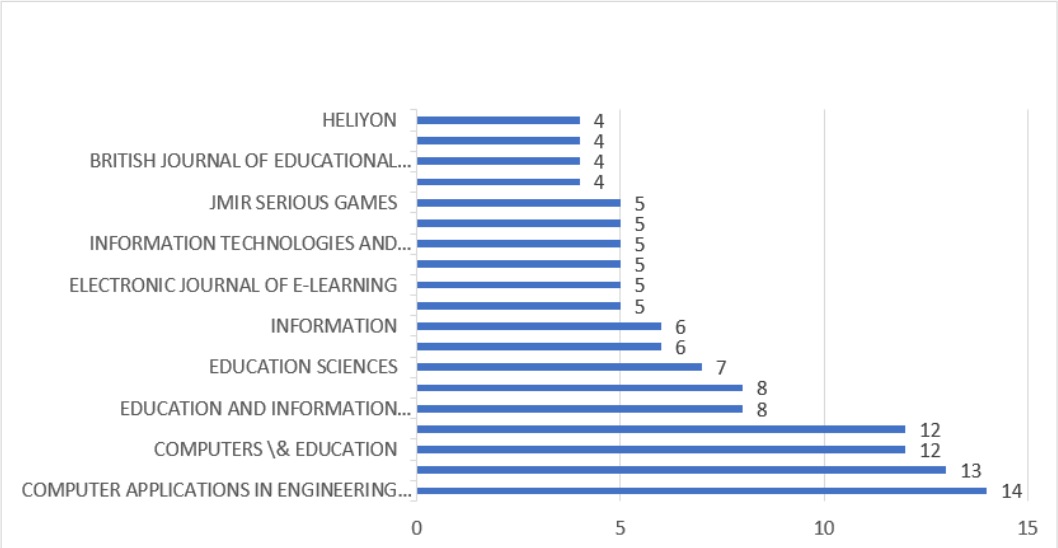

Figure 4. Top ten journals publishing gamification-themed articles (by subject area)

As shown in Figure 4, the journals that most frequently publish articles on gamification in computer engineering education are identified. Among them, Computer Applications in Engineering Education stands out as the leading source, hosting 14 publications. It is followed by Computers & Education with 13 articles, and both Education and Information Technologies and Education Sciences with 8 articles each.

This distribution indicates that research on gamification is concentrated in journals that focus both on engineering education and on educational technology, reflecting the interdisciplinary nature of the field.

