Matematik Eğitiminde Dijital Oyun Tabanlı Öğrenme Üzerine Bibliyometrik Analiz

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Öz

Matematikte öğrenmenin etkili bir şekilde gerçekleşmesi için öğretim süreçlerinde farklı modellerin kullanılması önemli görülmektedir. Özellikle somut kavramlardan soyut kavramlara geçişte yaşanabilecek problemlerin üstesinden gelmek için ek materyallerin kullanımına ihtiyaç vardır. Teknolojik gelişmeler, matematik derslerinde kullanılan yöntem ve teknikleri de etkilemiştir. Son yıllarda dijital oyunların eğitim-öğretim ortamlarında kullanımı artmıştır. Özellikle matematiği zor bir ders olarak gören öğrenciler için, matematiğin eğlenceli yönünü ortaya çıkarmada bu tür araçlar önemli bir araştırma alanı olarak öne çıkmaktadır. Dijital oyunların öğrenme motivasyonunu artırma, problem çözme ve yaratıcı düşünmeyi teşvik etme ve takım çalışmasını geliştirme gibi birçok olumlu katkısı olduğu bilinmektedir. Ancak, dijital oyunların sosyal beceriler üzerinde olumsuz etkileri de bildirilmiştir. Bu durum, konunun araştırılmasının önemini vurgulamaktadır. Ayrıca dijital oyun içeriklerinin teknolojik gelişmelere bağlı olarak sürekli gelişmesi, konunun güncel kalmasına sebep olmaktadır. Bu nedenle çalışmanın amacı matematik eğitiminde dijital oyunlara yönelik yapılan araştırmaların entelektüel yapısını ortaya koymaktır. Bu amaç doğrultusunda, Web of Science veri tabanında taranan matematik eğitiminde dijital oyunlarla ilgili yayınlar bibliyometrik yöntemlerle analiz edilmiştir. Çalışmada en etkili ülkeler, anahtar kelimelerin birlikte oluşumu, kavramsal, sosyal ve entelektüel eğilimler incelenmiştir. Araştırma sonuçları matematik eğitimcilerine alanda yazılmış makalelere geniş bir perspektiften bakış açısı sağlayarak, konunun ana hatlarını, konuyla ilgili eğilimlerin neler olduğunu ve farklı bileşenler arasındaki ilişkileri anlamalarına yardımcı olacaktır.

Anahtar Kelimeler: Matematik eğitimi, dijital-oyun tabanlı öğrenme, video oyunları, bibliyometrik analiz

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GENİŞLETİLMİŞ ÖZET

Giriş

Hayatımızın her alanında etkilerini gördüğümüz teknoloji, doğal olarak eğitim ve öğretim sürecini de etkilemiştir (Kocaman Karoğlu vd., 2020; Öner, 2020). Dijital oyunlar öğrencilerin bilişsel becerilerini geliştirmekte ve aynı anda birçok bilgiyi işlemelerine yardımcı olmaktadır. Ayrıca öğrenenler için akıl yürütme, hafıza startejilerinin gelişimi ve el-göz koordinasyonlarının gelişimine katkı sağlamaktadır. Tüm bunlar birlikte düşünüldüğünde video oyunlarının mükemmel bir öğrenme aracı olduğu söylenebilir (Hostetter, 2002). Birçok öğrenci için zor olan matematiğin, eğlenceli oyunlar ile öğretilmesi bu alanda araştırma yapmanın önemini ortaya koymaktadır (Widyasari vd., 2019). Matematik dersinde, eğitsel oyunların farklı becerileri geliştirmede faydalı olabileceği belirtilmiştir. Örneğin; stratejik ve akıl yürütme (Bottino vd., 2007), eleştirel düşünme (Cicchino, 2015), problem çözme ve cebir becerileri (Abramovich, 2010) gibi birçok noktada oyunların katkısı vardır.

Amaç

Dijital oyunların geleneksel öğretim uygulamalarına kıyasla etkili araçlar olduğu ifade edilmektedir (Fadda vd., 2022). Bu bağlamda dijital içeriklerle ilgili yapılmış çalışmaların incelenmesi ve genel bir bakış açısıyla alanyazına sunulması önemli görülmektedir. Bu ihtiyaçtan hareketle çalışmanın amacı Web of Science veri tabanında taranmış yayınları incelemektir. Bu çalışmalar öncelikle matematik eğitiminde dijital oyunlar konulu araştırmalarla ilgili derinlemesine analizi yapılmış, araştırma temaları belirlenmiş ve genel eğilimleri açısından incelenmiştir.

Yöntem

Araştırmanın Modeli

Bu çalışmada, matematik eğitiminde dijital oyunların kullanımıyla ilgili Web of Science (WoS) veri tabanında taranan yayınlar incelenmiş ve bibliyometrik analizi yapılmıştır. Bu kapsamda WoS veri tabanında matematik eğitiminde dijital oyunlar ile ilgili anahtar kelimeler makalelerin başlığı, özetleri ve anahtar kelimelerde aranarak 177 çalışmaya ulaşılmıştır. Ardından bu sonuçlara ilişkin veriler R programına aktarılmış, Biblioshiny yazılımı RStudio entegre geliştirme ortamı ile analiz edilmiştir.

Bulgular

Wos veri tabanında matematik dersi kapsamında dijital oyun kavramının 1996 yılından itibaren tarandığı görülmektedir. 493 yazarın toplam 177 çalışması 146 farklı kaynakta yayınlandığı tespit edilmiştir. Makale başına düşen toplam atıf sayısı 13,95 ve makale başına düşen yazar sayısı 2,79'dur. Matematik eğitiminde dijital oyunlar üzerine yapılan çalışmaların yıllık büyüme oranının 7,46 olduğu ve 2012 yılından itibaren çalışmalardaki artışın hızlandığı görülmektedir. Araştırma kapsamında yıllara göre ülkelerin katkıları incelendiğinde ise Amerika Birlerşik Devletleri dikkat çekmektedir. İnceleme kapsamında en çok atıf alan ülkeler incelenmiştir. Toplam 41 ülkeden ilk 20'si tablo 2'de verilmiştir. Elde edilen 177 çalışmada 544 anahtar kelimeye ulaşılmıştır. Aynı zamanda anahtar kelimelerden öne anahtar kelimelerin yıl bazında popülaritesi şekil 4'te verilmiştir. İncelenen çalışmaların yayınlandığı kaynaklar incelendiğinde ise British Journal of Educational Technology, Computers & Education,

Computers in Human Behavior, Journal of Computer Assisted Learning, Educational Technology & Society, Educational Technology Research and Development ve Frontiers in Psychology dergileri öne çıkmaktadır. Ülkeler arası işbirlikler incelendiğinde ise 5 farklı küme görülmektedir.

