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Review

Interweaving gaming and educational technologies: Clustering and forecasting the trends of game-based learning research by bibliometric and visual analysis

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ABSTRACT

This study aimed to highlight the applications and trends in game-based learning (GBL) by conducting a systematic review as well as bibliometric mapping analysis of the studies published in seven SSCI (Social Science Citation Index) educational journals from 1990 to 2019. A total of 743 journal papers were included in this study. The results revealed that most publications and citations for GBL research were from Taiwan and the United States. The author who contributed the most is Gwo-Jen Hwang, while Computers & Education is the journal with the most publications and the most citations. The most frequently studied keywords are interactive learning environments, followed by game-based learning and teaching/learning strategies. Based on reviewing the literature, this study provides a comprehensive summary overview of the existing research, integrating the available information on the research hot topics, and visualizing and identifying the main GBL trends. In addition, the roles of gaming in educational technology research were investigated. Accordingly, some suggestions regarding the application and research directions of GBL are provided based on the study's findings, which could be a reference for researchers conducting related research in the future.

1. Introduction

In the past decade, the application of and research on GBL have proliferated in education. Game-based learning (GBL) refers to the learning environment that integrates learning knowledge and skills into games, allowing learners to achieve learning through problem-solving and competition challenges while playing games [1,2]. Considering the development of technology, the current study focuses on examining the educational technology journals in the field of GBL. In the field of educational technology, digital games are generally adopted in game-based learning studies. However, during the analysis of the articles published in the selected educational technology journals, it was found that some studies adopted non-digital games (e.g., board games) in technological learning contexts (e.g., flipped classrooms or blended learning). Therefore, in this study, game-based learning is divided into two major categories, that is, digital game-based learning (DGBL) and the use of non-digital games in technological learning contexts (NDGTLC). The latter is defined as "incorporating non-digital games into the learning activities conducted in technology-enhanced learning contexts." Compared to DGBL, NDGTLC studies seem to have been less common in recent years owing to the popularity of computer and multimedia technologies [3].

GBL is now widely adopted in education. It has been used in professional training and to provide enjoyable and situated learning contexts in various courses, such as mathematics [4], science [5], computer science [6], language [7], business [8], medical education [9], and culture [10]. The integration of games into the learning process provides affirmative assistance for some students. It can enhance students' participation and enable them to acquire knowledge and improve their learning performance [11]. Moreover, there are interesting findings about the application of GBL in education. Scholars have pointed out that GBL can enable students to gain specialized knowledge and promote their learning achievement while playing games [12]. Students' learning motivation and performance can be facilitated through competition [13,14]. Besides, providing auxiliary scaffolding in the game can increase students' engagement and interest in the learning process [15]. Studies have also found that learning through games can not only improve learners' problem-solving skills, but can also enhance their

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critical thinking skills [16]. Moreover, the game mechanics are included in learning activities to facilitate motivation, promote interaction, engage learners in competition, enhance their problem-solving skills, and provide them with enjoyable entertainment [1,17,18]. However, some educators have found that novice students and those with low levels of self-efficacy may feel nervous and anxious in GBL environments, which can affect the learning effectiveness of the games [19]. Some students are unfamiliar with the operation and use of games, which may arouse negative emotions, making them become more nervous and anxious, and thus affecting their learning performance [20]. There are positive and negative points of view on GBL; therefore, we aimed to conduct a comprehensive review of GBL to recognize its role in learning.

Recently, a number of GBL literature reviews have appeared. They have applied data collection, knowledge integration, and analysis methods to provide some guidelines for GBL research. These literature reviews discuss GBL from different perspectives. For example, some have emphasized application in different fields such as science education [21], nursing education [22], language education [23], and argumentation game-based learning [24], while others have emphasized the difference in applying GBL for diverse learners, such as children [25], K-12 [26], higher education [27], and adult education [28].

From the above literature, it is clear that recognizing the trends of GBL in education is very important. However, in recent years, most literature review studies have focused on discussions of DGBL [22,29,30]. Nevertheless, NDGTLC has also made many contributions to education, but it seems to be less discussed. Furthermore, the above literature reviews are narrowly focused on specific subjects or objects in GBL. It can be seen that in the era of rapid technological change, a comprehensive understanding of the trends of GBL in education is still lacking. Besides, scholars such as Hsu et al. [31] have pointed out that many research topics mainly focus on particular fields, which may result in numerous topics not being discussed, many issues being ignored, or even divergent opinions. Understanding the worldwide spread of journals in GBL issues would help researchers explore appropriate topics in their further research [32]. Moreover, a literature review can provide some essential references for researchers or educational policymakers [33]. Hence, it is meaningful to inspect GBL research trends to provide data on the research trends in this field.

Compared to the previous systematic reviews of GBL research, the current study aimed to cover all GBL-related topics for a systematic review of the literature by bibliometric analysis. Highly cited articles offer a good indicator that can informatively reveal the research issues and trends that researchers have focused on in recent years. According to Svensson [34], the number of publications can quantify productivity, and the number of citations can usually measure influence. Through conducting analysis of the number of publications, citations, and the most prolific and influential authors, it is possible to identify those articles with a certain degree of impact. This research searched for articles in seven top education journals (the British Journal of Educational Technology, Computers & Education, Educational Technology & Society, Educational Technology Research & Development, the Journal of Computer Assisted Learning, Interactive Learning Environments, and Innovations in Education and Teaching International) that are recognized as having high impact factors in the Web of Science (WoS) database [29], with the intention of clarifying the following research questions to guide new research.

(1) What is the distribution of the citations and publications of the countries' research on GBL in the WoS?
(2) What are the most cited journal publications on GBL in the WoS?
(3) Who are the most prolific and influential authors doing research on GBL in the WoS?
(4) What are the most used keywords and the clusters of keywords in research on GBL in the WoS?
(5) How did game-based learning work with educational technologies?

2. Research methods

2.1. Resources

According to several literature reviews [21,23,30,35,36], this study adopted the Boolean expression ("game-based learning" or "GBL" or "learning games" or "serious games" or "educational games" or "game for learning" or "video game" or "gamification" or "digital games" or "game" or "gaming" or "gameful" or "gameplay") to search all the topics in the WoS from 1990 to 2019 on September 18, 2020. A total of 96,801 articles met the guidelines. We then narrowed the research field to the scope of education and educational research, and a total of 2,856 publications were identified. According to a literature review [29], the journals with high impact factors in education include the British Journal of Educational Technology (BJET), Computers & Education (C&E), Educational Technology & Society (ETS), Educational Technology Research & Development (ETR&D), the Journal of Computer Assisted Learning (JCAL), Interactive Learning Environments (ILE), and Innovations in Education and Teaching International (IETI). The above journals are not only peer-reviewed but are also listed in the Social Science Citation Index (SSCI). The current research was therefore limited to these top education journals. A total of 907 articles met the guidelines. Further, the study selected the items that matched "Article" and "English" among these 907 articles, which gave 839 articles. Researchers and experts then reviewed the abstracts of all 839 publications. After discussion, 96 items that did not have a GBL context or which addressed unrelated issues were excluded. In the end, the experts identified a total of 743 articles which were then selected for analysis and discussion in this study. The search process is demonstrated in Fig. 1.

2.2. Data distribution

This research retrieved articles about GBL published in the educational field from 1990 to 2019 in the WoS, and a publication distribution chart ordered by year of publication is shown in Fig. 2. There was a related study on the participation and learning impact of primary school students using computer games early in 1990 [37]. In the next few years, related research began to increase, then jumped suddenly when the number of publications in 2011 was nearly double that of 2010. The following years continued to show a slight increase, with the publications in GBL showing positive development. In 2018, there was a sharp increase of 34 related articles compared with the previous year, reaching a peak. Subsequently, a slight decline can be observed in 2019. However, GBL research has remained popular in recent years.

The current study then examined the articles published on GBL issues in these years in various journals, as presented in Table 1 and Fig. 3. Most articles were published in Computers & Education, with 305 articles accounting for 41%, followed by the British Journal of Educational Technology, and Educational Technology and Society with 110 articles each, accounting for 15%.

2.3. Data analysis

In this systematic review, text mining, co-occurrence analysis, and network analyses were carried out to evaluate the connections among the topics covered. The bibliometric analysis was applied using the VOSviewer program to disclose and visualize the conceptual structure among the selected articles which included the countries with the most publications, the journals with the most citations, the most prolific and influential authors, and the most used keywords.