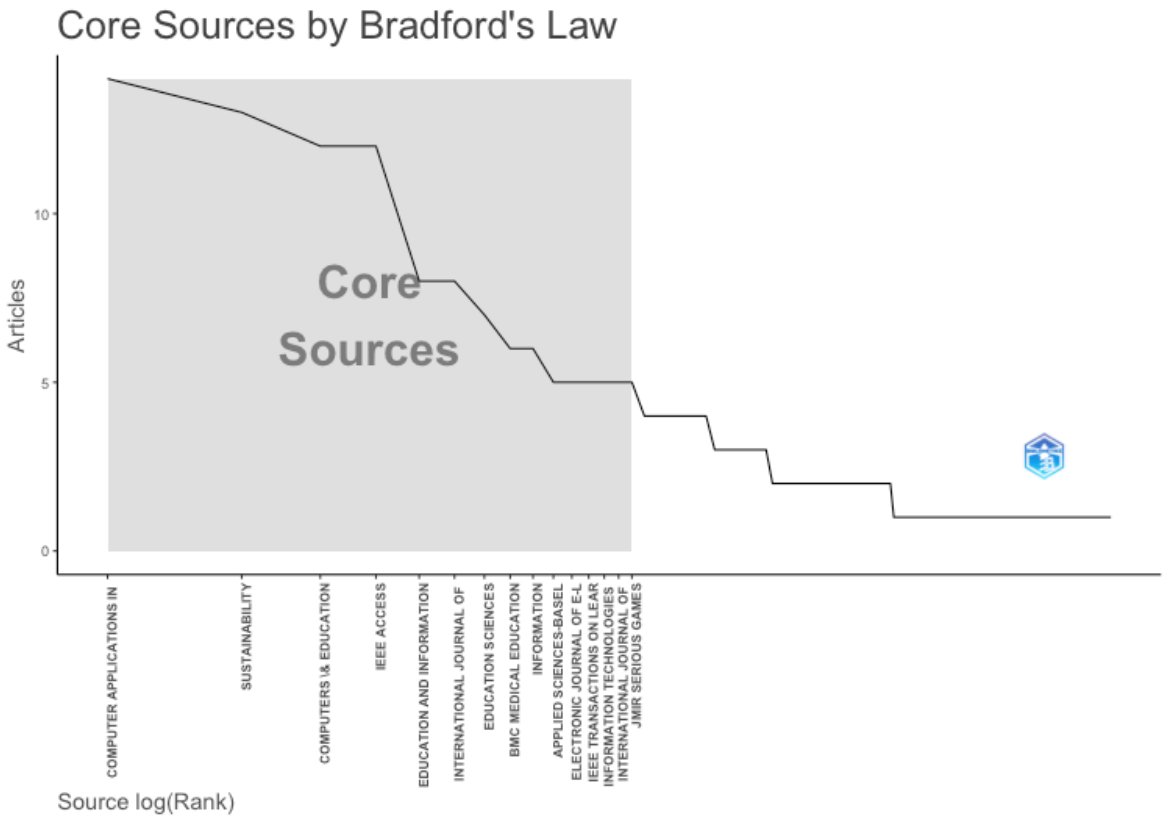

Figure 5. Core journals according to Bradford's Law Analysis

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As shown in Figure 5, the distribution is based on Bradford's Law, which is used in bibliometric analysis to identify the core journals within a research field. According to Bradford's Law, publications are divided into three zones based on their impact, with the first zone representing the "core sources." In this analysis, the journals located within the grey-shaded core zone are those with the highest scientific productivity.

Within this zone, journals such as Computer Applications in Engineering Education, Sustainability, Computers & Education, IEEE Access, and Education and Information Technologies have been identified as playing a central role in the knowledge production related to gamification.

When Figure 4 and Figure 5 are considered together, it becomes evident that research on gamification is concentrated across three main axes: engineering education, educational technologies, and multidisciplinary domains such as sustainability and information systems. This pattern highlights the interdisciplinary nature of the field and demonstrates how the topic of gamification in computer engineering education evolves through interaction with multiple knowledge domains.

Moreover, the inclusion of SSCI-indexed journals within this core cluster further strengthens the academic depth and visibility of the field in the broader scholarly literature.

3.4. Prolific Authors

As shown in Figure 6, based on Web of Science (WoS) data, the most prolific authors in the field of gamification in computer engineering education were analyzed.