Tartışma & Sonuç

Çalışmada matematikte dijital oyunlar ile ilgili Web of Science veri tabanında taranmış çalışmaların bibliometrik analizi yapılmıştır. Bu kapsamda 1996-2022 yılları arasında 177 çalışmaya ulaşılmıştır. 2012 yılından itibaren yayın sayısında hızlı artış tespit edilmiştir. Bununla birlikte 2020 yılında kısmi bir düşüş göze çarpmaktadır. Bunun olası bir nedeni küresel çapta yaşanan salgının deneysel araştırmaları kısıtlaması olarak gösterilebilir. Ayrıca yıllara göre ülkelerin bu alana katkıları incelendiğinde Amerika Birleşik Devletleri'nin önde olduğu tespit edilmiştir. Amerika Birleşik Devletleri'ni sırasıyla Çin, İspanya ve diğer ülkeler takip etmektedir. 1996-2022 yılları arasında en fazla alıntı yapılan ülke Amerika Birleşik Devletleri'dir. İncelenen çalışmalarda 544 anahtar kelime tespit edilmiştir. Anahtar kelimelerde matematikte dijital videoların bilişsel ve duyuşsal özelliklere katkıları, sınıf seviyeleri ve öğrenme yaklaşımları dikkat çekmektedir. Dijital oyun tabanlı öğrenmenin, çeşitli alanlarda öğrenmeyi geliştirmek için yaygın olarak kullanıldığı düşünüldüğünde (Chen vd., 2020), kavramlar arası karşılaştırmalı analizlerin yapılıp nitel veriler ile desteklenmesine ihtiyaç vardır.

Arama terimi olarak kullanılan video oyunların ilerleyen yıllarda dijital oyunlar olarak güncellendiği tespit edilmiştir. Ayrıca kullanılan anahtar kelimelerin arama terimleri ile ilişkili olduğunu göstermektedir. Bunun dışında kullanılan anahtar kelimler ise: problem çözme, oyunlaştırma, ilköğretim, iş birliğine dayalı öğrenme, artırılmış gerçeklik, motivasyon, bilişsel gelişim, matematik kaygısı ve rasyonel sayılardır. Bu kelimelerin kullanılması dijital oyunların bilişsel ve duyuşsal etkilerinin incelendiğini göstermektedir. Dijital oyunların bilişsel ve duyuşsal öğrenme teorilerine dayalı olarak tasarlanması durumunda eğitimsel faydaların ortaya çıkması beklenmektedir. Bunun gerçekleşebilmesi için öğretmen veya ebeveyn kontrolünün önemi açıktır. Gerekli ortamların hazırlanması durumunda dijital oyunların öğrenme motivasyonunu artırmada, aktif öğrenmeyi ve derse katılımı teşvik etmede ve matematiği anlamada olumlu yönlerinin olduğu söylenebilir.

Bibliometric Analysis on Digital Game-Based Learning in Mathematics Education

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Abstract

For effective learning in mathematics, it is important to use different models in teaching processes. The use of additional materials is necessary, especially in overcoming problems that may arise during the transition from concrete concepts to abstract concepts. Technological developments have also influenced the methods and techniques used in mathematics classes. In recent years, the use of digital games in educational environments has increased. These tools are particularly prominent as an important research area in bringing out the fun side of mathematics, especially for students who see mathematics as a difficult subject. It is known that digital games have many positive contributions, such as increasing learning motivation, promoting problem-solving and creative thinking, and improving teamwork. However, the negative effects of digital games on social skills have also been reported, emphasizing the importance of researching the subject. In addition, the continuous development of digital game content due to technological advancements keeps the subject current. Therefore, the aim of the study is to reveal the intellectual structure of research on digital games in mathematics education. To this end, publications related to digital games in mathematics education were analyzed using bibliometric methods from the Web of Science database. The most effective countries, co-occurrence of keywords, conceptual, social, and intellectual trends were examined in the study. The research results will provide mathematics educators with a broad perspective on articles written in the field, helping them to understand the main outlines of the subject, the trends related to the subject, and the relationships between different components.

Keywords: Mathematics education, digital game-based learning, video games, bibliometric analysis

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Bibliometric Analysis on Digital Game-Based Learning in Mathematics Education

Although there are differing views on how learning takes place, it is crucial to develop models for the teaching and learning process and to create suitable conditions to facilitate learning. While it is possible for learning to occur without a specific teaching model or learning theory, utilizing teaching models is essential to effectively teach complex concepts and skills that may not be achievable with traditional methods. Therefore, a thorough understanding of the learning process is necessary to utilize appropriate teaching models in this process (Altun, 2015). Effective mathematics education is vital for society, and it is essential for the development of modern civilization (Daly et al., 2019).

One of the most effective ways to facilitate learning is through active engagement of students in the process (Ellis, 2016). There are several approaches that can be utilized to achieve this goal, such as flipped classroom, problem-based learning, hands-on practical projects, and practice testing. Immersive and interactive game-based learning is a promising approach as well (Muntean et al., 2018). The repetitive nature of math can be monotonous for some students, and digital games can be used to make lessons more enjoyable (Rebollo et al., 2022).

Technology has infiltrated every aspect of our lives, including the education and training process (Kocaman Karoğlu et al., 2020; Öner, 2020). The global digital transformation has not only affected business practices and habits but also revolutionized the methods and techniques utilized in teaching (Savaş et al., 2021). Technological advancements have impacted the teaching methods utilized in classrooms, resulting in an increase in technology-enhanced instruction. This type of learning environment provides opportunities to create tailored teaching materials for students with diverse learning styles (Sani Bozkurt, 2017). Digital games are a great way to enhance cognitive skills, process multiple pieces of information simultaneously, and improve reasoning, memory strategies, and hand-eye coordination. Given these benefits, it can be concluded that video games are an exceptional learning tool (Hostetter, 2002).