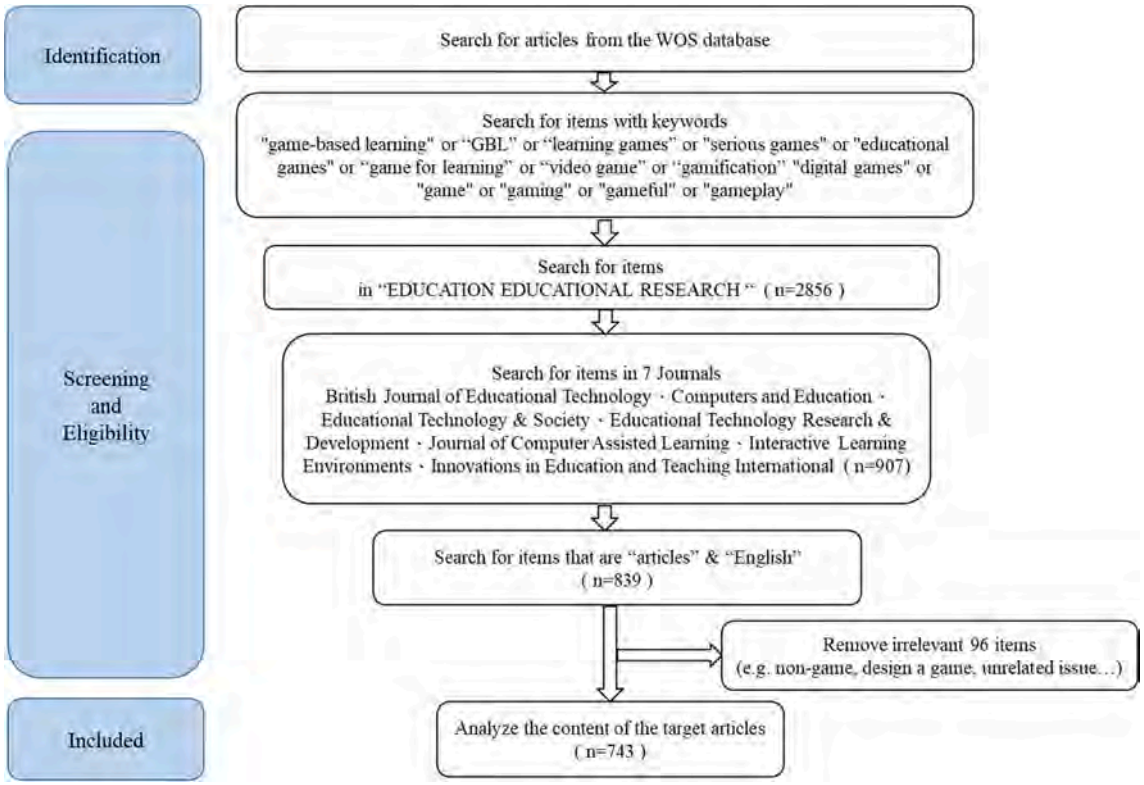

Fig. 1. Flow diagram of the article collection procedure.

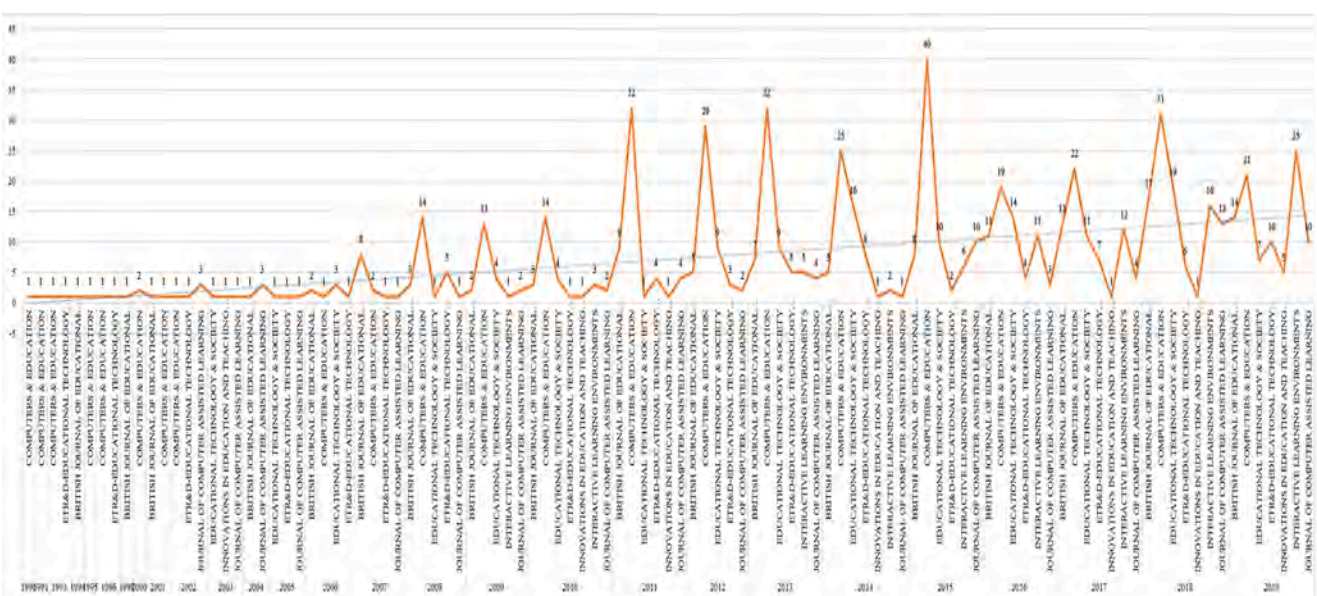

Fig. 2. Publication distribution for GBL.

Table 1
The number of publications by journal.

Journal	Publications
British Journal of Educational Technology	110
Computers and Education	305
Educational Technology & Society	110
Educational Technology Research & Development	60
Innovations in Education and Teaching International	11
Interactive Learning Environments	81
Journal of Computer Assisted Learning	66

3. Research results

3.1. Analysis of publications and citations among countries

Fig. 4 shows the number of citations of the articles published in GBL by country. For this analysis chart, the countries we selected had published more than 15 papers. It can be seen that Taiwan had published 208 articles, ranking first, followed by the United States (Publications = 166), the Netherlands (Publications = 53), England (Publications = 50), Spain (Publications = 49), China (Publications = 30), Finland

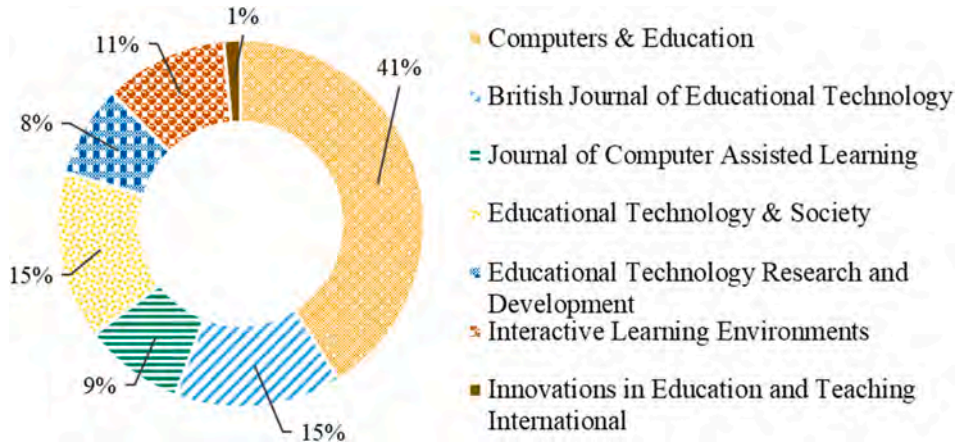

Fig. 3. The percentage of publications by journal.