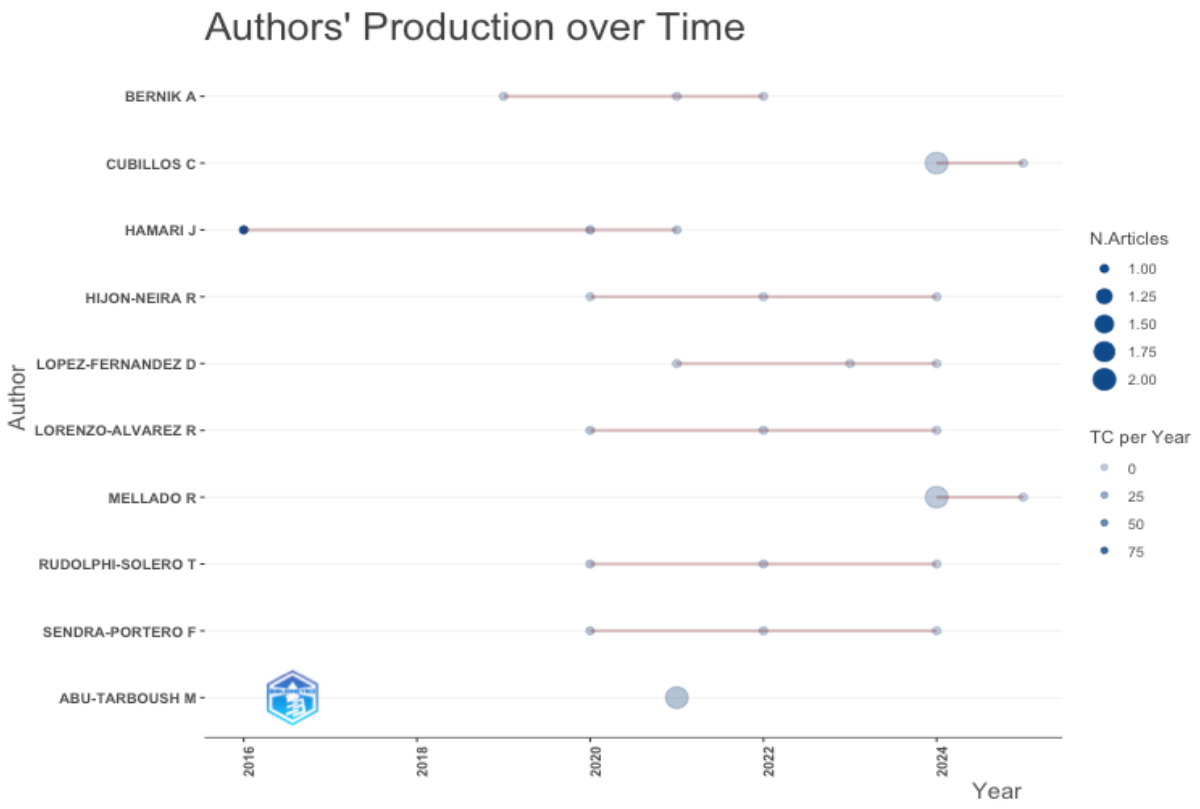

Figure 6. Most prolific authors in the field

According to the data presented in Figure 6, the most prolific authors in the domain of gamification in the context of computer engineering include Hamari J., Cubillos C., Mellado R., Hijon-Neira R., and Lopez-Fernandez D. The figure visualizes not only the number of publications but also the annual citation impact of each author's work. The size of the dots represents the total citations per year (TC/year) of the authors' publications.

Among these, Hamari J. stands out as the most influential and productive scholar, demonstrating consistent publication activity since 2016, along with the highest average annual citation rate (indicated

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by the largest dot). His work has laid the theoretical foundations of gamification and significantly influenced its application in educational technologies.
Cubillos C. and Mellado R. have emerged as highly productive authors in the recent period (2023–2024); however, their citation impact is currently lower than Hamari's, likely due to the recency of their publications. Authors such as Hijon-Neira R., Lorenzo-Alvarez R., Sendra-Portero F., and Rudolph-Solero T. exhibit a more stable, moderate level of productivity and citation impact.

This analysis reveals that academic output on gamification tends to cluster around certain key authors, who play a central role in shaping the field. Moreover, the continuity of scholarly production over time reflects the dynamic nature of the topic and the sustainability of academic interest. In particular, the works of highly cited authors serve as foundational references for future research by establishing the theoretical groundwork of the field.

