

Review

Study Trends and Core Content Trends of Research on Enhancing Computational Thinking: An Incorporated Bibliometric and Content Analysis Based on the Scopus Database

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Abstract: Over the last decade, research on evolving computational thinking (CT) has garnered heightened attention. Assessing the publication tendencies and nucleus contents of investigations on progressing CT to direct future research initiatives, develop policies, and integrate them into instructional materials is timely and exceedingly essential in education. Therefore, this research reviewed publications on progressing CT to identify research trends and core contents published in the Scopus database from 2008 to May 2022. For this reason, this study applied bibliometric and content analysis to 132 selected publications. After examining bibliometrics, the findings indicate a steady increase in publications related to game-based learning (GBL) and CT, reaching a peak in 2021, with the United States emerging as the most prolific contributor in terms of authors, institutions, and countries). The leading country in citations is primarily China. The document that received the most citations is Hsu's 2018 paper on "Computers and Education". Analysis of keywords and themes reveals core content tendencies, emphasizing teaching methods and attitudes aimed at improving CT via GBL. These results offer valuable insights for researchers and educators to inform their future work. However, future studies may benefit from including other databases such as Web of Science (WoS) and PubMed, employing alternative bibliometric software like VOSviewer or CiteSpace, as well as collecting data from June 2022.

Keywords: computational thinking; bibliometric analysis; game-based learning; content analysis; content trend



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1. Introduction

CT has attracted the interest of educational scholars and practitioners in recent years as it has emerged as a vital ability [1] for the twenty-first century [2]. Others emphasize CT as a cognitive process, while some experts describe it as a [3] problem-solving strategy [4]. For computer science (CS) and all sciences, the acquisition of CT is fundamental [5]. Tsarava [6] mentioned that Wing also emphasized the importance of CT skills [7] for everyone and not only programmers and computer scientists [8]. Wing determined CT [9] as a method [10] for solving problems [11] that involve conceptualizing, creating abstractions [12], and designing systems [13]. It is similar to logical thinking [14] and necessitates understanding basic computing concepts [15].

According to a 2012 National Research Council (NRC) report, given the critical role that CT [16] plays in the twenty-first century, educators should help students understand CT [17] by incorporating its content into existing curricula [18] in schools across the globe [19]. The International Society of Education Technology urges teachers to teach and integrate these abilities into the curriculum [20] to equip students of all ages with problem-solving skills for the real world [9]. In Wing's opinion, everyone can solve problems with CT skills with ideas

from CS [2]. Utilizing CT skills, students can create solutions for complicated systems [21], and teachers can impart knowledge of the systems. For the management of information, solving problems, and understanding human behavior, CT skills must be developed [22]. The literature has given different definitions to CT, so it is arguable what universal abilities and skills comprise its development and how these should be incorporated into educational content [9]. In addition, significant research has been conducted to determine the CT-related skills, strategies, and tools that can support students' academic progress. Thus, the question of how to improve K–12 pupils' CT is receiving more attention [23].

Governments and non-governmental organizations (NGOs) have launched numerous programs and educational environments to assist the development of CT abilities as its popularity grows [24]. Notably, these have included a variety of kid- and teen-oriented computer-based, user-friendly, game-based platforms [24]. Because digital games are engaging and appealing to an extensive population of individuals, GBL has been suggested as one instructional framework for learning programming [25] that has been demonstrated to benefit students [9,26].

Due to technological advancements [27], digital GBL research [28] has recently garnered increased attention [29]. GBL research and application in education have exploded in the last ten years. In a learning environment known as GBL, knowledge and skills are incorporated into games so that students can learn while taking on challenges that require problem-solving [30] and competition [31]. A prior study built an application for virtual reality immersion with mini-games and an expedition to improve learner motivation [32], engagement, and immersive experience. Furthermore, students acquired knowledge to enhance their problem-solving abilities [33]. Some authors have asserted in recent years that teaching programming to children can help them learn and develop CT [34,35].

According to previous findings, students' CT skills can be improved by using programming approaches [36]. This method [2] has been positively linked to improving the student's cognitive abilities, self-management problem-solving, communication, collaboration, and critical thinking. In the context of a GBL setting, the study revealed that the most persistent learners demonstrated high levels of patience as they persistently sought the optimal solution across various themes [24]. Teachers can use computer gaming techniques to promote CT in elementary school children. These strategies not only help students develop their CT skills [37] and conceptual understanding [38] but also help students have less advanced prior learning attitudes and knowledge [39]. CT was not only a distinct discipline or field; it was also applicable to several other areas, particularly computer science and programming. Many nations have included courses about CT in K–12 curricula to develop students' programming, digital, and CT competencies. Previous results demonstrated that students' CT concerning conceptual skills and knowledge considerably improved after playing the adaptive computer game in education. Additionally, students who played the adaptive computer game had noticeably greater interest levels, happiness, acceptance, and flow state of technology in CT learning [38]. The advancement of computer curriculum and CT skills can be supported effectively by video game making in science material [40]. Previous research demonstrated [41] the effectiveness of learning CT via games [26] to foster students' motivation, teamwork, perseverance, abstraction, and creativity [16].

The above-mentioned evidence demonstrates that the GBL strategy and the students' CT skills are very significant because of their high effectiveness in educating students. The acquisition of CT skills [42] enhances students' problem-solving abilities [2], and GBL has been proposed as an effective instructional approach for enhancing CT skills [26,43]. Hence, it is crucial to discern trends via the analysis of literature aimed at enhancing CT skills in order to pinpoint the nation and paper that have made the most substantial contributions in identifying key themes, diverse keywords, and primary documents within each cluster, the interconnected network of author documents, and central content areas.

This study conducts content and bibliometric analysis with R programming [44] to analyze CT publications from 2008 to May 2022. The study adds to the body of literature in the ensuing facets: (i) These identified trends and networks serve as valuable resources

for researchers to search for the CT and GBL fields. The results serve as references, aiding researchers in understanding the current state of research, selecting research topics, determining suitable publication outlets, and providing guidance for future investigations. Collaboration with scholars from highly cited papers or countries is encouraged. (ii) Additionally, the findings are essential for administrators in formulating policies to support teachers and students, selecting research topics and trends for participation, and fostering international cooperation via research and exchange programs. Administrators can identify opportunities for development and training to assist instructors in integrating these trends into teaching practices. (iii) Furthermore, recognizing these trends assists instructors in creating dynamic and productive learning environments to prepare students for future challenges. Adaptation of teaching approaches allows for the seamless integration of these trends into the curriculum. The research also helps instructors design curricula that facilitate students' access to essential research and develop research skills. Instructors can identify related concepts and connections to integrate into lessons. In light of this, the main research objectives (RO) are listed as follows:

1. RO1. Publication trends of CT and GBL as factors to influence student education;
2. RO2. The most cited countries and the most globally cited documents;
3. RO3. The co-occurrence network and co-citation network.