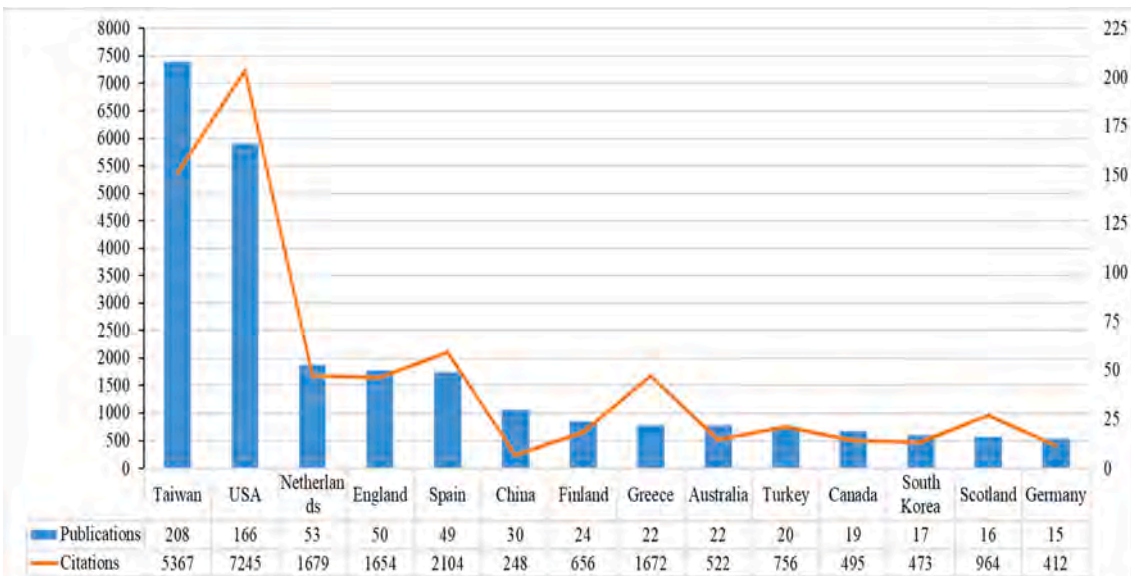

Fig. 4. Distribution of publications and citations by country.

(Publications = 24), Greece (Publications = 22), Australia (Publications = 22), Turkey (Publications = 20), Canada (Publications = 19), South Korea (Publications = 17), Scotland (Publications = 16), and Germany (Publications = 15).

Furthermore, this research also compiled an analysis of the citation status of published articles in each country and found that the citation status of an article is not necessarily proportional to the number of published articles. We sorted the number of citations and have displayed them in Table 2. For countries with more than five articles, it was found that the country with the most citations is the United States, with 7,245 citations, followed by Taiwan (Citations = 5,367), Spain (Citations = 2,104), the Netherlands (Citations = 1,679), Greece (Citations = 1,672), England (Citations = 1,654), Scotland (Citations = 964), Turkey (Citations = 756), Finland (Citations = 656), Belgium (Citations = 566), France (Citations = 524), and Australia (Citations = 522). As shown in Table 2, Belgium and France had published 14 and eight articles, respectively, but these articles had a high number of citations. Fig. 5 shows the average number of citations for each country. The size of the nodes represents the number of citations of published articles in each country. The higher the number of citations, the larger the node for that country, while a deeper color indicates higher average citations. The country with the highest average was Greece (average number of citations = 76) followed by Austria (average number of citations = 71), France (average number of citations = 65.5), and Scotland (average number of citations = 60.25). Besides, the coefficient of correlation was 0.94, which indicates a strong positive relationship between the number of publications and the number of citations.

3.2. The most-cited journals

Fig. 6 shows the analysis of citations and publications of each journal (in order of journal name). The most-cited journal was Computers & Education. The number of citations was 15,210 for 305 publications, followed by the British Journal of Educational Technology (Publications = 110, Citations = 3,212), Educational Technology & Society (Publications = 110, Citations = 2,106), Interactive Learning Environments (Publications = 81, Citations = 632), Journal of Computer Assisted Learning (Publications = 66, Citations = 2,350), Educational Technology Research and Development (Publications = 66, Citations = 2,011), and Innovations in Education and Teaching International (Publications = 11, Citations = 182).

In order to understand the average citations for each journal, citation analysis was applied, and the visualization is shown in Fig. 7. The size of the node represents the number of citations for the journal, where the

Table 2
The citation ranking of countries.

Country	Publications	Citations	Average number of citations
USA	166	7245	43.64
Taiwan	208	5367	25.80
Spain	49	2104	42.94
Netherlands	53	1679	31.68
Greece	22	1672	76.00
England	50	1654	33.08
Scotland	16	964	60.25
Turkey	20	756	37.80
Finland	24	656	27.33
Belgium	14	566	40.43
France	8	524	65.50
Australia	22	522	23.73
Canada	19	495	26.05
Italy	13	487	37.46
South Korea	17	473	27.82
Austria	6	426	71.00
Germany	15	412	27.47
Chile	10	285	28.50
China	30	248	8.27
Singapore	11	240	21.82
South Africa	6	238	39.67
Norway	5	233	46.60
New Zealand	5	202	40.40
Israel	6	180	30.00
Czech Republic	5	131	26.20
Sweden	7	88	12.57
Brazil	7	20	2.86

higher the number of citations, the larger the node. A deeper color indicates higher average citations. The journal with the most average citations was Computers & Education (Ave. cited = 49.87), followed by the Journal of Computer Assisted Learning (Ave. cited = 35.61), Educational Technology Research and Development (Ave. cited = 33.52), the British Journal of Educational Technology (Ave. cited = 29.20), Educational Technology & Society (Ave. cited = 19.15), Innovations in Education and Teaching International (Ave. cited = 16.55), and Interactive Learning Environments (Ave. cited = 7.8).

3.3. Author analysis

In order to identify the most prolific and influential authors, the current study revealed the relationship between citations and publications by authors. This study was based on the conditions of publishing more than six articles and having more than 200 citations in GBL-related research to search for the most productive and influential authors. Table 3 is a statistical table of the average number of citations for authors who published GBL-related research. It shows that Gwo-Jen Hwang not only published 26 articles but also received 1,208 citations. Both publications and citations were twice as many as the second place, Jon-Chao Hong (Publications = 14, Citations = 119), followed by Ming-Yueh Hwang (Publications = 13, Citations = 119), and Fengfeng Ke (Publications = 11, Citations = 582). This demonstrates that Gwo-Jen Hwang was the most prolific scholar in the field of GBL education.

Moreover, the overlay visualization of average publication year for each author is shown in Fig. 8. The overlay color of each frame corresponds to the authors' average publication year of all their papers. In this map, each frame in blue represents the research activities with older average publication years, and those in yellow show the research activities with more recent average publication years. The size of each frame indicates the average number of publications, where a larger frame shows more publications. The study found that Gwo-Jen Hwang not only had the most publications, but the average publication years were also more recent. From the above summary of the authors' analysis results, it was revealed that Prof. Gwo-Jen Hwang was the most prolific and influential author in the field of GBL research in recent years.

3.4. Keywords analysis

The keywords in an article provide essential information to understand the critical points of the paper. The researchers usually specify the hot topics in the keywords section. Therefore, this study explored the trend of hot topics through the study of keywords in GBL. Co-occurrence

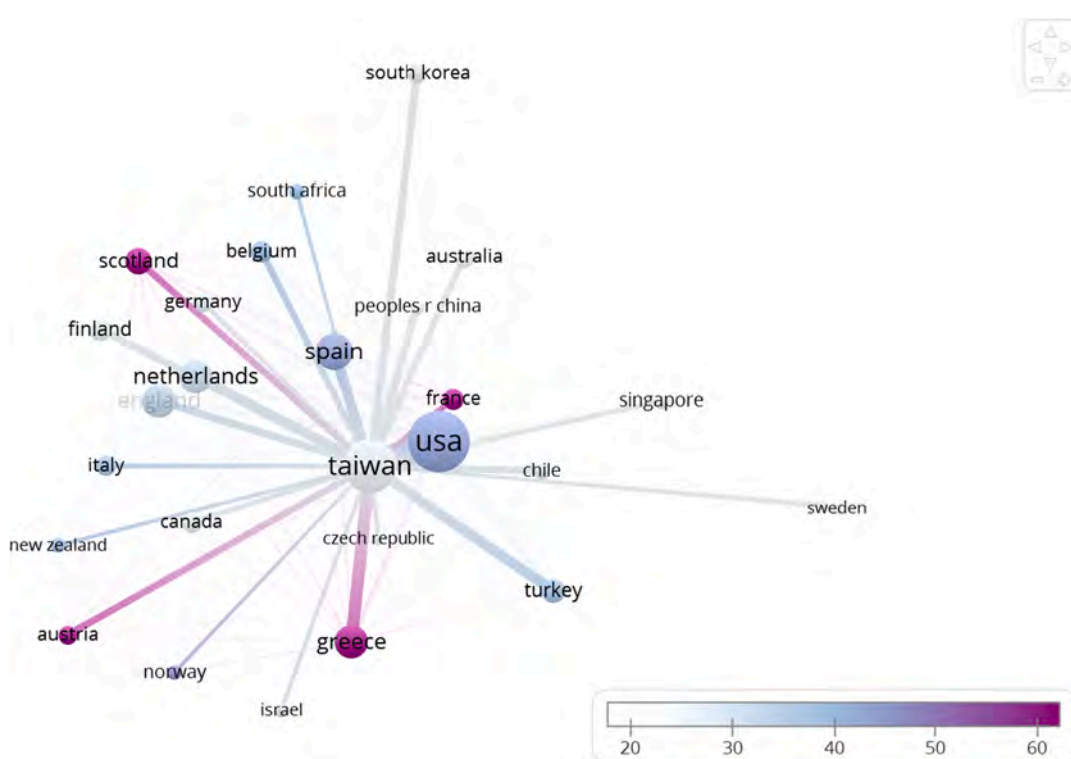

Fig. 5. The average number of citations of the articles for each country.