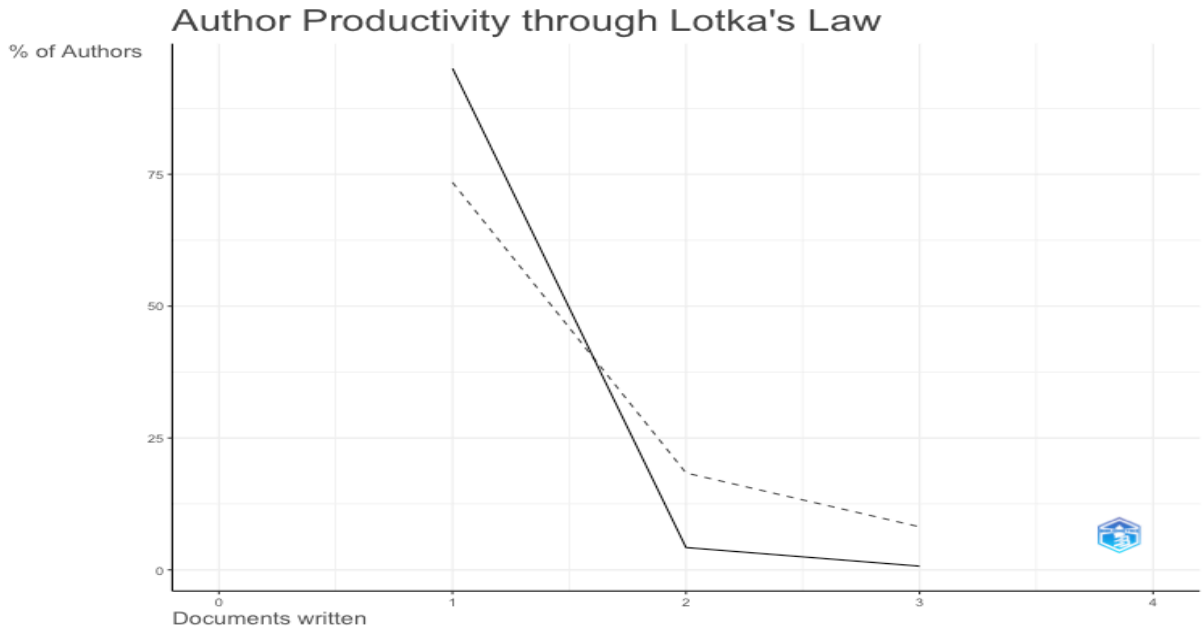

Figure 7. Author distribution according to Lotka's Law

Figure 7 illustrates the distribution of author productivity within the literature on gamification in computer engineering education, analyzed through the framework of Lotka's Law. According to Lotka's principle, the majority of authors in a scientific field produce only one publication, while a much smaller number are responsible for multiple publications. This distribution is commonly referred to in bibliometric literature as an inverse proportional productivity model.

In the graph, the solid line represents the observed distribution, while the dashed line indicates the theoretical distribution predicted by Lotka [25]. As seen in the analysis, approximately 80% of authors in the examined literature have published only one article. This indicates that the field includes a large number of one-time contributors, whereas the number of authors with continuous and high productivity remains quite limited. The proportion of authors with two or more publications falls below 20%.

This finding supports the earlier "Authors' Production over Time" analysis, which identified a few key authors—such as Hamari, Cubillos, and Mellado—as consistently productive, while most others have contributed only once. The Lotka distribution makes this structure more systematically visible.

This pattern suggests that the field is still in a developmental stage, with scholarly output concentrated around a limited number of authors. At the same time, it points to an expanding research landscape through the involvement of new scholars. To ensure sustainable knowledge production and to enhance the field's theoretical depth, greater co-authorship, interdisciplinary collaboration, and theme-focused research should be encouraged.

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3.5. Most Relevant Institutions

In terms of research on gamification in computer engineering education, the institutions with the highest number of publications indexed in the Web of Science (WoS) database were identified. The results are presented in Figure 8.

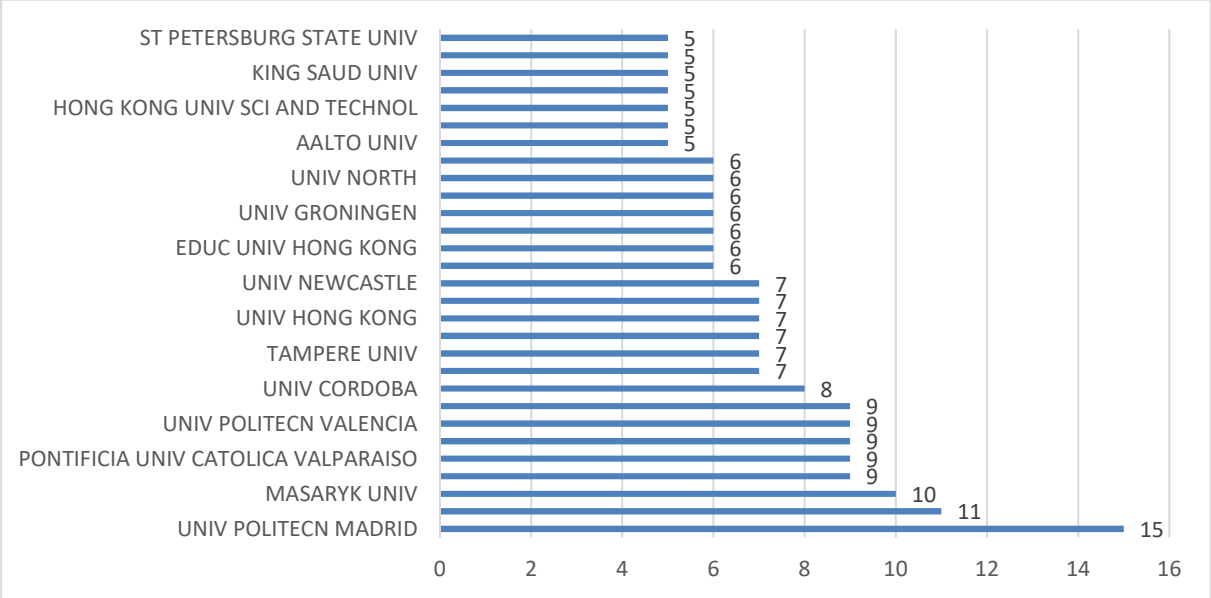

Figure 8. Top Institutions Publishing on Gamification in the Computer Engineering Education