In addition, big and time-changing data presents a challenge in detailed, specific, and accurate analysis to recognize trends in the acquisition of CT knowledge. It is very crucial to have a suitable method to perform this analysis. Bibliometric analysis is an appropriate choice in this case because some researchers claim the advantages of this analysis. As an illustration, Aria and Cuccurrulo [45] asserted that bibliometric analysis can bring about a transparent, systematic, and reproducible evaluation procedure. In contrast to other methods, bibliometrics offers more impartial and trustworthy evaluations. Bibliometrics is helpful in the context of the enormous amount of conceptual advancements, new information, and data. Unlike manually coding text-based data sources and customary content-based analysis, bibliometric analysis has distinctive aspects. The efficiency of implementing manual technology is typically constrained by the ongoing growth of literary data with the spread of "big data", while bibliometric analysis is particularly ideal for dealing with a large-scale dataset. Furthermore, since bibliometric analysis is predominantly quantitative-based [46], its findings are typically generated more objectively and reliably than those obtained via content analysis research methods, which often rely on prioritizing conceptual categories [47]. This analysis [48] provides advantages over experimentally based research approaches in terms of the quantity of data acquired and a more objective examination, allowing for the discovery of novel research patterns and topics. Also, this analysis was chosen because of its capacity for storing comprehensive data and its potential for making it freely accessible to academics.

Moreover, researchers used the bibliometric method to analyze trends and development in education, almost on GBL and rarely focusing on CT. For example, in a previous study, GBL related to distant learning was analyzed using bibliometric analytic techniques [49]. Hwang and Chen [31] conducted a comprehensive review and bibliometric analysis of the published papers to emphasize the applications of GBL and its tendencies.

The previous authors [50] utilized bibliometrics, text mining, and social network analysis to provide meaningful, current data to illustrate the evolution of the issue and the state of research at this time. In the bibliometric analysis of trends, Chen et al. 2022 [29] analyzed papers on GBL in mathematics education and science published from 1991 to 2020. The previous authors [51] investigated bibliometric data from papers about determining research trends from 2013 to 2016. The bibliometric analysis [48] of publications on STEM education games published in conference proceedings and journals between 2010 and 2020 is presented. In terms of CT, the previous study employed the bibliometric analysis approach [52] to examine changes in study trends related to CT over the past twelve years.

Additionally, raising CT skills on GBL approaches has a noteworthy impact on the existing educational system. In recent years, bibliometric analysis has been used in research

on GBL or CT skills. However, using this analysis of documents on boosting CT via GBL is a gap in research. This study applies bibliometric and content analysis in the literature to find publication and content trends of CT improvement on GBL in education. The research utilizes data archived in the Scopus database, ensuring unlimited access for exploration. Section 2 of the study details the specific research procedure and the bibliometric methodology employed. Following this, Section 3 delves into the analysis of results, followed by a discussion and conclusion in Section 4. The final section of the research concludes by addressing the limitations of the employed methodology and recommendations for future work.

2. Materials and Methods

For data collection, this study utilized Elsevier’s Scopus database, which integrates meticulously curated citations and abstract databases containing extensive academic literature across various disciplines [53]. Scopus boasts a substantial collection of peer-reviewed publications, including conference proceedings, journals, and books [54]. The bibliometric analysis provides a static representation of the field at a given point in time; the field growth over time can be tracked by dividing the timeframe into multiple periods [45,50]. The main emphasis of this study’s methodology was the bibliometric analysis, which was reviewed in [55]. Bibliometric analysis can offer a quantitative evaluation [48] of a product of science in a particular field of research over a specific period. The investigation covered factors such as trends in publications and citations, prolific writers, journals, geography, collaboration, and the development of research themes [31,47,56]. Via the application of bibliometric analysis, this research can be evaluated using quantitative and qualitative methods, with parameter and theme analysis being the respective focuses of bibliometric studies [56]. The research procedure comprises two steps: data collection and data analysis, as illustrated in Figure 1. This figure demonstrates the specific activities undertaken in each step.

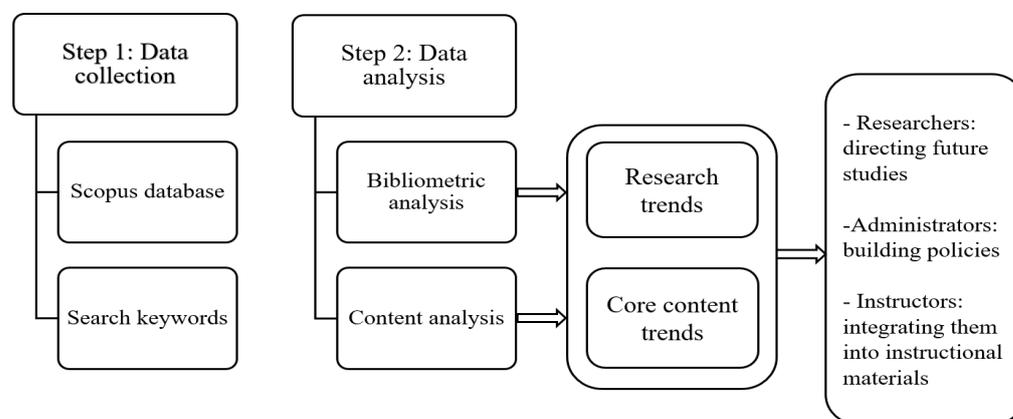


Figure 1. Steps of bibliometric and content analysis.

2.1. Step 1: Data Collection

The bibliometric analysis relies on data sourced from Scopus, which is renowned for its comprehensive coverage of scientific outputs relevant to this investigation. To conduct the necessary data collection, the search terms “game-based learning” and “computational thinking” were utilized in the Scopus interface, employing binary operators such as “AND” and restricting the search timeframe up to May 2022 with the language set to “English”. Protocols were applied to ensure consistency and accuracy in database querying. The publications included in this study encompass book chapters, journal articles, and conference proceedings. According to Chand Bhatt [56], book chapters provide a theoretical foundation for the fields of education in CT and GBL, while conference papers introduce new ideas for education research. The initial search yielded 4029 publications discussing

CT and 5927 papers discussing GBL in education. After combining the two keywords using the “AND” operator, 132 publications were obtained, as shown in Table 1. The BibTeX method was employed to download the full text of each paper for further analysis.