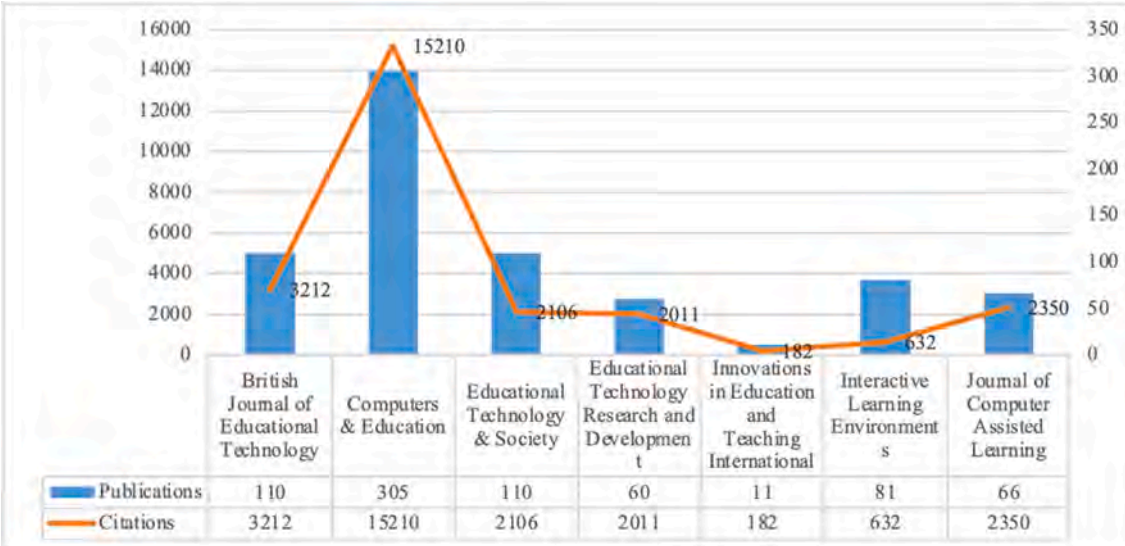

Fig. 6. The publications and citations for each journal.

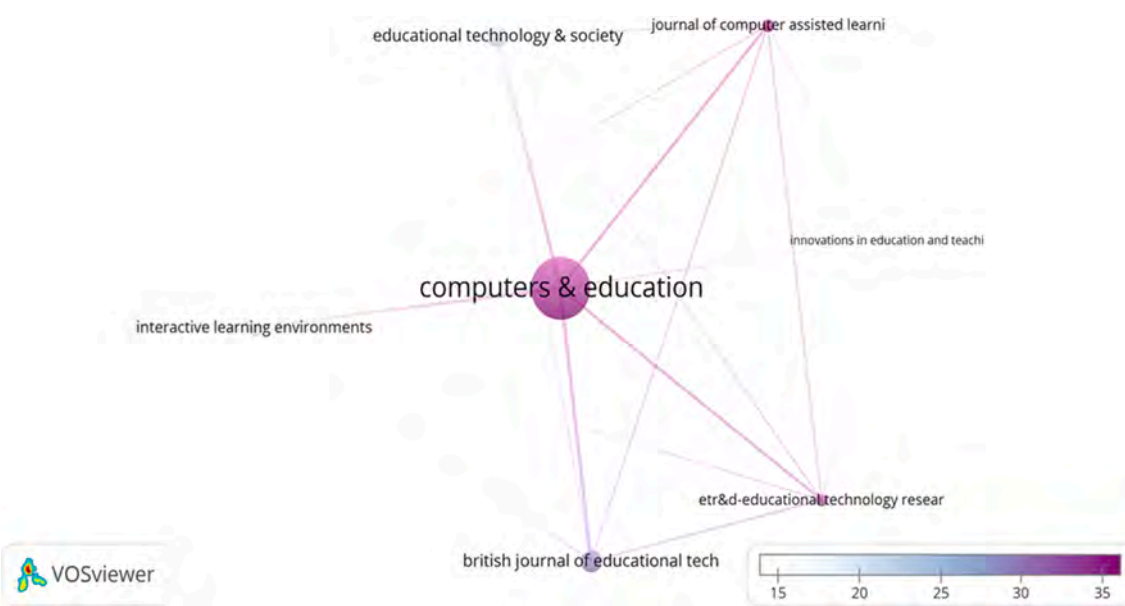

Fig. 7. The most cited journals.

analysis and text mining were applied to perform cluster analysis of keywords and to present the trends of current GBL topics. We set the minimum number of occurrences of a keyword as more than five, and a total of 80 keywords were selected. The top 10 keywords are shown in Table 4. The most-used keywords were "interactive learning environments" which appeared 118 times, followed by "game-based learning" at 96 times, and "teaching/learning strategies" at 64 times.

The cluster density visualization of keywords displays the density of each cluster of keywords (Fig. 9). The frequently adopted keywords are categorized into several clusters based on their occurrences and are presented in different colors. According to Fig. 9, the cluster density visualization of keywords shows that there are four clusters. The most used keywords ordered by occurrences in each cluster are interactive learning environments (bluish green), game-based learning (blue), serious games (vermillion), and virtual reality (yellow). In other words, the four clusters with the following keywords as the head are "interactive learning environments" (f = 118), "game-based learning" (f = 96), "serious games" (f = 34), and "virtual reality" (f = 33).

Fig. 10 shows the distribution of the used keywords by year. The keyword "Interactive learning environments" was adopted most frequently around 2014. Use of "game-based learning" gradually increased after 2015. Due to the advancement of technology, "digital game-based learning" and "gamification" were used more frequently in recent years.

3.5. Analysis of publications of DGBL and NDGTLC

After analyzing the GBL publications, we found two categories of game-based learning studies in the educational technology journals, that is, DGBL and the use of non-digital games in technological learning contexts (NDGTLC). We then examined the articles to comprehend whether the games reported in the studies were digital or non-digital. Out of 743 articles, we found that only five adopted NDGTLC, as shown in Table 5. This result shows that with the development and advancement of technology, most GBL studies applied technology-assisted GBL rather than traditional non-digital games.

Table 3
Top authors ranked by number of publications.

Rank	Author	Publications	Citations
1	Hwang, Gwo-Jen	26	1208
2	Hong, Jon-Chao	14	119
3	Hwang, Ming-Yueh	13	119
4	Ke, Fengfeng	11	582
5	Sung, Han-Yu	9	480
6	Fernandez-Manjon, Baltasar	9	148
7	Chen, Zhi-Hong	9	73
8	Nussbaum, Miguel	8	147
9	Chan, Tak-Wai	8	131
10	Van Oostendorp, Herre	7	227
11	Chen, Ching-Huei	7	72
12	Westera, Wim	7	45
13	Tai, Kai-Hsin	7	23
14	Cheng, Meng-Tzu	6	371
15	Connolly, Thomas M.	6	332
16	Hainey, Thomas	6	332
17	Wouters, Pieter	6	205
18	Hou, Huei-Tse	6	164
19	Torrente, Javier	6	116

Studying the top-ranking authors' publications revealed that the authors have made significant contributions to DGBL. According to the publications of the most prolific scholar, Gwo-Jen Hwang, he proposed ubiquitous game-based learning and applied various learning strategies such as the repertory grid approach, concept mapping, and contextual decision-making based on GBL [5,38,39]. By employing these learning strategies in the game-based learning environment, it was found that students not only increased their learning motivation and self-efficacy but also enhanced their problem-solving ability and learning performance [4,5,10]. The publications of another prolific scholar, Hong, Jon-Chao, focused on the role that the educational values of digital games play in competitive anxiety, cognitive process, and learning effectiveness. He studied computer-assisted learning and interactive learning environments, and suggested that game design is vital for enhancing self-efficacy, eliminating competitive anxiety, and increasing learning knowledge [40,41,42].