Figure 8 visualizes the institutions that have made the most significant contributions to publications on gamification in computer engineering education. The institution with the highest contribution is Universidad Politécnica de Madrid (Spain), with 15 publications. This institution's leadership in the field of gamification underscores Spain's global influence in educational technology research. In second place is Universidad de Málaga (Spain), which has demonstrated notable productivity with 11 publications. The prominence of these two institutions highlights the significant role of Spain-based research networks and grant-supported projects in advancing gamification studies. They are followed by Masaryk University (Czech Republic, 10 publications) and, with nine publications each, Jilin University (China), Pontificia Universidad Católica de Valparaíso (Chile), Sichuan University (China), Universidad Politécnica de Valencia (Spain), Universidad Rey Juan Carlos (Spain), and Universidad de Córdoba (Spain). The presence of four different universities from Spain among the top ten further illustrates the country's strong interdisciplinary and international contributions to the field. Tabriz University of Medical Sciences (Iran) appears on the list with 7 publications, as the only medical university represented. This indicates that gamification is not limited to engineering and education domains but is also finding applications in diverse fields such as health education.

This analysis reveals that institutions from Spain, China, and Latin America are particularly prominent in the global gamification research landscape. Moreover, it demonstrates that Europe and Asia are strong actors in the race for leadership in this field. The concentration of institutional activity in specific countries also suggests a fertile ground for international collaboration.

3.6. Word Cloud Generated from Studies

Keywords often provide the first insight into the concepts and focus of a research study. Therefore, word cloud analysis holds an important place in bibliometric research. This method counts the frequency of keywords used within a body of literature, highlights the most frequently occurring terms, and generates a visual representation in the form of a word cloud [26].

Visually, the largest word in the center of the cloud typically represents the most frequently used keyword across the analyzed studies. Accordingly, Figure 5 illustrates the size and frequency of appearance of words or word phrases related to the theme of gamification in computer engineering education, using varying colors to distinguish different frequency levels.

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Figure 9. Word cloud of gamification-themed publications

According to the analysis results presented in Figure 9 and Figure 10, the most frequently emphasized key concepts in gamification-themed publications in computer engineering education have been identified. Among the most commonly used keywords are “computer science” and “game-based learning”, each appearing 16 times. This indicates that the studies predominantly focus on the application of gamification strategies within ICT-related disciplines, particularly in the field of computer science.