Table 1. The keyword selection technique of the study.

Search Keywords	Result	Combination #1 AND #2
“computational thinking”	4029	132
“game-based learning”	5927	

2.2. Step 2: Data Analysis

2.2.1. Bibliometric Analysis

The bib file was downloaded to be used for data analysis by applying Biblioshiny from R-Studio with version 4.1.1 on 10 August 2021. Before uploading the data to Biblioshiny, the data were merged into a single bib file for using R-Studio, a development environment integrated with the R language [57]. Following this, the shiny application Biblioshiny, which provides a web interface for the bibliometric R-package [55], was utilized for data analysis. In the Biblioshiny interface, the Scopus file containing raw data was imported for analysis. This process resulted in the acquisition of the dataset, sources, authors, documents, and conceptual structure required for conducting descriptive and network analyses.

2.2.2. Content Analysis

The second technique employed in this study involves content analysis. The main aim of content evaluation is to categorize scientific findings conceptually and categorically to uncover underlying dynamics [58]. Previous research has suggested that employing content analysis helps in uncovering significant trends and crucial insights that may otherwise remain undiscovered [59]. Consequently, following the bibliometric method, all selected publications are analyzed to identify the trends of core contents.

3. Results

3.1. Bibliometric Analysis

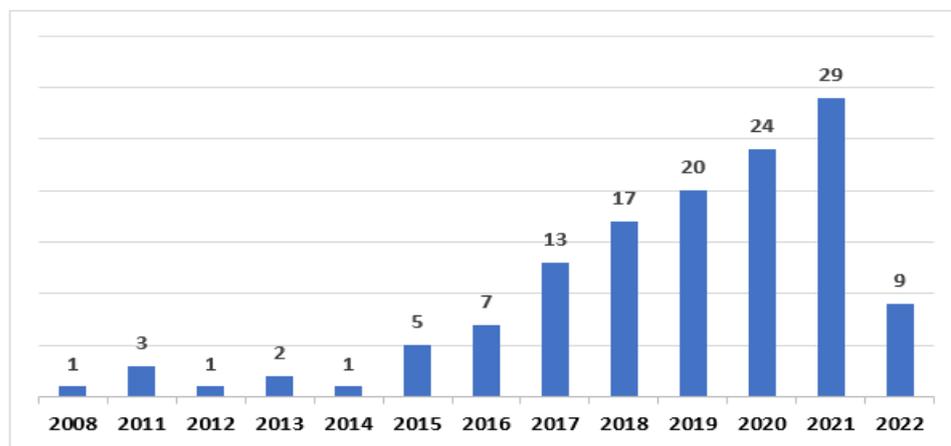
3.1.1. Analysis of Trends

Data information is obtained after employing bibliometric analysis. Table 2 provides the distribution of the vital details of data collection. Documents with the keywords “computational thinking” and “game-based learning” were identified from 2008 to 2022, including 78 sources, 132 papers as book chapters, articles, conference papers, and 4320 references. A variety of document types were identified, with conference papers totaling the highest number at 84, followed by articles at 42. Conference reviews constituted the lowest count with 4, and book chapters were the least common with only 1. The document contents encompassed a total of 534 keywords, supplemented by 337 author’s keywords. Among the document authors, a total of 327 were identified, with 14 authors of documents single-authored and 313 authors of documents multi-authored.

Publication trends are one of the most significant indicators in a field or sector [52]. A total of 132 papers published from 2008 to 31 May 2022 were identified. Figure 2 illustrates the development of scientific production trends using the keywords “CT” and “GBL” over the years. The publication trend exhibits slight oscillations within three documents from 2008 to 2014. However, there was a significant increase in documents from one paper in 2014 to five in 2015 and from 7 in 2016 to 13 in 2017. Subsequently, the number of published documents stabilized at around four each year from 2017 to 2021, with a notable nine papers in 2022. It is important to note that data for 2022 are collected from the first five months of the year. Based on these findings, publications focusing on CT and GBL have garnered interest from researchers between 2008 and 2022. The publication trend has shown a consistent increase, reaching its peak in 2021.

Table 2. Principal data-related information.

Description	Results
Timespan	2008:2022
Sources (Books, Journals, etc.)	78
Publications	132
Average years from publication	3.26
The mean quantity of citations found in every document	7.386
Annual average of citations for each document	1.476
References	4320
Article	43
Chapter of a book	1
Conference document	84
Review of the conference	4
Plus keywords	534
Author's Keywords	337
Authors	327
Authors of single-authored documents	14
Authors of multi-authored documents	313
Documents for each author	0.404
Writers for each document	2.48
Co-authors for each document	3.52
Index of collaboration	2.75

**Figure 2.** Annual scientific production.

Studies based on CT and GBL show relationships between authors, keywords, and countries. After applying bibliometrics to the top 20 authors, 19 authors, 7 countries, and 13 keywords were identified in a relationship in the research passage. Figure 3 illustrates a plot depicting the relationships among countries, authors, and keywords. Over the 14-year period from 2008 to 2022, three countries emerged as prominent among the seven countries, with many authors using keywords related to CT and GBL in their publications. For instance, the USA leads with nine authors, while Israel and Spain follow as the second countries, each with five authors.

During this period, the authors used a total of 13 keywords in their published documents. "CT" and "GBL" were the most commonly used keywords employed by 19 and 18 authors, respectively, in their publications. Additionally, "middle school" was utilized by 11 authors, while "educational games" and "collaboration" were used by six authors each. These findings suggest that the top 19 authors, 13 keywords, and seven countries are interrelated in the context of CT and GBL during the specified period.

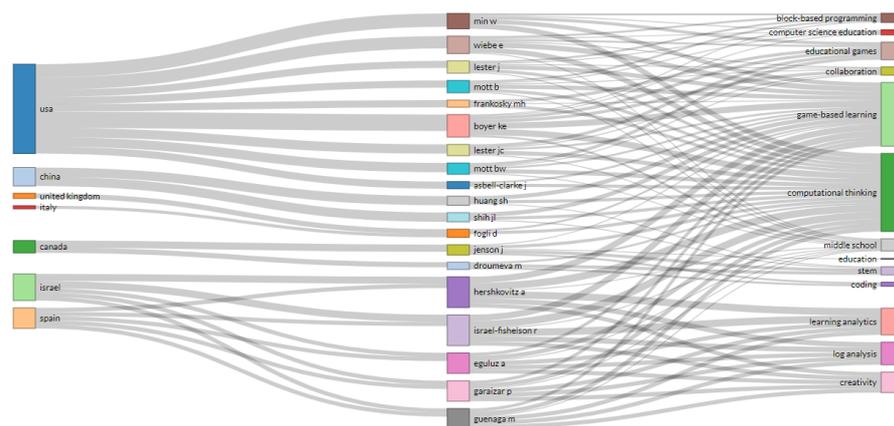


Figure 3. Three fields plot.