On the other hand, it is interesting to see how these non-digital games work in technology-based learning contexts. The earliest NDGTLC study was conducted by Struwig et al. [43], who used a medical microbiology board game, which was found to play a vital role in enhancing medical students' knowledge of infectious diseases in medical microbiology lectures. The study found that playing the game had a positive impact on increasing students' learning experiences. It is important to indicate that the authors did not try to use any form of technology to work with Med Micro Fun With Facts (MMFWF). They revealed that such an approach enhanced the students' verbal expression skills of medical terminology and peer interactions as well as their learning outcomes. On the other hand, they indicated the need to situate students in clinical reasoning contexts in which they could practice applying knowledge to deal with medical cases, implying the potential role of technologies in providing situated and interactive learning contexts.

As for the study of Hew et al.[44], the game mechanics based on the self-determination theory of motivation in the "designing questionnaire" course were developed in a higher-educational context. It was used to identify the consequences of student cognitive and behavioral engagement during the gamified conditions. The result disclosed no significant difference in students' factual knowledge. However, the experimental groups contributed to the quality of the discussion forum. The game worked with the online learning system, Moodle, to reward the players with digital badges and digital points, and to demonstrate leader boards as well as to post forum messages.

Later, Naik [45] proposed an innovative GBL approach with an arithmetic-fraction rummy game ("The deck consisted of 34 cards showing fractional numbers and 20 cards showing addition, subtraction, division, multiplication and equality operators") to teach mathematics

Table 4
Top 10 keywords of the GBL research.

Author keywords	Occurrences
interactive learning environments	118
game-based learning	96
teaching/learning strategies	64
media in education	42
elementary education	37
serious games	34
digital game-based learning	34
virtual reality	33
applications in subject areas	31
improving classroom teaching	31

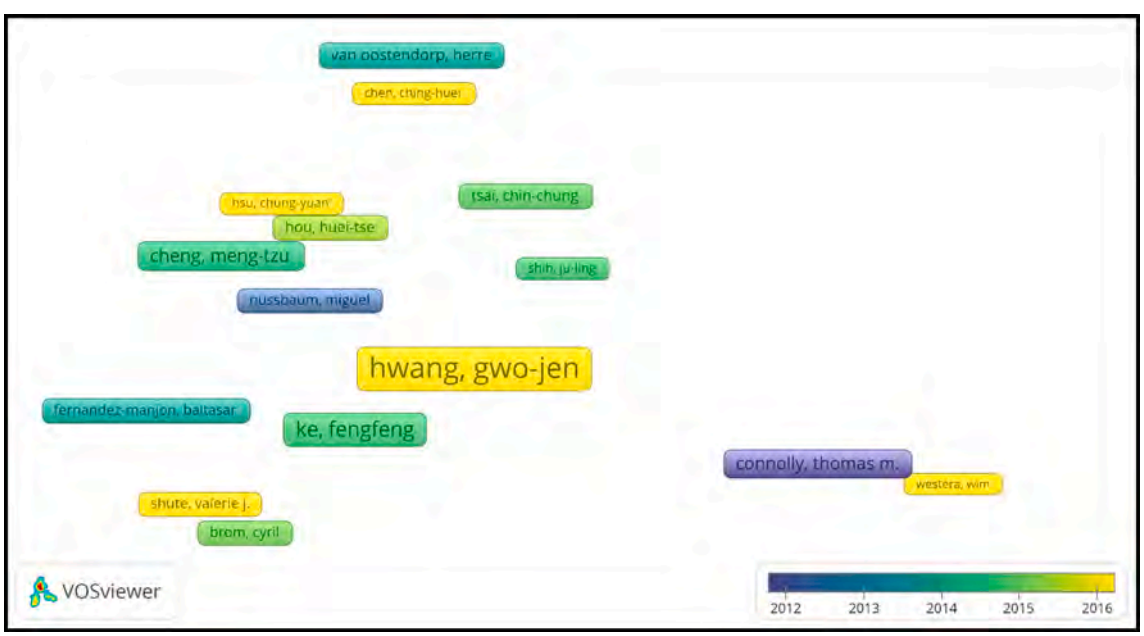

Fig. 8. The average publication years for each author.

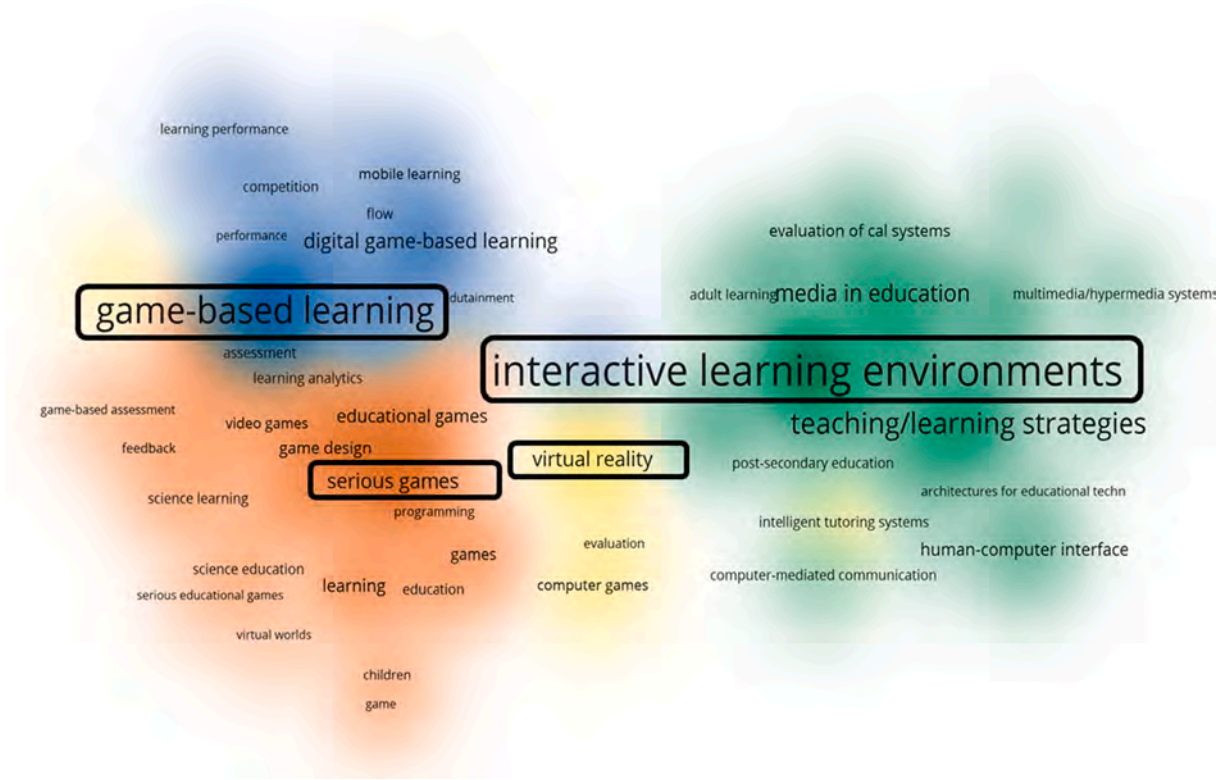

Fig. 9. The keyword cluster map.