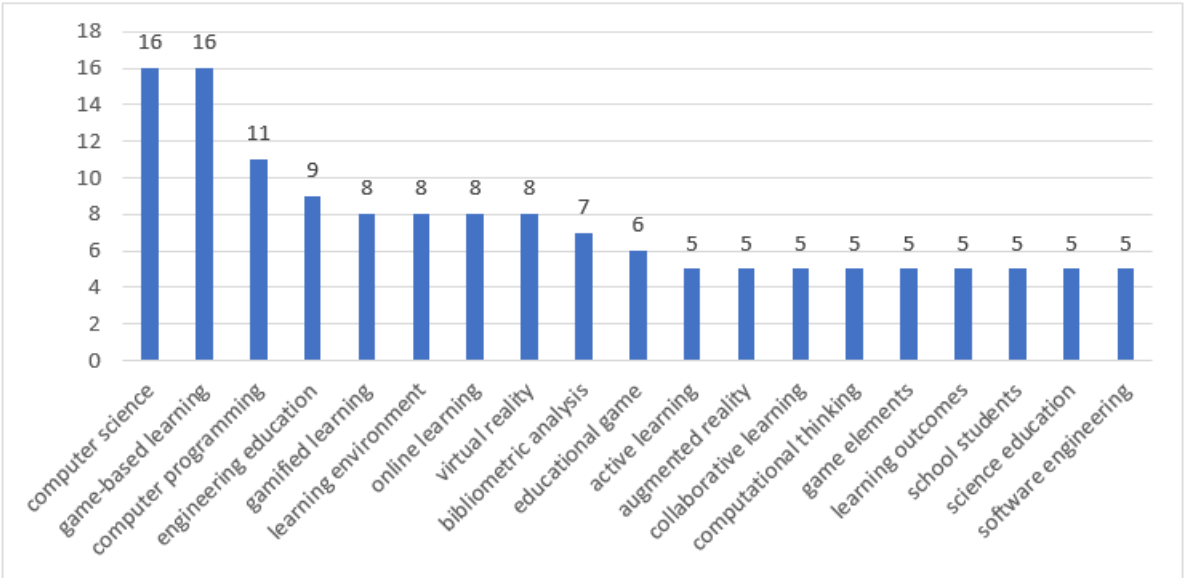

Figure 10. Keyword Frequency Table for Gamification-Themed Publications

Among the high-frequency terms following these top keywords are “computer programming” (11 occurrences) and “engineering education” (9 occurrences). This suggests that gamification is positioned not only as a pedagogical approach, but also as a didactic tool that effectively supports the teaching of programming and technical content. Additionally, terms such as “gamified learning”, “online learning”, “virtual reality”, “learning environment”, and “bibliometric analysis”, each appearing 7–8 times, reflect a strong focus on technological integration and learning environment design as core themes in the literature. Mid-frequency terms (5–6 occurrences), including “educational game”, “active learning”,

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"computational thinking", "collaborative learning", and "learning outcomes", point to a learner-centered perspective, with emphasis on the cognitive and interactive benefits of gamification. This suggests that gamification is closely associated not only with pedagogical advantages but also with cognitive and social development. Less frequent but thematically important keywords—such as "achievement badges", "gamification framework", "academic performance", "medical students", and "chemical design"—demonstrate the breadth of the field. These terms reflect connections to both application contexts and assessment methodologies, indicating that gamification is an interdisciplinary approach applied not only in computer engineering but also in medicine, chemistry, and general science education.

Overall, the keyword distribution reveals that gamification research is clustered around themes such as the teaching of technical content, the design of digital learning environments, and the transformation of learner behaviors. This demonstrates the theoretical and practical potential of gamification in both educational technology and engineering education literature.

3.7. Research Trends

Using bibliometric analysis, it is possible to identify research trends based on authorship, citations, journals, and subtopics, and to monitor the evolution of scholarly interest (Secinaro et al., 2020). Accordingly, the trridetyoends in gamification-themed studies in computer engineering education are illustrated in Figure 11.

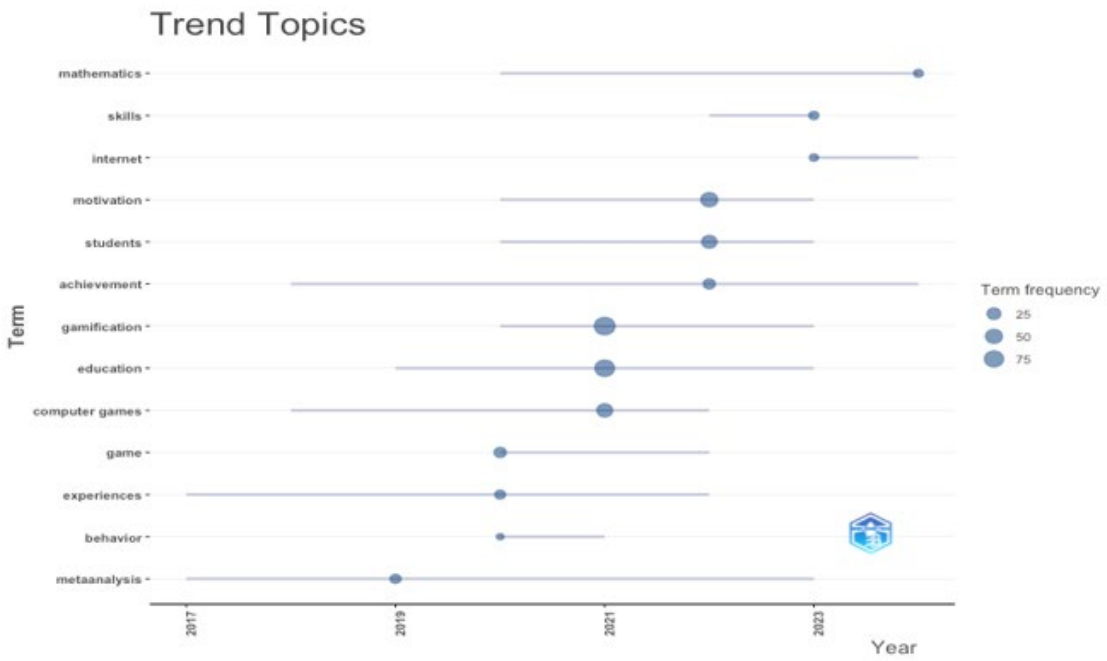

Figure 11. Trend Analysis: Temporal distribution of keywords (2017–2024)

Figure 11 presents a trend analysis showing the emergence and prominence of thematic keywords in publications on gamification in computer engineering education from 2017 to 2024. The size of each term represents its frequency of occurrence in the literature.