Computer games are gaining increasing importance in the global market and capturing the attention of a considerable segment of the population. This has raised questions about their impact on children, including whether they are harmful or beneficial, whether learning occurs during gameplay, and if so, what is being learned (Kirriemuir & Mcfarlane, 2004). At this point, attention is drawn not only to the positive but also to the negative effects of digital games on children (Toran et al., 2016). Given that 36% of children play digital games (Türkiye İstatistik Kurumu [TÜİK], 2021), parents (Işıkoğlu Erdoğan, 2019; Toran et al., 20016) and teachers (Nacar et al., 2021; Yıldız Durak & Karaoğlan Yılmaz, 2019) have serious responsibilities. Instead of focusing only on the negative aspects of digital games, it is recommended to integrate digital games that promote children's development and have educational purposes into classrooms (Işıkoğlu Erdoğan et al., 2021) and to conduct activities to raise students' awareness (Korkmaz & Korkmaz, 2019). Digital games have value beyond mere entertainment, as they can also create a self-directed learning environment for students when appropriately supported (Seng & Yatim, 2014).

Digital Game-Based Learning in Mathematics Education

The integration of technology in mathematics education promotes the application of higher-order thinking skills among students (Hegedus & Penuel, 2008). Recent technological advancements have spurred research into the use of technology in the classroom, with digital game-based learning emerging as an effective method for teaching mathematics (Hussein et al., 2022). Game-based learning provides teachers with the opportunity to break free from the confines of the classroom and allow for more exploration and reflection time. Benefits for students include opportunities for interaction, communication, and collaboration with peers and teachers, as well as reduced cognitive load and the potential for a transition from passive recipients to active thinkers (Deng et al., 2020). Educational digital games catered to specific content areas promote visual and auditory learning, thereby supporting student-centered education in the teaching and learning process. This approach enables learners to develop new identities, imagination, creativity, and an opportunity to identify their interests and skills (Savaş et al., 2021).

Teaching mathematics is a challenging task for many students, and incorporating enjoyable games into the process highlights the significance of research in this field (Widyasari et al., 2019). When students become confused or frustrated during their learning process, experimenting with alternative strategies may activate cognitive and metacognitive processes (Di Leo et al., 2019). Furthermore, it has been demonstrated to have positive effects on student motivation (Chang et al., 2012; Whitton, 2011), enhance learning outcomes (Coller & Scott, 2009; Panoutsopoulos & Sampson, 2012), increase retention (Stewart et al., 2011), encourage active learning and participation (Ebner & Holzinger, 2007), and boost student confidence (Ku et al., 2014; Shi et al., 2022).

It has been reported that educational games can be useful for the development of various mathematical skills. For example; strategic thinking (Bottino et al., 2007), critical thinking (Cicchino, 2015), problem solving, and algebra skills (Abramovich, 2010). Students think that mathematics is not easy to understand. Teachers do try to help students understand mathematics, but their efforts do not easily produce results (Papadakis & Kalogiannakis, 2017). At this point, it is emphasized that the use of digital content in mathematics instruction, especially in the early grades, can be very effective in achieving success in mathematics (Thai et al., 2022).

Current Study

With developments in technology, research on the use of games in educational environments is growing rapidly (Sardone & Devlin-Scherer, 2010). The playful aspect of digital games has resonated in education. In particular, the way to create educational environments that increase student success is to use computer games, which are the passion of children, in educational processes (Yıldırım, 2016). Because it is found that digital games are effective tools compared to traditional teaching practices (Fadda et al., 2022). Therefore, it is important to examine the studies on digital games and present them in the literature from a general perspective. Based on this need, the objective of this study is to examine the studies in the Web of Science database. These studies were first analyzed in depth for research on digital games in mathematics education, research topics were identified and examined for general trends. In

addition, the network between countries, institutions, and keywords is presented. Specifically, this study answers the following research questions (RQ):

RQ1: What is the trend of digital game in mathematics education in terms of publication year, document type, country, keywords and most relevant journals?

RQ2: What is the conceptual, social and intellectual tendency towards digital games in mathematics education?

Methodology

There are several methods for conducting a literature review, including meta-analysis, systematic review, and bibliometric analysis, to name a few. At this point, it is important to compare bibliometric analysis with other review methods (Donthu et al., 2021). Bibliometric analysis is a technique used to analyze large amounts of data to identify emerging trends, research components, and patterns (Castañeda et al., 2022). With the increasing number of publications, it has become increasingly difficult to transform the data obtained through traditional methods into meaningful information. In this context, bibliometric analysis has gained importance in scientific research (Atabay et al., 2019). The purpose of this study was to conduct a bibliometric analysis of publications related to digital games in mathematics education, which were indexed in the Web of Science database.

Data Collection

Data were retrieved from the Web of Science database, which was selected for its high-quality indexes, extensive coverage over time, and capability to download a large number of articles and references simultaneously. The search query used was as follows: (AB=("mobile game") OR AB=("digital game") OR AB=("video game") OR AB=("virtual game")) AND (AB=(math*) OR AB=(algebra) OR AB=(geometry)) OR (TI=("mobile game") OR TI=("digital game") OR TI=("video game") OR TI=("virtual game")) AND (TI=(math*) OR TI=(algebra) OR TI=(geometry)) OR (KP=("mobile game") OR KP=("digital game") OR KP=("video game") OR KP=("virtual game")) AND (KP=(math*) OR KP=(algebra) OR KP=(geometry)), which resulted in 320 studies as of November 2022.

Data Analysis Process

Out of the 320 studies analyzed, 143 were excluded from the study due to several reasons, such as being non-English language, book chapters, or digital games not related to mathematics education. As a result, a total of 177 studies were identified in the Web of Science database. The data on these studies were then transferred to the R program, and the Biblioshiny software was utilized for analysis using the RStudio integrated development environment (IDE).

Results

Descriptive Findings

Table 1 presents an overview of the study, including key information about the data, document content, authors, author collaboration, and document types.

Table 1

Main Information

Description	**Results**
Main Information About Data	
Timespan	1996:2022
Sources (Journals, Books, etc)	146
Documents	177
Annual Growth Rate %	7,46
Document Average Age	6,9
Average citations per doc	13,95
References	5104
Document Contents	
Keywords Plus (ID)	265
Author's Keywords (DE)	544
Authors	
Authors	493
Authors of single-authored docs	17
Authors Collaboration	
Single-authored docs	20
Co-Authors per Doc	3,1
International co-authorships %	20,34
Document Types	
Article	93
Proceedings paper	84

According to table 1, research on the use of digital games in mathematics education has been conducted since 1996. In the past 27 years, a total of 177 studies have been published by 493 authors from 146 different sources. The average number of citations per article is 13.95, and the average number of authors per article is 2.79. The annual growth rate of studies on digital games in mathematics education is 7.46. The distribution of studies by year is presented in figure 1.