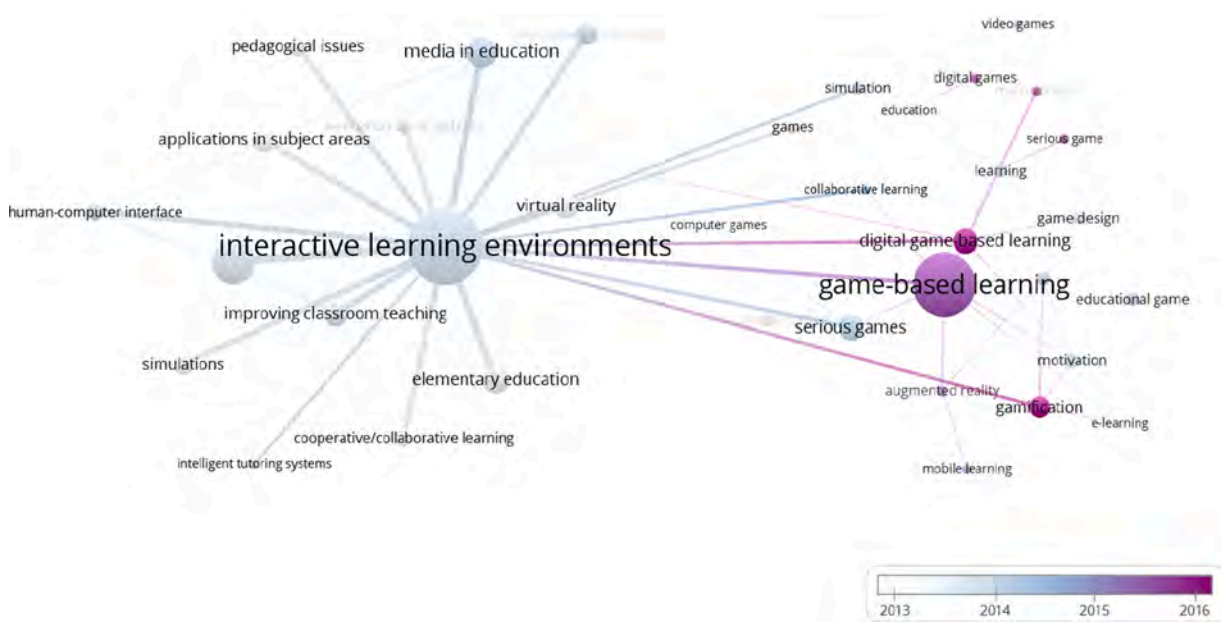

Fig. 10. The distribution of the used keywords by year.

in higher education. The results showed that the mechanism overcame the motivational barriers and received positive feedback from the students. It should be noted that no technology was adopted to work with the game. The authors stated that the study mainly focused on promoting students' learning attitudes, and that their learning performance was not taken into account. More importantly, they indicated the need to analyze students' learning process in the future, implying the possibility of using technology to record and analyze learning behaviors or interactive content. Similarly, Huang and Ho [46] also applied an ethics board game in a university business course without using any technology. They reported that there was no difference between this NDGTLC approach and traditional instruction in terms of learning performance; moreover, they also indicated the need to analyze students' learning process in the future. This again implies the possibility of using technology to record and analyze learning behaviors or interactive content.

The latest study of Gil-Doménech and Berbegal-Mirabent [47] developed a structural teamwork GBL activity in a mathematics course for business and management students to acquire knowledge on the

Table 5
The publications of non-digital game-based learning.

Author	Keywords	Title	Journal
Struwig, M. C., Beylefeld, A. A., & Joubert, G. (2014)	medical education; nominal group technique; board game; infectious diseases; observation; play; innovation; microbiology	Learning medical microbiology and infectious diseases by means of a board game: Can it work?	Innovations in Education and Teaching International
Hew, K. F., Huang, B., Chu, K. W. S., & Chiu, D. K. (2016)	Gamification; Behavioral engagement; Cognitive engagement; Blended learning	Engaging Asian students through game mechanics: Findings from two experiment studies	Computers & Education
Naik, N. (2017)	GBL; game-based learning; mathematics; HE; higher education; math game; non-digital games	The use of GBL to teach mathematics in higher education	Innovations in Education and Teaching International
Huang, W., & Ho, J. C. (2018)	Ethics; game-based; learning; moral reasoning; training	Improving moral reasoning among college students: a game-based learning approach	Interactive Learning Environments
Gil-Doménech, D., & Berbegal-Mirabent, J. (2019)	Higher education; university mathematics education; mathematics; teaching practices; active learning; game-based learning; teamwork	Stimulating students' engagement in mathematics courses in non-STEM academic programmes: A game-based learning	Innovations in Education and Teaching International

resolution of derivatives and integrals. Due to the competitive base of the learning activity, students showed high interest, motivation, collaboration, and satisfaction. The results showed that students' academic records were significantly improved. The game works with an online learning management system to manage the learning materials and discussion forum posts as well as providing the space for students to upload their solutions to the learning tasks.

From the above findings, it is concluded that the non-digital games generally played the roles of facilitating social interaction and behavioral engagement, while the technologies might play the roles of providing auxiliary information and documenting learning information, and a forum for discussion and knowledge sharing, as well as recording students' learning process. That is, using technologies to work with those non-digital games has the potential to enrich the gaming contexts, promote the game-based learning outcomes, and facilitate the analysis of the learning process.

4. Discussion and conclusions

This study applied bibliometric analysis using keywords to search for articles published on GBL in seven journals in the WoS. A total of 743 related publications were retrieved. In particular, the study has presented the statistical distribution of the publications, ascertained the impactful countries, identified prolific and influential authors, recognized the hot keywords used in articles, and compared the number of publications on DGBL and NDGTLC.

Firstly, the distribution of publications over the years was explored. It was found that the number of articles on GBL grew steadily, peaking in 2018, with a decrease in 2019. However, the research on GBL is still prevalent. It is inferred that the reason for this is that nowadays, with the advancements in mobile technology, learning environments have become more diversified. For example, with the use of mobile technology to support learning, students no longer have to stay in the classroom; that is, they can immerse themselves in the interactive learning environment through the combination of technology and learning tasks. Researchers are turning to discover the impact of technology applications on learning instead of focusing on GBL [48,49].

The distribution of the countries in the studies was then inspected. The research found that the countries with the most publications are Taiwan (208), the United States (166), the Netherlands (53), England (50), and Spain (49). This could be due to the fact that these countries have conducted digital learning via nation-wide programs with effective promotional strategies, such as the establishment of nation-wide special interest groups. For example, Taiwan initiated a 10-year digital learning program from 2003 to 2012 to improve technology-supported learning [50], while the United States proposed a 5-year plan called the National Education Technology Plan 2010 (NETP 2010) in order to focus more on technology and promote innovation for the future of education [51]. This result indicated that these countries have paid more attention and made an important contribution to GBL education. Therefore, it is suggested that researchers from other countries exploring GBL could refer to these countries' research experience.

The citation impact of publications is an essential indicator of the high quality of academic journals. The most-cited journals were therefore also examined in this research. It was found that Computers & Education had the most publications and also the most citations. The number of publications and citations in Computers & Education increased greatly over the past decade. This result shows that Computers & Education is the most influential and indicative journal in this field. It plays a vital role as a guidebook and useful reference in the field of GBL.

The prolific and influential authors were also examined in this research. It was indicated that Gwo-Jen Hwang had both the most publications and the most citations. This result highlights his contributions to GBL and indicates that his articles are highly referential. Moreover, Cheng, Meng-Tzu ranked the first in terms of citation rate, showing that her publications have a significantly high impact on GBL. Studying the authors' publications and citations revealed that the above authors have made significant contributions to GBL. Their articles can serve as a good reference for researchers or educators studying GBL in the future. To achieve the purpose of game-based learning, it is suggested that GBL may need to be assisted by appropriate learning strategies to improve its learning effectiveness in the classroom learning environment.

Combining the above findings, the research examined the countries with the most publications, the most-cited journals, and the most prolific and influential authors. The top-ranked authors such as Gwo-Jen Hwang, Jon-Chao Hong, and Ming-Yueh Hwang are all from Taiwan. Ke, Fengfeng, who had the highest citation rate, is from the United States. This result is consistent with the United States having the highest number of citations. The articles have been published and cited mostly in Computers & Education in the field of GBL. For example, Gwo-Jen Hwang has 26 publications related to GBL, of which 10 are published in Computers & Education. The above outcomes demonstrate that these authors, countries, and this journal have significant positions, contributions, and indicative references in GBL. It is recommended that other researchers can take these results as references in their future research.

Furthermore, the most used keywords were also examined. The co-occurrence analysis showed that the most used keywords were "interactive learning environments," "game-based learning," "teaching/learning strategies," and "media in education." These keywords were considered to be more critical in GBL. The results are parallel with the finding of [52]. Cluster analysis showed that there were four clusters of keywords. The four clusters with the following keywords as the head are "interactive learning environments," "game-based learning," "serious games," and "virtual reality." The "interactive learning environments" received the most consideration among authors in the GBL issue. Interactive learning environments indicate the context which supports learners to acquire knowledge through interactive learning mechanisms.