Early Period Themes (2017–2019):

- During this phase, dominant keywords included "meta-analysis", "experiences", "behavior", "game", and "computer games."
- These findings suggest that early studies on gamification primarily focused on theoretical evaluations, learning experiences, and the behavioral impact of games.
- The literature also explored how gamification tools relate to game-based pedagogical models.

Period of Intensification and Pedagogical Focus (2020–2022):

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- After 2020, the most frequent keywords in the visualization were “gamification”, “education”, “motivation”, and “students.”
- This reflects the surge in interest in digital education during the COVID-19 pandemic, where gamification was increasingly discussed in relation to enhancing student engagement, fostering motivation, and facilitating interaction in remote learning environments.
- Pedagogically oriented, applied research appears to have become more prominent during this period.

Emerging Themes (2023–2024):

- In 2023 and beyond, keywords such as “skills”, “internet”, and “mathematics” have gained visibility.
- This shift indicates that gamification is expanding into skills-based education (particularly digital skills), internet-supported learning environments, and interdisciplinary applications, especially in mathematics education.
- The increasing integration of gamification into STEM education and sustainable digital pedagogies is also suggested.

The time-series trend reveals a developmental trajectory: beginning with theoretical and experiential focuses, moving toward pedagogical applicability, and finally diversifying into skill development and digital learning integration. Keywords such as “motivation,” “education,” and “students” remain central to the discourse, while newer themes like “mathematics,” “internet,” and “skills” show strong potential for shaping future research directions in this domain.

4. Results and Discussion

This study employed a bibliometric approach to examine the international literature on gamification in computer engineering education, aiming to uncover the structural characteristics, research trends, thematic focuses, and intellectual production centers of the field. Based on data from the Web of Science database, a total of 343 articles were analyzed, and the implementation of gamification in engineering education was evaluated through a multidimensional lens.

The findings reveal that gamification has gained significant academic momentum, particularly after 2018, with the number of publications peaking in 2021. This surge appears to be closely related to the increased interest in digital learning environments during the COVID-19 pandemic [28]. The fact that the most cited studies were published between 2013 and 2015 suggests that the theoretical foundations of the field were laid during this period and have guided subsequent research.

Prominent authors such as Hamari, Cubillos, Mellado, and Hijon-Neira were found to exhibit high levels of productivity and scholarly impact. However, in line with Lotka’s Law, the vast majority of authors have contributed with only a single publication, indicating that the field is still in a developmental stage. This highlights the need to support consistently productive research groups and foster interdisciplinary collaborations.

Journal analysis results show that studies on gamification are most frequently published in journals such as Computer Applications in Engineering Education, Sustainability, and Computers & Education, which focus on both engineering and educational technologies. According to Bradford’s Law, these journals constitute the core knowledge sources of the field and play a central role in the dissemination of research on gamification.

According to keyword and thematic analyses, terms such as “game-based learning”, “computer science”, “engineering education”, and “virtual reality” are among the most frequently repeated and form the thematic core of the literature. Time-series analysis indicates that from 2017 to 2019, research on gamification primarily focused on theoretical and behavioral themes, while the post-2020 period saw a shift towards pedagogical applications, student motivation, and content integrated with digital environments. These findings are supported by previous studies [29, 30].

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In light of these results, there is a clear need for more in-depth qualitative analyses, interdisciplinary collaborations, and application-oriented research in the field of gamification. Future studies are encouraged to move beyond the mere use of game elements and instead focus on models that holistically address learners' cognitive, affective, and social development. Additionally, further exploration into sustainable digital pedagogies, the role of gamification in online learning environments, and the use of learning analytics is recommended.

Overall, this study provides researchers with a structural roadmap and increases the visibility of knowledge clusters within the literature, firmly establishing gamification in computer engineering education as a growing and dynamic field of inquiry. Moreover, this study identifies emerging themes such as interdisciplinary applications and digital skill development.

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