Figure 1

Annual Scientific Production

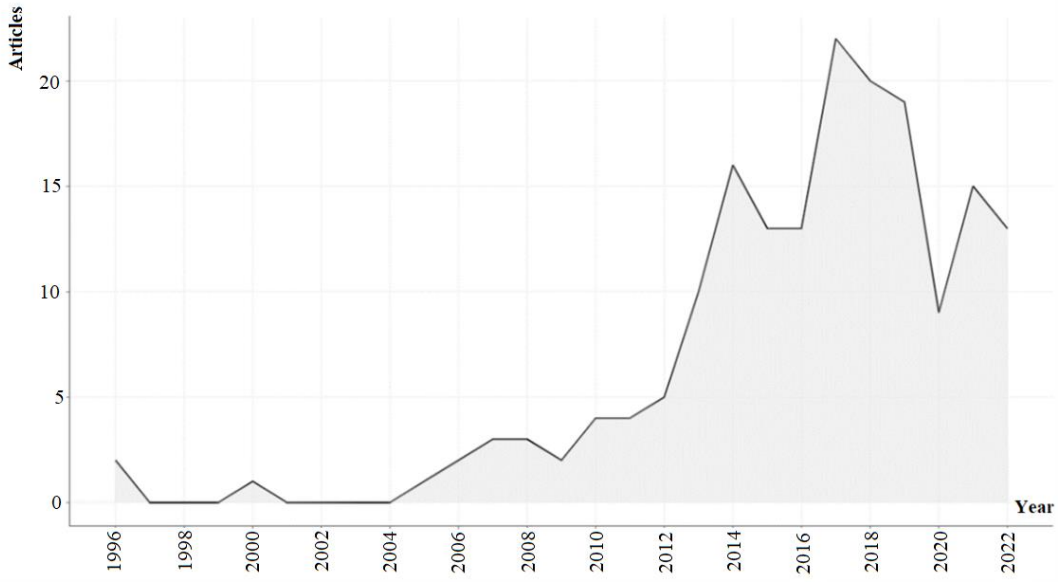
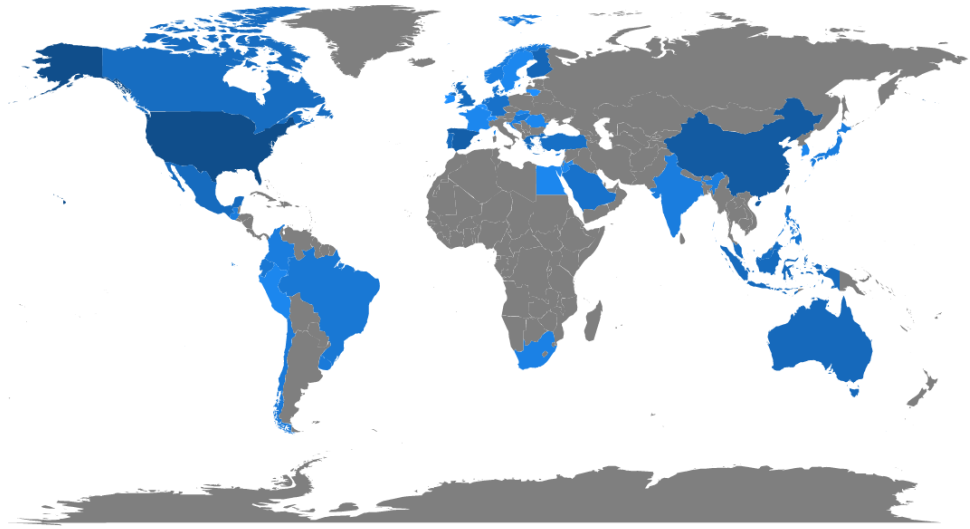


Figure 1 demonstrates an accelerating increase in the number of studies on digital games in mathematics education since 2012, but with a decrease in the number of articles in 2020. Figure 2 illustrates the contributions of the top 20 countries.

Figure 2

Country Scientific Production



Region	Freq
USA	158
China	54
Spain	40
Finland	21
Australia	18
Greece	16
Indonesia	16
Mexico	16
Portugal	16
UK	15
Canada	14
Malaysia	12
Turkey	11
Germany	10
Saudi Arabia	9
Netherlands	8
Denmark	7
Hungary	7
Brazil	6
Ecuador	6

Upon analyzing the contributions of the top twenty countries within the scope of this research, it was found that the United States of America made the most contributions (n=158), followed by China (n=54), Spain (n=40), Finland (n=21), Australia (n=18), Greece (n=16), Indonesia (n=16), Mexico (n=16), Portugal (n=16), United Kingdom (n=15), Canada (n=14), Malaysia (n=12), Turkey (n=11), Germany (n=10), Saudi Arabia (n=9), Netherlands (n=8), Denmark (n=7), Hungary (n=7), Brazil (n=6), and Ecuador (n=6). The review examined the

countries that were most frequently cited, and the 20 most frequently cited countries are listed in table 2.