Several studies applied GBL through game design, scaffolding, multimedia, and interactive interfaces in different interactive learning-supported environments to help learners understand and solve learning tasks [53,54]. In terms of "game-based learning" and "teaching/learning strategies," researchers focused on applying teaching/learning strategies during GBL; that is, they were concerned with gamification, motivation, engagement, competition, participation, involvement, flow, and edutainment [55]. This finding implies that researchers in the field of GBL could emphasize the teaching/learning strategies to improve learning efficacy when designing GBL. Moreover, education is the process of providing systematic instruction to facilitate learning and the acquisition of knowledge and skills. Authors paid attention to improving teaching/learning strategies to acquire knowledge when developing learning games to enhance learners' cognition [56,57]. Finally, over the past decade, the variety of technological tools and applications has rapidly developed. One of them in particular, virtual reality, has become a popular educational tool among authors. Due to the advancements in technology and mobile devices, the use of virtual reality for GBL has greatly increased [58]. The contextual process of applying instructional strategies in learning games with advanced technology support allows learners to interact and cooperate with their peers, stimulates motivation, competition, and entertainment, and supports learners in acquiring knowledge to achieve their learning purposes. It could be seen as the research direction and focus of further studies.

Moreover, the study found that there were relatively few publications on NDGTLC. Compared with previous reviews on DGBL publications, NDGTLC publications only accounted for a small percentage. This demonstrates that technological advancement has significantly affected the development of GBL studies. This finding is consistent with researchers' efforts to apply technology-supported game design, such as implementing the concepts of traditional board games in digital environments to provide interactive gaming contexts with diverse types of media, including images, text, videos, and audio [59,60]. On the other hand, there are some reasons to support the use of non-digital games. First, non-digital games do not require any technical assistance, which could reduce the burden on educators and learners in terms of cost-effectiveness and skills development [3]. Second, face-to-face interactions in non-digital gaming contexts might enhance communications and collaboration between peers [47]. Third, significant relationships between personality traits and the use of technology have been found; therefore, developing GBL should take this into account [61]. However, digital educational technology has certain advantages over manual approaches when executing GBL mechanics. With technology-supported learning, the advantage might be the convenience and time saving that it can provide. Moreover, teachers could track students' learning perspectives and activities more easily by means of educational technology. With the advancements in learning technology, this implies that the combination of game mechanics and digital educational technology will create more diverse learning methods and enable students to enhance their learning effectiveness.

From the above discussion, limitations and suggestions for further research are proposed as follows. This study found that "digital game-based learning" and "gamification" have been widely adopted in recent years. It is suggested that future research can place greater emphasis on the pedagogical features to show more diverse perspectives. However, GBL is widely conducted in different subjects or disciplines; the search scope of the current study was limited to seven major educational journals. Other potential articles may have been omitted from the investigation. It is recommended that future research explore GBL development in various fields, such as business, and search other databases, such as Scopus. One limitation of the present study is that the ranking of the authors based on the number of citations could be affected by their self-citations. To more precisely analyze the author ranking, it is suggested that self-citations be taken into account in future research. From the perspective of publication distribution, it is advised that the technology-supported learning issue be covered in future studies. Moreover, it is suggested that in the future more comprehensive review research can apply content analysis using a coding scheme that recognizes the content of the selected articles related to research method, target group, learner performance, and learner affect.

Compared to previous literature reviews on GBL, articles were retrieved and analyzed in the current study to provide a more detailed bibliometric analysis of the literature and to visualize the GBL trends. This work significantly contributes to the bibliometric analysis of the research method adopted, the publication countries involved, the prolific and influential authors, the number of publications on DGBL and NDGTLC, and the most used keywords identified. The possible research trends and issues were proposed to serve as a reference for scholars, educators, or research institutions making decisions about the development and application of games for learning. From the review results and the discussion, the findings of the current study provide a useful reference in GBL-related fields for researchers as a meaningful direction for future studies.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] A. McFarlane, A. Sparrowhawk, Y. Heald, others, Report on the educational use of games, TEEM (Teachers evaluating educational multimedia), Cambridge, 2002.
[2] M. Qian, K.R. Clark, Game-based Learning and 21st century skills: A review of recent research, Comput. Human Behav. 63 (2016) 50–58.
[3] N.Naik, A comparative evaluation of game-based learning: Digital or non-digital games?, in: Eur. Conf. Games Based Learn., 2014: p. 437.
[4] C.-M. Hung, I. Huang, G.-J. Hwang, Effects of digital game-based learning on students' self-efficacy, motivation, anxiety, and achievements in learning mathematics, J. Comput. Educ. 1 (2-3) (2014) 151–166.
[5] H.Y. Sung, G.J. Hwang, A collaborative game-based learning approach to improving students' learning performance in science courses, Comput. Educ. 63 (2013) 43–51, https://doi.org/10.1016/j.compedu.2012.11.019.
[6] M. Papastergiou, Digital game-based learning in high school computer science education: Impact on educational effectiveness and student motivation, Comput. Educ. 52 (2009) 1–12.
[7] S.J. Franciosi, The effect of computer game-based learning on FL vocabulary transferability, J. Educ. Technol. Soc. 20 (2017) 123–133.
[8] J. Carenys, S. Moya, Digital game-based learning in accounting and business education, Account. Educ. 25 (6) (2016) 598–651.
[9] T.J. Brigham, An introduction to gamification: adding game elements for engagement, Med. Ref. Serv. Q. 34 (4) (2015) 471–480.
[10] G.-J. Hwang, S.-C. Chang, P.-Y. Chen, X.-Y. Chen, Effects of integrating an active learning-promoting mechanism into location-based real-world learning environments on students' learning performances and behaviors, Educ. Technol. Res. Dev. 66 (2) (2018) 451–474.
[11] J. Hamari, D.J. Shernoff, E. Rowe, B. Coller, J. Asbell-Clarke, T. Edwards, Challenging games help students learn: An empirical study on engagement, flow and immersion in game-based learning, Comput. Human Behav. 54 (2016) 170–179.
[12] Q.-F. Yang, S.-C. Chang, G.-J. Hwang, D. Zou, Balancing cognitive complexity and gaming level: Effects of a cognitive complexity-based competition game on EFL students' English vocabulary learning performance, anxiety and behaviors, Comput. Educ. 148 (2020), 103808.
[13] J.C. Burguillo, Using game theory and competition-based learning to stimulate student motivation and performance, Comput. Educ. 55 (2) (2010) 566–575.
[14] S.Y. Chen, Y.-M. Chang, The impacts of real competition and virtual competition in digital game-based learning, Comput. Human Behav. 104 (2020), 106171.
[15] M. Taub, R. Sawyer, A. Smith, J. Rowe, R. Azevedo, J. Lester, The agency effect: The impact of student agency on learning, emotions, and problem-solving behaviors in a game-based learning environment, Comput. Educ. 147 (2020), 103781.