Based on the data obtained in the study, the top 20 publications comprising 74 papers related to CT and GBL for educational purposes were identified. Figure 4 illustrates the sources with the highest value during the specified period. Among these sources, a group of journal publications consistently increased the number of published papers. Among them, “*Lecture Notes in Computer Science*” emerged as the leading source with the highest number of published papers, totaling 11. Following closely is “*Conference Proceedings of the European Conference on GBL*” with 10 papers, and the “*ACM International Conference Proceeding Series*” with 9 papers. The group with the lowest number of published papers gradually increased, with “*Advances in Intelligent Systems and Computing*” starting with four papers and progressively increasing to five and six papers for the “*Journal of Educational Computing Research*” and the “*International Conference on CT Knowledge Proceedings*”, respectively. Additionally, during this period, four journal sources had three publications each, seven sources had two publications each, and many sources had only one publication each. These findings indicate that six sources significantly influence the CT and GBL topic. “*Lecture Notes in Computer Science*” stands out as the most influential leading source during the specified period.

After identifying the top 20 contributing authors on CT and GBL topics from the selected data, a total of 90 papers were identified from the beginning of the research to May 2022. Figure 5 illustrates the authors who had the most impact during this period. The top three authors emerged as the most prominent, with publications related to CT and GBL. For instance, Boyer K. stood as the most active author with eight published documents. Following closely by authors Hershkovitz A. and Israel-Fishelson R., both have seven publications each. Min W and Wiebe E each have six published documents during this period.

Among the top 20 institutes identified from the selected data, the total number of published papers amounted to 88. Figure 6 illustrates the institutes with the most relevance. The universities ranked in the top four of documents related to CT and GBL published from 2008 to 2022. The most prominent university is North Carolina State University, with 11 published documents. The University of Tübingen follows in second place, albeit with the number of publications decreased, totaling eight during this period. Next in descending order are the University of Florida and Tel Aviv University, each with seven published documents, followed by the University of Salamanca with six.

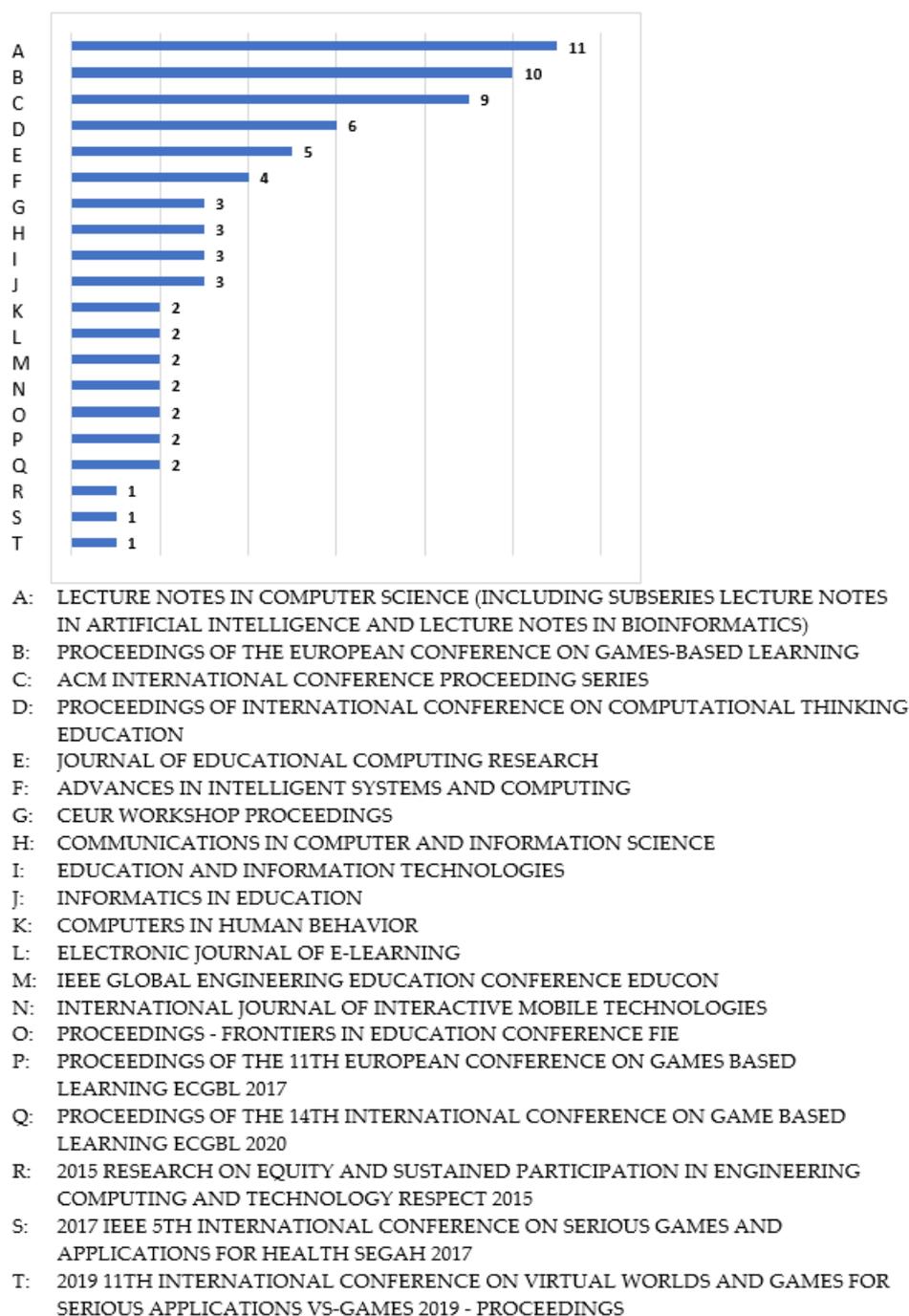


Figure 4. Most relevant sources.