Table 2

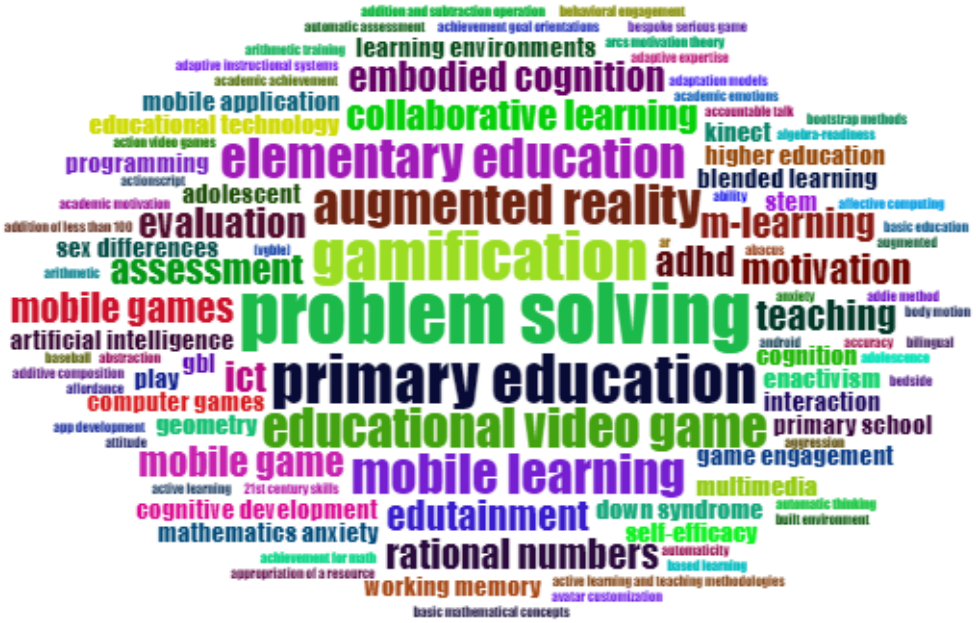
Most Cited Countries

Country	TC	Average Article Citations
USA	903	20,52
Canada	687	171,75
China	230	11,50
Greece	104	17,33
Finland	98	10,89
Australia	58	9,67
Germany	54	27,00
Netherlands	41	20,50
Malaysia	37	9,25
Spain	33	2,20
United Kingdom	21	4,20
Denmark	18	9,00
Indonesia	16	2,67
Chile	15	15,00
Croatia	11	11,00
Mexico	11	1,83
Turkey	9	3,00
Egypt	7	7,00
Portugal	7	1,40
Ecuador	6	2,00

Table 2 presents the most frequently cited countries in the scope of the research, with the United States of America being the most cited country (n=903), followed by Canada (n=687), China (n=230), Greece (n=104), Finland (n=98), Australia (n=58), Germany (n=54), Netherlands (n=41), Malaysia (n=37), Spain (n=33), United Kingdom (n=21), Denmark (n=18), Indonesia (n=16), Chile (n=15), Croatia (n=11), Mexico (n=11), Turkey (n=9), Egypt (n=7), Portugal (n=7), and Ecuador (n=6). The 177 studies identified in this review yielded 544 keywords. Figure 3 displays a word cloud of the first 100 most frequently used words after excluding the keywords used in the research.

Figure 3

Author's Keyword



In figure 3, the most frequently repeated words in the top 100 words are mobile learning/m-learning (n=7), problem solving (n=6), gamification (n=5), primary education (n=5), augmented reality (n=4), elementary education (n=4), collaborative learning (n=3), rational numbers (n=3), motivation (n=3), cognitive development (n=2), anxiety (n=2), and blended learning (n=2). In addition, figure 4 displays the popularity of the top keywords on a yearly basis.

Figure 4

Distribution of Digital Video in Mathematics Education by Topic Over the Years

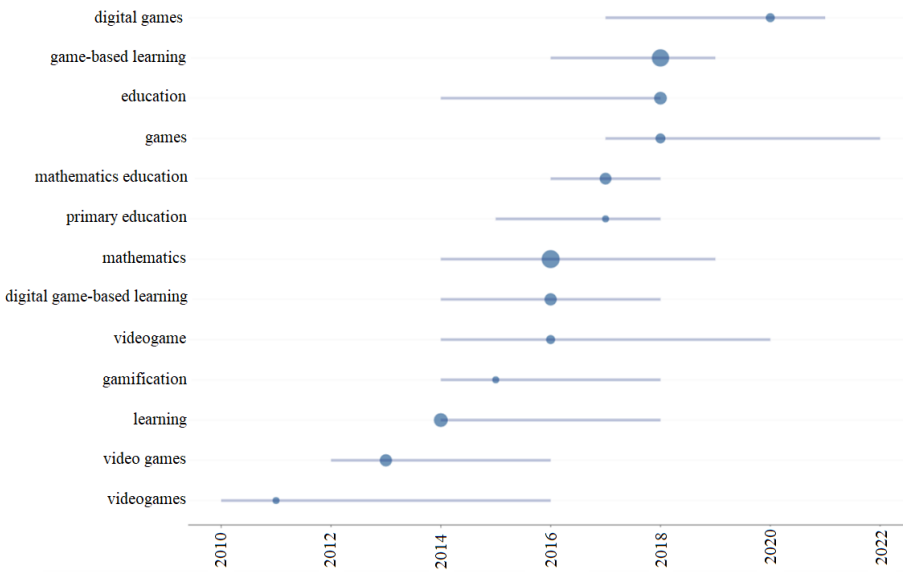


Figure 4 shows the change of words according to years. In addition, it was determined that video games are more frequently used as digital games today. The sources where the reviewed studies were published are given in table 3.

Table 3

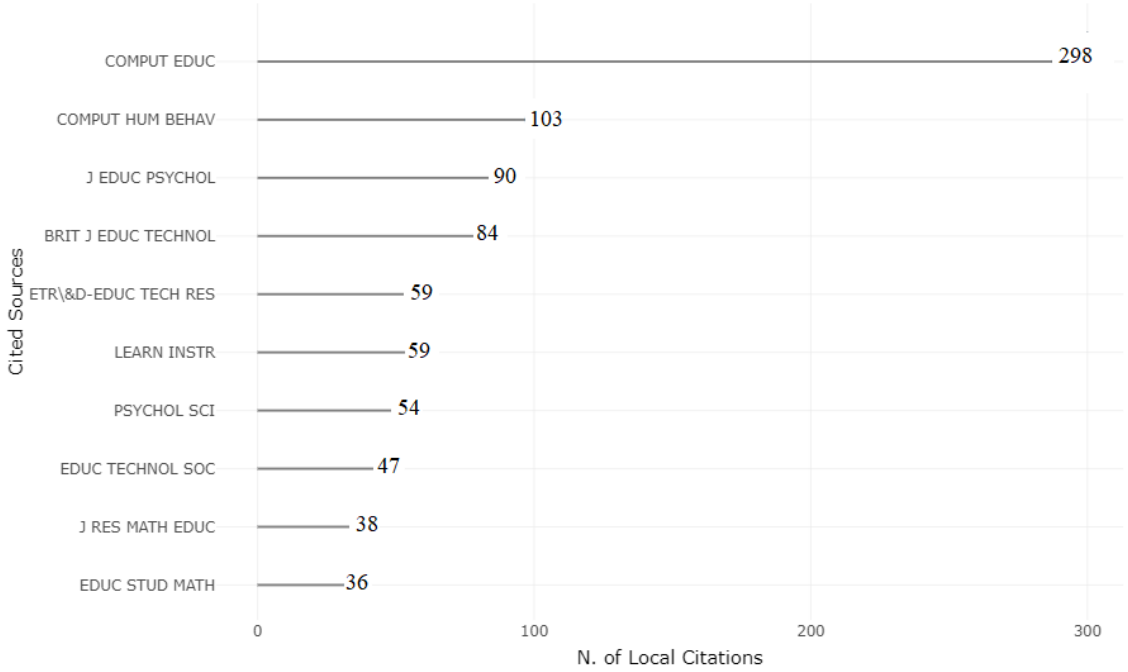
Most Relevant Sources

Sources	Articles
British Journal of Educational Technology	4
Computers & Education	4
Computers in Human Behavior	4
Journal of Computer Assisted Learning	4
Educational Technology & Society	3
Etr&D-Educational Technology Research and Development	3
Frontiers in Psychology	3
10th International Conference of Educatıon, Research and Innovation (Iceri2017)	2
2nd European Conference on Games Based Learning	2
Australasian Journal of Educational Technology	2
Education and Information Technologies	2
Education Sciences	2
Interactive Learning Environments	2
International Journal of Emerging Technologies in Learning	2
International Journal of Gaming and Computer-Mediated Simulations	2