[16] M.I. Cicchino, Using game-based learning to foster critical thinking in student discourse, Interdiscip. J. Probl. Learn. 9 (2) (2015), https://doi.org/10.7771/1541-5015.1481.
[17] S.Deterding, M.Sicart, L.Nacke, K.O'Hara, D.Dixon, Gamification. using game-design elements in non-gaming contexts, in: CHI'11 Ext. Abstr. Hum. Factors Comput. Syst., 2011: pp. 2425–2428.
[18] G. Petri, C.G.vonWangenheim, How to evaluate educational games: a systematic, J. Univers. Comput. Sci. 22 (2016) 992–1021.
[19] S. Vandercruysse, M. Vandewaetere, F. Cornillie, G. Clarebout, Competition and students' perceptions in a game-based language learning environment, Educ. Technol. Res. Dev. 61 (6) (2013) 927–950.
[20] J.C. Yang, M.Y.D. Lin, S.Y. Chen, Effects of anxiety levels on learning performance and gaming performance in digital game-based learning, J. Comput. Assist. Learn. 34 (3) (2018) 324–334.
[21] F. Gao, L. Li, Y. Sun, A systematic review of mobile game-based learning in STEM education, Educ. Technol. Res. Dev. 68 (4) (2020) 1791–1827.
[22] C.-Y.Chang, G.-J.Hwang, Trends in digital game-based learning in the mobile era: a systematic review of journal publications from 2007 to 2016, Int. J. Mob. Learn. Organ. 13 (2019) 68–90.
[23] Hsiu-Ting Hung, Jie Chi Yang, Gwo-Jen Hwang, Hui-Chun Chu, Chun-Chieh Wang, A scoping review of research on digital game-based language learning, Comput. Educ. 126 (2018) 89–104.
[24] Omid Noroozi, Hojjat Dehghanzadeh, Ebrahim Talaee, A Systematic Review on the Impacts of Game-Based Learning on Argumentation Skills, Entertain. Comput. 35 (2020) 100369, https://doi.org/10.1016/j.entcom.2020.100369.
[25] R.M. Yilmaz, F.B. Topu, A. Takkaç Tulgar, An examination of the studies on foreign language teaching in pre-school education: a bibliometric mapping analysis, Comput. Assist. Lang. Learn. (2019) 1–24.
[26] Umit Tokac, Elena Novak, Christopher G. Thompson, Effects of game-based learning on students' mathematics achievement: A meta-analysis, J. Comput. Assist. Learn. 35 (3) (2019) 407–420.
[27] Francesco Crocco, Kathleen Offenholley, Carlos Hernandez, A proof-of-concept study of game-based learning in higher education, Simul. Gaming. 47 (4) (2016) 403–422.
[28] Monica Nour, Sin Hang Yeung, Stephanie Partridge, Margaret Allman-Farinelli, A narrative review of social media and game-based nutrition interventions targeted at young adults, J. Acad. Nutr. Diet. 117 (5) (2017) 735–752.e10.
[29] G.-J.Hwang, P.-H.Wu, Advancements and trends in digital game-based learning research: a review of publications in selected journals from 2001 to 2010, Br. J. Educ. Technol. 43 (2012) E6–E10.
[30] N. Bado, Game-based learning pedagogy: a review of the literature, Interact. Learn. Environ. 1–13 (2019).
[31] Y.-C.Hsu, H.N.J.Ho, C.-C.Tsai, G.-J.Hwang, H.-C.Chu, C.-Y.Wang, N.-S.Chen, Research trends in technology-based learning from 2000 to 2009: A content analysis of publications in selected journals, J. Educ. Technol. Soc. 15 (2012) 354–370.
[32] Tim N. Höffler, Detlev Leutner, Instructional animation versus static pictures: A meta-analysis, Learn. Instr. 17 (6) (2007) 722–738.
[33] G.-J.Hwang, C.-C.Tsai, Research trends in mobile and ubiquitous learning: A review of publications in selected journals from 2001 to 2010, Br. J. Educ. Technol. 42 (2011) E65–E70.
[34] Göran Svensson, SSCI and its impact factors: A "prisoner's dilemma"? Eur. J. Mark. 44 (1/2) (2010) 23–33.
[35] Azita Iliya Abdul Jabbar, Patrick Felicia, Gameplay engagement and learning in game-based learning: A systematic review, Rev. Educ. Res. 85 (4) (2015) 740–779.
[36] Fengfeng Ke, Designing and integrating purposeful learning in game play: A systematic review, Educ. Technol. Res. Dev. 64 (2) (2016) 219–244.
[37] J. Wishart, Cognitive factors related to user involvement with computers and their effects upon learning from an educational computer game, Comput. Assist. Learn., Elsevier (1990) 145–150.
[38] H.Y. Sung, G.J. Hwang, Y.F. Yen, Development of a contextual decision-making game for improving students' learning performance in a health education course, Comput. Educ. 82 (2015) 179–190, https://doi.org/10.1016/j.compedu.2014.11.012.
[39] G.J. Hwang, L.H. Yang, S.Y. Wang, A concept map-embedded educational computer game for improving students' learning performance in natural science courses, Comput. Educ. 69 (2013) 121–130, https://doi.org/10.1016/j.compedu.2013.07.008.
[40] J.-C. Hong, C.-L. Cheng, M.-Y. Hwang, C.-K. Lee, H.-Y. Chang, Assessing the educational values of digital games, J. Comput. Assist. Learn. 25 (2009) 423–437, https://doi.org/10.1111/j.1365-2729.2009.00319.x.
[41] Jon-Chao Hong, Ming-Yueh Hwang, Kai-Hsin Tai, Pei-Chun Lin, Self-efficacy relevant to competitive anxiety and gameplay interest in the one-on-one competition setting, Educ. Technol. Res. Dev. 63 (5) (2015) 791–807, https://doi.org/10.1007/s11423-015-9389-2.
[42] Jon-Chao Hong, Chih-Min Tsai, Ya-Jiuan Ho, Ming-Yueh Hwang, Ching-Ji Wu, A comparative study of the learning effectiveness of a blended and embodied interactive video game for kindergarten students, Interact. Learn. Environ. 21 (1) (2013) 39–53, https://doi.org/10.1080/10494820.2010.542760.
[43] Magdalena C. Struwig, Adriana A. Beylefeld, Georgina Joubert, Learning medical microbiology and infectious diseases by means of a board game: Can it work? Innov. Educ. Teach. Int. 51 (4) (2014) 389–399.
[44] K.F. Hew, B. Huang, K.W.S. Chu, D.K.W. Chiu, Engaging Asian students through game mechanics: Findings from two experiment studies, Comput. Educ. 92 (2016) 221–236.
[45] Nitin Naik, The use of GBL to teach mathematics in higher education, Innov. Educ. Teach. Int. 54 (3) (2017) 238–246.
[46] W. Huang, J.C. Ho, Improving moral reasoning among college students: a game-based learning approach, Interact. Learn. Environ. 26 (2018) 583–596.
[47] Dolors Gil-Doménech, Jasmina Berbegal-Mirabent, Stimulating students' engagement in mathematics courses in non-STEM academic programmes: A game-based learning, Innov. Educ. Teach. Int. 56 (1) (2019) 57–65.
[48] S. Cai, E. Liu, Y. Yang, J.-C. Liang, Tablet-based AR technology: Impacts on students' conceptions and approaches to learning mathematics according to their self-efficacy, Br. J. Educ. Technol. 50 (2019) 248–263.
[49] T.J. Dunn, M. Kennedy, Technology Enhanced Learning in higher education; motivations, engagement and academic achievement, Comput. Educ. 137 (2019) 104–113.
[50] Chin-Chung Tsai, Nian-Shing Chen, Gwo-Dong Chen, The current status and future of e-learning in Taiwan, Innov. Educ. Teach. Int. 47 (1) (2010) 5–7.
[51] R.B. Kozma, ICT, education transformation, and economic development: An analysis of the US national educational technology plan, E-Learning Digit. Media. 8 (2011) 106–120.
[52] X. Chen, G. Yu, G. Cheng, T. Hao, Research topics, author profiles, and collaboration networks in the top-ranked journal on educational technology over the past 40 years: a bibliometric analysis, J. Comput. Educ. 6 (2019) 563–585.
[53] M.D. Hanus, J. Fox, Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance, Comput. Educ. 80 (2015) 152–161.
[54] Chuen-Tsai Sun, Li-Xian Chen, Hsiu-Mei Chu, Associations among scaffold presentation, reward mechanisms and problem-solving behaviors in game play, Comput. Educ. 119 (2018) 95–111.
[55] Jan L. Plass, Bruce D. Homer, Charles K. Kinzer, Foundations of game-based learning, Educ. Psychol. 50 (4) (2015) 258–283.
[56] Andrew Emerson, Elizabeth B. Cloude, Roger Azevedo, James Lester, Multimodal learning analytics for game-based learning, Br. J. Educ. Technol. 51 (5) (2020) 1505–1526.
[57] F. Ke, K. Xie, Y. Xie, Game-based learning engagement: A theory-and data-driven exploration, Br. J. Educ. Technol. 47 (2016) 1183–1201.
[58] Heesung Kim, Fengfeng Ke, Effects of game-based learning in an OpenSim-supported virtual environment on mathematical performance, Interact. Learn. Environ. 25 (4) (2017) 543–557.
[59] Gwo-Jen Hwang, Po-Han Wu, Chi-Chang Chen, An online game approach for improving students' learning performance in web-based problem-solving activities, Comput. Educ. 59 (4) (2012) 1246–1256.
[60] Chia-Jung Wu, Gwo-Dong Chen, Chi-Wen Huang, Using digital board games for genuine communication in EFL classrooms, Educ. Technol. Res. Dev. 62 (2) (2014) 209–226.
[61] Tim Barnett, Allison W Pearson, Rodney Pearson, Franz W Kellermanns, Five-factor model personality traits as predictors of perceived and actual usage of technology, Eur. J. Inf. Syst. 24 (4) (2015) 374–390.