Based on the obtained data, the top 20 countries with contributions to 210 published papers on CT and GBL have ranked. The publications of these countries are presented in Table 3. Active countries in this context refer to those that have contributed significantly to the literature body on CT and GBL by publishing ten or more papers during the specified period. These countries are considered to have made substantial contributions to research in the field, indicating a high level of engagement and productivity in CT and GBL-related research endeavors. Leading the pack with 55 publications is the United States, making it the most active nation. China follows in second place, albeit with a significant gap compared to the USA, with 23 publications. The third-ranking country, Greece, has several publications totaling 18.

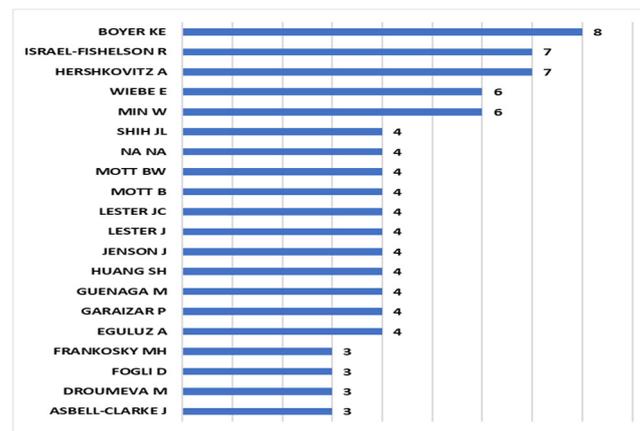


Figure 5. Most relevant authors.

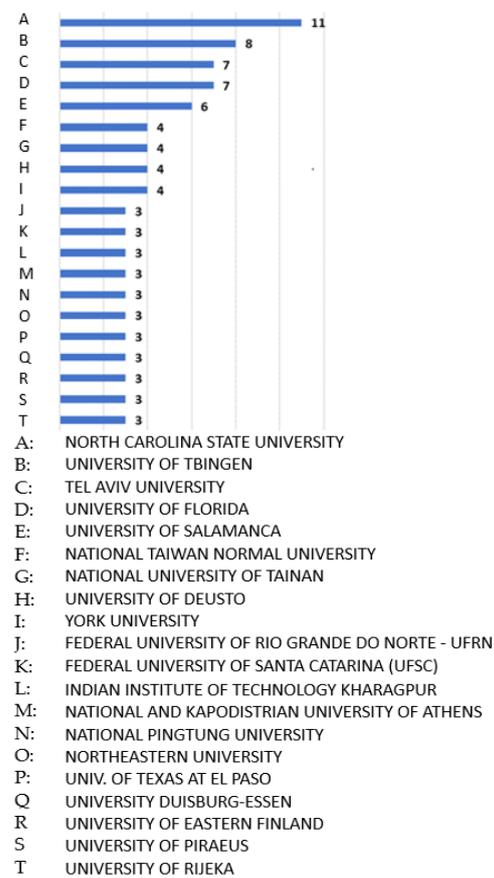


Figure 6. Most relevant institutes.

Table 3. The number of country article publications.

Rank	Country	Publication
1	USA	55
2	China	23
3	Greece	18
4	Germany	16
5	UK	14
6	Brazil	12
7	Spain	11
8	Canada	10
9	Malaysia	10

Table 3. *Cont.*

Rank	Country	Publication
10	Israel	7
11	Croatia	5
12	Finland	5
13	Sweden	5
14	Denmark	4
15	India	3
16	Italy	3
17	Thailand	3
18	Austria	2
19	Poland	2
20	Portugal	2

3.1.2. Citation Analysis of Countries and Documents

Citation Analysis of Countries

The countries with the most citations represent valuable contributions to the education community related to CT and GBL. A ranking of 20 nations based on citation volume is provided in Table 4. The most influential countries in CT and GBL research are from Asia and Europe, particularly Taiwan and Spain. Publication trends from Europe are also widespread. For example, China and Spain lead in citations with 206 and 164, respectively. The United Kingdom (Europe) and the USA (North America) follow closely, with 118 and 80 citations, respectively, ranking third and fourth. However, other European countries such as Greece, Estonia, Germany, Denmark, Poland, and Switzerland are also noteworthy. The number of quality papers on CT and GBL from various countries across continents has advanced, indicating intense global competition in investigations related to CT and GB.

Table 4. Most cited countries.

Rank	Country	Total Citations
1	China	206
2	Spain	164
3	UK	118
4	USA	80
5	Greece	40
6	Israel	40
7	Canada	16
8	Estonia	11
9	South Korea	5
10	Malaysia	3
11	Germany	2
12	Denmark	1
13	Poland	1
14	South Africa	1
15	Switzerland	1

Citation Analysis of Documents

The most cited articles demonstrate high-quality content with research hotspots on CT and GBL, which are attractive to researchers in related areas. The total number of citations of a document represents the value of its contribution to the community. From the given data, twenty published papers have been sorted by citation count using the R language and the Biblioshiny bibliometric program. The documents that have received the most citations worldwide are presented in Table 5. The top three journal articles are cited the most during the specified period.

Table 5. Most globally cited documents.

Paper	Total Citations
Hsu Tc, 2018, Comput Educ	186
Garca-Pealvo Fj, 2018, Comput Hum Behav	119
Kazimoglu C, 2012, Procedia Comput Sci	101
Jenson J, 2016, Electron J E-Learning	36
Kazimoglu C, 2011, International Journal of Game-Based Learning	30
Tsarava K, 2017, Proc Eur Conf Games Based Learn, Ecgb	28
Kanaki K, 2018, Educ Inf Technol	27
Akram B, 2018, Proc Int Conf Educ Data Min, Edm	23
Wu Ml, 2011, Lect Notes Comput Sci	22
Hershkovitz A, 2019, Interact Learn Environ	21
Garca-Pealvo Fj, 2018, CT In The Stem Disciplines: Foundations And Research Highlights	21
Min W, 2015, Lect Notes Comput Sci	19
Francisco Jgp, 2016, Acm Int Conf Proc Ser	18
Min W, 2020, Ieee Trans Learn Technol	17
Turchi T, 2019, Multimedia Tools Appl	17
Israel-Fishelson R, 2020, J Educ Comput Res	14
Min W, 2017, Lect Notes Comput Sci	13
Hooshyar D, 2021, J Educ Comput Res	11
Altanis I, 2018, Educ Sci	11
Lin Sy, 2020, Elect Commer Res Appl	10

Table 5 shows evidence that the paper authored by Hsu TC in 2018, published in the journal *Computers & Education*, has received the highest number of citations, totaling 186. Following closely, the paper by García-Peñalvo FJ, published in 2018 in *Computers in Human Behavior*, includes 119 citations. Ranking third is the paper by Kazimoglu C., published in 2012 in *Procedia Computer Science*.