Table 3 shows that the journals British Journal of Educational Technology (n=4), Computers & Education (n=4), Computers in Human Behavior (n=4), Journal of Computer Assisted Learning (n=4), Educational Technology & Society, (n=3), Educational technology research and development (n=3), and Frontiers in Psychology (n=3) stand out. In addition, there are 5104 references in 177 studies. Information on the references is given in figure 5.

Figure 5

Most Local Cited Sources (from Reference Lists)



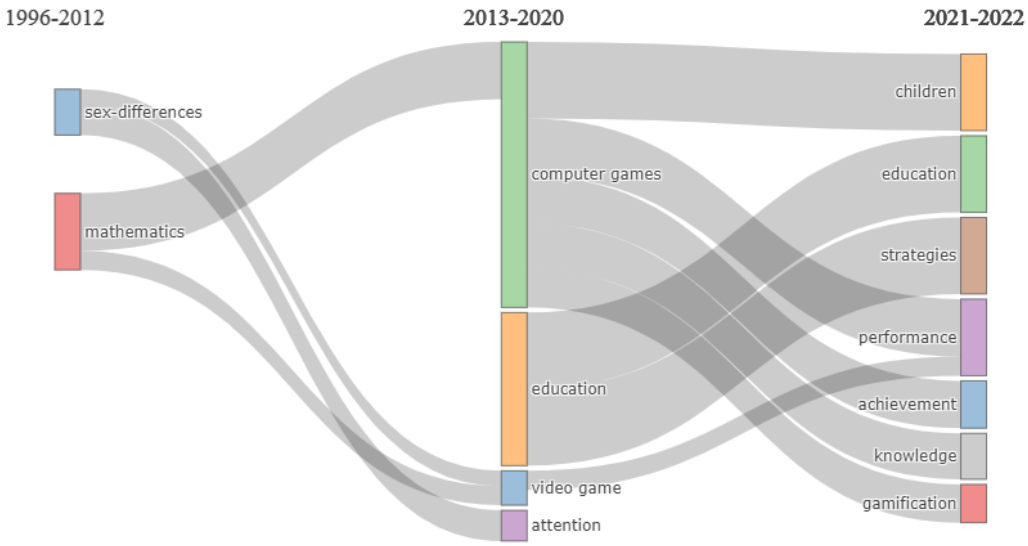
When the frequency of these references is analyzed, Computers & Education (n=298), Computers in Human Behavior (n=103), Journal of Educational Psychology (n=90), British Journal of Educational Technology (n=84), and Learning and Instruction (n=59) come to the fore.

Conceptual, Social and intellectual findings

Figure 6 depicts the thematic evolution using a Sankey diagram, which is a specific type of flowchart. In this study, the Sankey diagram is used to visualize the thematic development in the field of digital games and mathematics research over time. This figure assists in understanding the temporal evolution of keywords related to digital games used in mathematics education. Quantitative information, such as thematic flow, direction, and transformational relationships, can be clarified (Soundararajan et al., 2014). Keywords were analyzed in three time periods. The year 2012, when annual growth rates of studies increased, and the year 2020, when a partial decline was observed, were preferred while selecting these periods. Figure 6 displays the thematic evolution for 1996-2012, 2013-2020, and 2021-2022.

Figure 6

Thematic Evolution



The words thematized between 1996-2012 as gender differences and mathematics appear between 2013-2020 as computer games, education, video game, and attention, and between 2021-2023 as children, education, strategies, achievement, success, knowledge, and gamification. Cooperation between countries is given in figure 7.