3.1.3. Network Analysis Co-Occurrence Network

In this section, emphasis is placed on analyzing co-occurrence networks using the Biblioshiny bibliometric software with the R language. In terms of selecting keywords, authors can establish connections between different research topics and identify closely related ones. Moreover, the frequency of a keyword can indicate the primary subjects covered in articles within the field [52]. In this paper, the bibliometric method is applied to organize themes into clusters related to CT and GBL. Consequently, the primary themes have emerged from the beginning of the research to the present. Figure 7 shows the co-occurrence network with four clusters containing various nodes based on CT and GBL keywords. Betweenness represents the correlation of a keyword for CT and GBL domains in papers. A higher betweenness value suggests a stronger correlation of the keyword within the documents of a cluster. The number of nodes reflects the diversity of themes in the CT and GBL research field.

From Figure 7, the red network represents cluster 1, comprising 29 nodes forming the primary network. The node “CT” exhibits the highest betweenness at 473.4, followed by “GBL” with a betweenness of 176.8. “Students” comes next with a betweenness of 127.8. Among the top five nodes, “education computing” has the lowest betweenness at 27.3, whereas “computer games” has a higher betweenness at 54.3. This evidence highlights the correlation between keywords such as CT [60], GBL [61], students [62], computer games [63], and others.

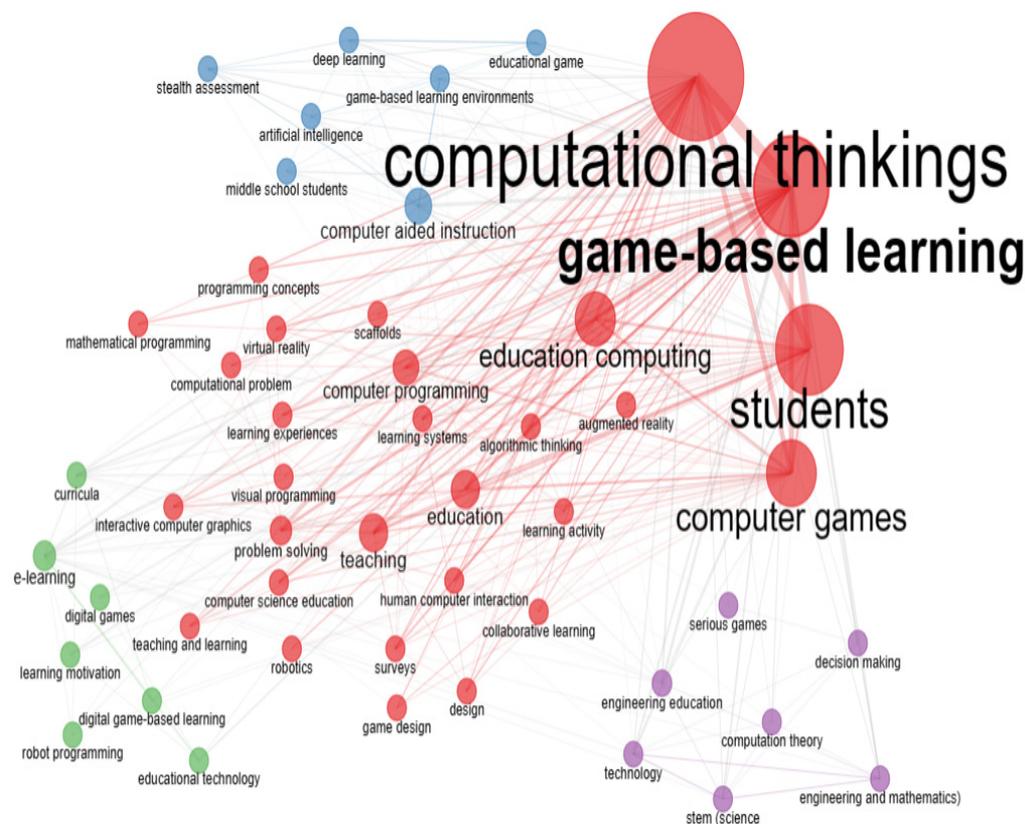


Figure 7. Co-occurrence network.

Cluster two appears as the blue network with seven nodes. The top three nodes with the highest betweenness include “computer-aided instruction” at 5.96, “GBL environments” at 0.51, and “artificial intelligence” at 0.25. This demonstrates the relationship among keywords like computer-aided instruction [24], GBL environments [64], artificial intelligence, educational games [65], and middle school students [66].

Cluster 3 forms a green network with seven nodes. The node “e-learning” has the highest betweenness at 9.5, while nodes such as “curricula” and “educational technology” have lower betweenness at 1.9 and 0.5, respectively. This cluster suggests themes related to e-learning, including curricula, digital games, learning motivation, digital GBL [67], and others.

Cluster 4 emerges a purple network with seven nodes, with three nodes exhibiting the highest betweenness. “Engineering education” leads with a betweenness of 0.9, followed by “technology” at 0.5 and “decision-making” at 0.4. This cluster identifies domains related to engineering education, such as technology [68], decision-making [69], computation theory, serious games [70,71], and others.

Co-Citation Network

Figure 8 illustrates the co-citation network comprising three distinct networks identified after applying the Biblioshiny bibliometric software with the R language. The co-citation network reveals three clusters and 38 documents centered around CT and GBL. In the co-citation network, betweenness is described as the interaction of documents’ authors on themes based on CT and GBL and indicates the most cited author’s documents. A higher betweenness signifies increased interaction among authors’ documents. The nodes in the network represent the number of authors’ documents interacting in the research field based on CT and GBL.