Figure 7

Collaboration Between Countries

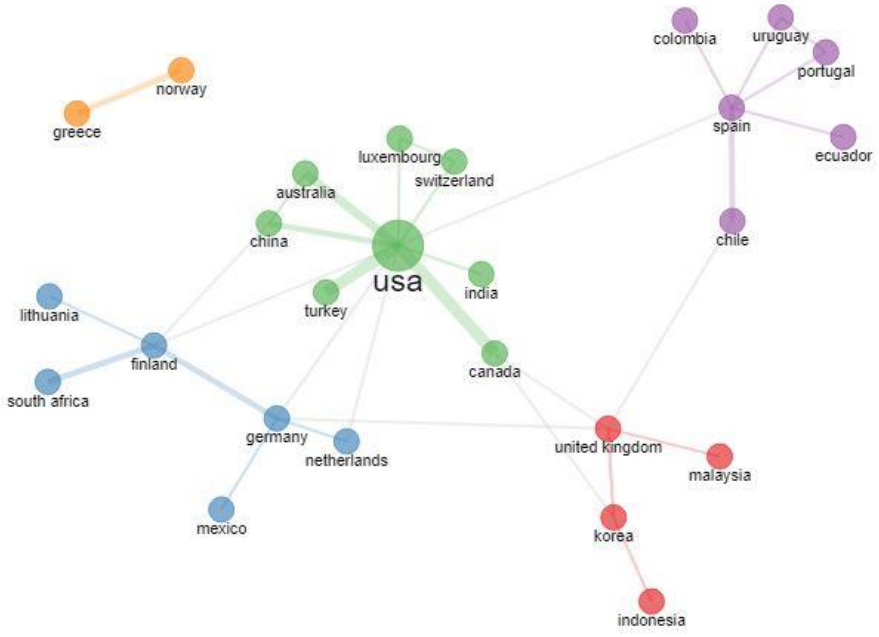


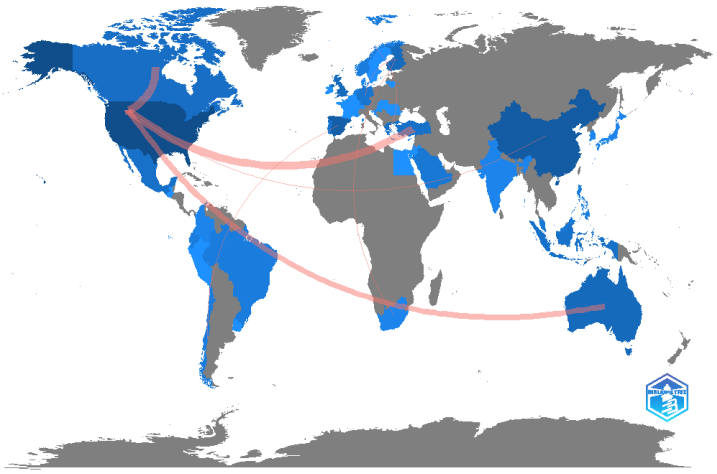
Figure 7 shows five different clusters. In terms of general structure, the United States of America, Canada, India, Switzerland, Luxembourg, Turkey, Australia, and China are green; the United Kingdom, Korea, Indonesia, and Malaysia are red; Germany, the Netherlands, Finland,

South Africa, Lithuania, and Mexico are blue; Norway and Greece are orange; and Spain, Chile, Ecuador, Portugal, Uruguay, and Colombia are purple. Collaboration Worldmap is given in figure 8.

Figure 8

Collaboration Worldmap

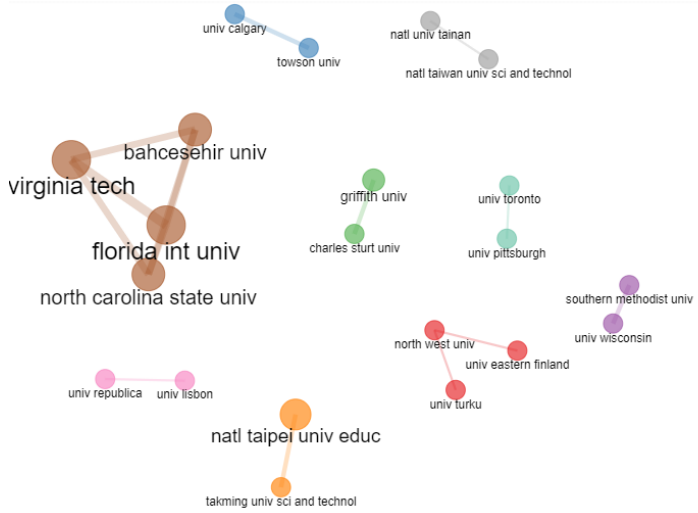
From	To	Frequency
USA	Canada	4
USA	Turkey	4
USA	Australia	3
Finland	Germany	2
Finland	South Africa	2
Greece	Norway	2
Spain	Chile	2
Usa	China	2
Canada	Korea	1
China	Australia	1
China	Finland	1
Finland	Lithuania	1
Germany	Netherlands	1
Indonesia	Korea	1
Luxembourg	Switzerland	1
Mexico	Germany	1
Portugal	Uruguay	1
Spain	Colombia	1
Spain	Ecuador	1
Spain	Portugal	1



When the first 20 collaborations between countries are examined; USA-Canada (n=4), USA-Turkey (n=4), USA-Australia (n=3), Finland-Germany (n=2), Finland-South Africa (n=2), Greece-Norway (n=2), Spain-Chile (n=2), USA-China (n=2), Canada-Korea (n=1), China-Australia (n=1), China-Finland (n=1), Finland-Lithuania (n=1), Germany-Netherlands (n=1), Indonesia-Korea (n=1), Luxembourg-Switzerland (n=1), Mexico-Germany (n=1), and Portugal-Uruguay (n=1). Inter-institutional collaboration in the study is shown in figure 9.

Figure 9

Instution Collaboration Network



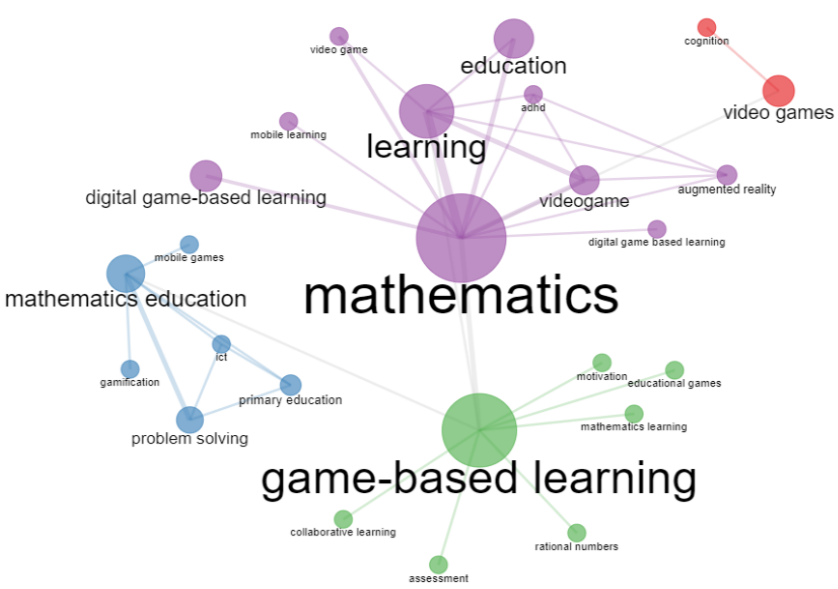
Node	Cluster
Univ. Pittsburgh	9
Univ. Toronto	9
Natl Taiwan Univ. Sci and Technol	8
Natl Univ. Tainan	8
Univ. Lisbon	7
Univ. Republica	7
Florida Int. Univ.	6
Virginia Tech	6
Bahcesehir Univ.	6
North Carolina State Univ.	6
Natl Taipei Univ. Educ	5
Takming Univ. Sci and Technol	5
Univ. Wisconsin	4
Southern Methodist Univ.	4
Griffith Univ.	3
Charles Sturt Univ.	3
Towson Univ.	2
Univ. Calgary	2
Univ. Turku	1
North West Univ.	1
Univ. Eastern Finland	1

When figure 9 is examined, nine different clusters stand out. These institutions: University of Pittsburgh - University of Toronto, National University of Science and Technology in Taiwan - National University of Tainan, University of Lisbon - University of the Republic, Florida International University - Virginia Tech - Bahçeşehir University - North Carolina State University,