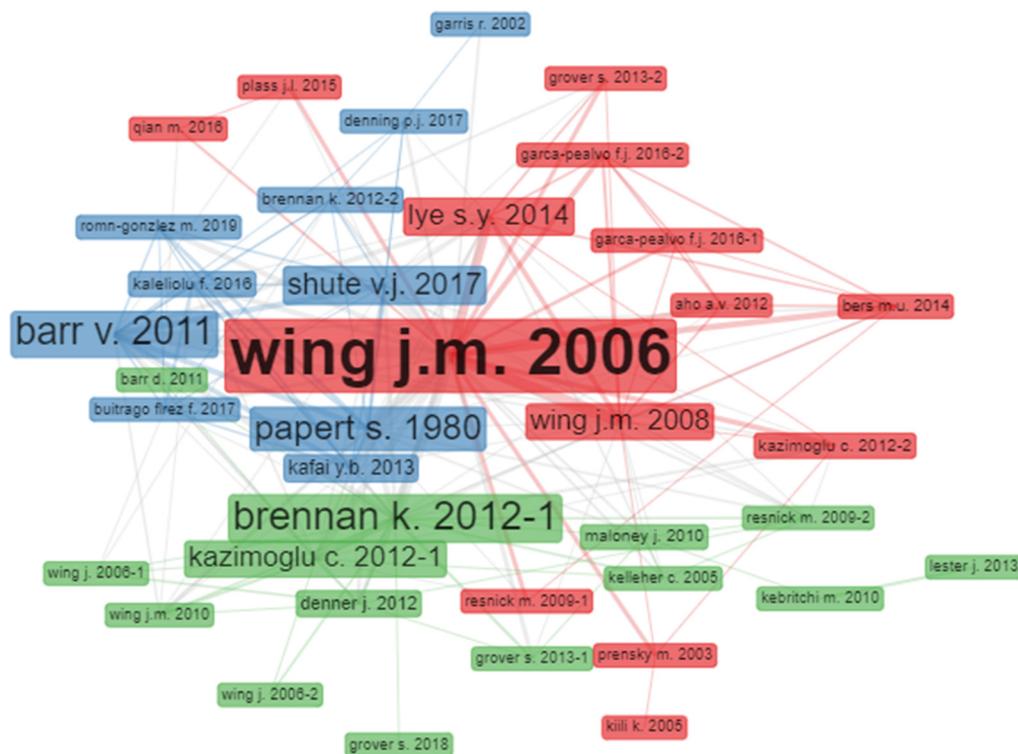


Figure 8. Co-citation network.

The first cluster forms the primary network with the red nodes encompassing 14 documents. The most significant article in this cluster, with a betweenness of 321.9, is based on CT and was explained by Wing [72] who initially introduced the concept as skills and attitudes for learning and application. This article has garnered over 4000 citations. Another article by the same author emphasizes that CT will impact students as they face new academic challenges [73]. Additionally, a paper by Prensky [74] identifies that digital GBL helps children stay motivated in their learning.

The second noticeable cluster is a green network with 14 nodes. The primary documents in this cluster are based on the [75] development of CT via digital games [76] to improve students' performance [77] and attitudes. The document with the highest betweenness in this cluster, at 128.6, revolves around the development of CT via Scratch programming [78]. This paper, authored by Brennan and Resnick, has amassed over 4000 citations. Additionally, Maloney et al. [79] illustrated an independent study facilitated by experimentation, peer collaboration, and creations [80] promoted by the Scratch Programming Language. Furthermore, Kebritchi et al. [81] demonstrated that digital games contribute to motivation [82] and students performance.

An impressive third cluster is blue nodes with ten documents. The co-citation study draws attention to the primary theme of CT in K–12 and teaching programming. In this cluster, Barr and Stephenson [83] identified that the delivery of CT for K–12 is the most significant article, and it necessitates systemic change, teacher involvement, and valuable significant resource creation. More than 4000 citations are included in the paper. It provides a comprehensive explanation of CT, covering aspects such as definition, intervention, curricular evaluation, and learning models [84]. Moreover, it demonstrates how CT skills can be developed via various means, including games, interactive stories [85], and simulations [78].

3.2. Emerging Content Trends

Trends in emerging content are discerned by analyzing documents from the co-occurrence and the co-citation network. These networks, as shown in Figures 7 and 8, reveal the interconnections among key concepts and prominent authors in the CT and GBL

fields. By examining documents, researchers can identify research hotspots and academic interest trends.

The analysis of content within publications based on the co-occurrence network highlights several primary trends across different clusters. In cluster 1, research primarily focuses on CT and GBL, encompassing areas such as teaching and learning tools, teaching and learning activities, teaching approach, GBL assessment framework, and attitudes like engagement, motivation, learning interest, confidence, encouragement [86–99]. Cluster 2 delves into CT, GBL, computer science, and assessment frameworks, particularly emphasizing strategies for teaching CT [99,100]. Cluster 3 researches CT, GBL, digital tools, and teaching strategies, focusing on attitudes such as motivation and engagement [15,101–103]. Cluster 4 explores factors related to CT development, game design, teaching method, attitudes (especially engagement, encouragement, and confidence), GBL, and learning activities [93,104–107]. Overall, the analysis underscores trends in teaching methods, activities in teaching and learning, tools for learning and teaching, frameworks for assessment, and attitudes such as engagement, motivation, encouragement, and confidence across the clusters.

The analysis of main content trends derived from content analysis on studies based on the co-citation network reveals distinct themes across various clusters. In cluster 1, a prevalent trend is the digital game utilization to facilitate learning and teaching CT, which serves to motivate student learning [108]. Cluster 2 predominantly focuses on promoting CT via digital games to enhance attitudes and improve students' learning outcomes [34,109]. Notably, computer games are found to positively impact students' achievement and motivation.

Meanwhile, cluster 3 highlights themes such as CT integration in K-12 education, instructional methods for CT, programming instruction, and the development of CT skills via learning games, interactives, and simulations [78,110–113]. These tendencies in co-citation networks underscore the importance of teaching approaches aimed at enhancing students' achievement and attitudes via GBL [114].

3.3. Sustainable Education in the Future

By integrating games into teaching and fostering students' CT skills, this study aims to provide a valuable resource for researchers, educational policymakers, and instructors, ensuring long-term sustainability.

In terms of teaching students, it is hoped that the findings will positively influence student education with more attention from teachers, education leaders, and researchers on trends of developing students' CT skills via GBL. Additionally, it anticipates that educators will consistently employ creativity and dedication in each teaching session to accomplish educational objectives, including enhancing student engagement [109], motivation [43], attitudes [115], and academic performance [116]. This underscores the importance of integrating educational games into the curriculum to foster the development of CT skills within the context of the technology age [90]. Games help students enhance mental computation skills [117] by acquiring CT skills [118]. The Trachtenberg system, recognized for its rapid mental computation capabilities [119], consists of a set of easily memorized operations facilitating quick arithmetic calculations. These operations entail straightforward algorithms aimed at helping students enhance their CT skills [120]. Therefore, it expects that there are appropriate policies to promote the development of the application of GBL to develop students' CT skills and help students achieve academic performance. This study will be a helpful source to researchers as a springboard for planning upcoming studies. Given the significance of GBL's effectiveness in fostering CT [34], it is anticipated that this teaching strategy will continue to gain traction across various subjects and academic levels, including mathematics, language arts, and science [16] in the foreseeable future [121].