National Taipei University of Education - Takming University of Science and Technology, University of Wisconsin - Southern Methodist University, Griffith University - Charles Sturt University, Towson University - University of Calgary, and University of Turku - North West University - University of Eastern Finland. When analyzing the network between the keywords used by the authors, four clusters can be identified. These keywords and the relationship between them are shown in figure 10:

Figure 10

Author Keywords Co-Occurrence Network



Node	Cluster
mathematics	4
learning	4
education	4
digital game-based learning	4
videogame	4
augmented reality	4
mobile learning	4
adhd	4
video game	4
digital game based learning	4
game-based learning	3
educational games	3
mathematics learning	3
assessment	3
collaborative learning	3
motivation	3
rational numbers	3
mathematics education	2
problem solving	2
gamification	2
primary education	2
ict	2
mobile games	2
video games	1
cognition	1

When figure 10 is examined, mathematics, learning, education, digital game-based learning, video games, augmented reality, mobile learning, adhd, video games, and digital game-based learning were separated as the first cluster; game-based learning, educational games, mathematics learning, assessment, collaborative learning, motivation, and rational numbers were separated as the second cluster; mathematics education, problem solving, gamification, primary education, ict, and mobile games were separated as the third cluster; and video games and cognition were separated as the fourth cluster.

Discussion

This study performed a bibliometric analysis of publications related to digital games in mathematics education, which were indexed in the Web of Science database. This study found a total of 177 publications on digital games in mathematics between 1996 and 2022, with an increasing trend since 2012. However, a partial decrease in the number of publications was observed in 2020, which could be attributed to the global pandemic and its impact on experimental research. The United States of America was found to be the leading country in terms of contribution to the field, followed by China, Spain, and other countries. Moreover, the United States of America was the most cited country among the publications analyzed. The study also identified 544 keywords, with a focus on the contributions of digital videos to cognitive and affective characteristics, grade levels, and learning approaches in mathematics. This finding is supported by previous studies in the literature. Antequera-Barroso et al. (2022) discovered that video game challenges elicit positive emotions in contrast to the negative emotions that arise

when solving math problems. They also found that students were unaware they were using problem-solving skills learned in school in video games. Kärki et al. (2022) researched the impact of digital games on rational numbers and found that games had a positive impact on understanding of rational numbers. Yang and Chen (2021) demonstrated that digital game-based learning significantly improved students' learning performance and retention. In their study, Sun et al. (2021) found that digital game-based learning experiences had a positive impact on students' knowledge, arithmetic ability, and interest in mathematics. This supports the idea that educational technologies, such as digital games, can be effective tools for teaching and learning mathematics. The utilization of educational technologies in instructional settings typically provides advantages for comprehending mathematics, particularly for educators in the field (Pratama & Setyaningrum, 2018).

When analyzing the distribution of words over time, it was observed that the term "video game" was gradually replaced by "digital game." The four initial journals contributing to the literature were identified as the British Journal of Educational Technology, Computers & Education, Computers in Human Behavior, and Journal of Computer Assisted Learning. This is a typical finding, given the focus on mathematics and digital games.

Upon examination of the conceptual, social, and intellectual findings of the study, five clusters emerged in terms of country cooperation, while nine clusters were identified in terms of institutional cooperation. Additionally, the thematic structure of the literature was analyzed in three distinct time periods: 1996-2012, 2013-2020, and 2021-2022, as depicted in Figure 7. In the first period analyzed (1996-2012), the theme of sex-differences and mathematics was later updated to computers games, education, video games, and attention in the second period (2013-2020). Between 2021 and 2022, the themes that gained importance were children, education, strategies, performance, achievement, knowledge, and gamification. In the latest period, cognitive skills have become more prominent, which may be attributed to advancements in technology and the quality of games that can be developed. For instance, augmented reality applications have become more accessible and are being used more frequently in educational settings, making it easier to examine their effects on cognitive and affective skills. When the network between author keywords was analyzed, four clusters emerged, with the keywords mathematics, game-based learning, video games, and mathematics education being prominent. This is expected since these keywords are related to the search terms used in the study.

Limitations and Future Directions

The study has several limitations, including the use of only one database, the exclusion of book chapters, and the fact that the documents were gathered until November 2022. To provide a more comprehensive overview of the literature on digital games and mathematics education, it is recommended to explore other databases in addition to Web of Science and include book chapters in the analysis. Moreover, most of the studies reviewed in this analysis focused on kindergarten and primary school students, despite the fact that digital games may also appeal to middle and high school students. To gain a better understanding of the effectiveness of game-based learning in a wider range of age groups and educational levels, more research is needed. The studies reviewed in this analysis primarily examined the cognitive and affective effects of digital games. Given that digital game-based learning is widely used to improve learning in various fields (Chen et al., 2020), comparative analyses between different

concepts should be conducted and supported with qualitative data. Finally, the results of this study suggest that research on digital games in mathematics education is conducted more frequently in certain countries. To facilitate cooperation and knowledge sharing between countries, it is recommended to increase international collaborations in this area.

Conclusion

In this study, a bibliometric analysis was conducted to examine research on digital games in mathematics education. The study analyzed the most influential countries, co-occurrence of keywords, and conceptual, social, and intellectual trends. The results indicate that there has been increasing interest in the use of digital games in mathematics education in recent years. This interest is largely due to the direct impact of technological advancements on the content of digital games in educational and training environments. Additionally, the keywords used in the research were related to the search terms. Other keywords included problem-solving, collaborative learning, motivation, cognitive development, math anxiety, and rational numbers. The use of these terms indicates that the cognitive and affective effects of digital games are being studied. Developing digital games based on cognitive and affective learning theories can lead to educational benefits. However, it is important to note that teacher and parental control is necessary for the successful implementation of digital games in the classroom.

Overall, the study suggests that digital games have positive effects in increasing motivation to learn, promoting active learning and participation in the classroom, and enhancing students' understanding of mathematics. This can be achieved through the creation of an appropriate framework that supports the use of digital games in mathematics education.

Conflict of Interest Statement

The author declared no potential conflicts of interest regarding the research, authorship and/or publication of this article.

Support/Financing Information

The author received no financial support for the research, authorship and/or publication of this article.

Ethics Committee Decision

In this study, all the rules specified in the "Directive on Scientific Research and Publication Ethics of Higher Education Institutions" were followed. None of the actions specified in the second part of the Directive, "Actions Contrary to Scientific Research and Publication Ethics", were carried out. The study does not require ethics committee permission since it was not conducted on humans.

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