In this research, the most prevalent themes included CT and GBL, along with computer-aided instruction, e-learning, and engineering education. Given the global impact of COVID-19, these themes are particularly pertinent, as they address challenges faced in

the shift to online learning environments. When students engage in GBL to acquire CT skills [26,122] online [123], various challenges arise. However, the integration of CT skill development via GBL offers numerous benefits to learners, including achieving learning objectives, fostering motivation [124], and enhancing problem-solving abilities. Ultimately, this approach cultivates a generation equipped with the skills and knowledge essential for the modern era.

4. Discussion and Conclusions

The bibliometric analysis delves into trends, co-occurrence, and co-citation network patterns sourced from the Scopus database, emphasizing parameter and theme analysis. Out of a pool of 132 publications selected based on two keywords, the study utilizes R-studio in conjunction with Biblioshiny software to facilitate bibliometric analysis. Via this approach, the research objectives are identified, leading to the emergence of valuable insights that can benefit researchers, administrators, and instructors alike.

RO1 focuses on investigating the publication trends influencing student education, particularly in the areas of CT and GBL. Analysis of data spanning from 2008 to May 2022 reveals a noteworthy increase in publications related to these areas, particularly evident in 2021. This upward trend indicates a growing interest [125] in leveraging GBL [29] to enhance CT skills and positively impact student learning. Contributions from regions such as North America (USA), Asia (Israel), and Europe (Spain) have been substantial and are expected to continue expanding. Notably, publications from sources and countries like *"Lecture Notes in Computer Science"* by Springer and the United States, including the most published authors and most published institutes have emerged as vital references for future research. For example, Boyer is the most contributing author with eight papers. The book *"Lecture Notes in Computer Science"* and the author's document, Boyer, are suggested as references for researchers for future studies. Searching for CT and GBL areas to support educators in teaching and learning, this book and this author are highlighted. Institutions like North Carolina State University in the USA have made significant contributions, offering valuable insights for educators and administrators alike. The results hope contributions from the highest publications on CT and GBL, such as developing instructors' professional capacity to improve students' performance, motivation, and engagement. Moreover, it expects to inspire other schools' instructors in their teaching and research to enhance learning communities.

By integrating these trends into teaching strategies and curricula, educators can support instructors via professional development and training and enhance student achievement, engagement, and motivation, fostering a conducive learning environment. This analysis serves as a foundational understanding of the current research landscape in CT and GBL, guiding future educational initiatives and research endeavors.

RO2 focuses on investigating the most cited countries and the most globally cited documents. The evaluation of citation results highlights China as the most cited country, followed by Spain during the study period. This underscores the significant contributions of China and Spain in the field of CT and GBL, attracting attention from researchers worldwide and prompting policymakers to support educational goals such as assisting instructors and brightening up students' achievement. Additionally, the most globally cited document, authored by Hsu in 2018 from Taiwan, focuses on acquiring and instructing CT, particularly via GBL. Hsu et al. focused on issue-based education, learning via projects, GBL in CT activities, collaborative learning, mathematical computing, programming skills training, and the CT performance and viewpoints of the students. This document stands out for its comprehensive exploration of CT development via GBL strategies and teaching tools [126], making it a valuable resource for instructors, policymakers, and researchers alike. Regarding understanding global research trends, researchers can identify impactful topics and potential collaborators, while administrators can facilitate international collaboration and curriculum development.

Instructors can leverage this data to enhance student access to significant research and emphasize the importance of research skills in their teaching. Policymakers can make appropriate policies to accommodate instructors and learners and for researchers who direct their future research.

RO3 focuses on investigating the co-occurrence network and co-citation network analysis of CT and GBL keywords. The co-occurrence analysis conducted in this study revealed the interaction among the most popular keywords, unveiling research hotspots and academic interests [31]. Clusters, representing groups of interconnected keywords, emerged from this analysis, each encapsulating distinct themes within the realm of CT and GBL. Notably, clusters 1, 2, 3, and 4 showcased prominent keywords such as CT and GBL, computer-aided instruction, e-learning, and engineering education, respectively. Cluster 1 exhibited the most diverse range of keywords, totaling 29 interactions, highlighting the breadth of topics explored in the realm of CT and GBL. Research within each cluster focused on distinct themes, including [127] the development of CT skills via GBL [128,129] teaching approaches [130] in cluster 1, assessment frameworks for GBL [131] in cluster 2, various aspects of CT and GBL, along with attitudes like engagement [132] and motivation [103] in cluster 3, and CT-related topics to be interesting in cluster 4. The content analysis of these clusters identified prevalent themes, including GBL evaluation frameworks, teaching strategies, and attitudes like confidence, encouragement, motivation, and [133] engagement. These research trends provide valuable insights for guiding future investigations and curriculum development in educational support. Administrators can leverage these findings to allocate resources effectively, while instructors can integrate relevant concepts into their teaching methodologies to enhance student learning experiences. Researchers can recognize the scope and interconnectedness of different concepts in the field to direct the development of research projects and identify current and emerging trends on CT and GBL to choose pertinent research topics in the future. Ultimately, these instructional approaches aim to equip students with the knowledge and skills necessary for success in today's digital age.

In the co-citation network analysis, clusters represent distinct groupings of scholarly documents and authors to be closely linked based on the frequency of citations between them. Three major clusters were identified in this study, each highlighting specific themes within the realm of CT and GBL research. Cluster 1 focuses on CT skills and their application in computer games [134], emphasizing the role of gaming in fostering learning and skill development. Notably, Wing's work stands as a seminal document in this cluster, highlighting key aspects of CT implementation. Cluster 2 delves into the advancement of CT via digital games, particularly emphasizing its impact on student achievement [40] and attitudes [135]. Brennan and Resnick's research [78] on CT evolution via Scratch programming emerges as a central document within this cluster. Cluster 3 centers around CT in K-12 education [136] and programming instruction. Barr and Stephenson's work serves as a cornerstone document in this cluster, advocating for the integration of CT into K-12 curricula, underscoring the importance of systemic reforms and teacher involvement. These clusters reveal the primary documents within each thematic area and highlight the interconnectedness of influential authors within the CT and GBL domains. By analyzing the content tendencies within these clusters, valuable insights into instructional strategies that enhance student performance and attitude via GBL are uncovered. This information can aid researchers and policymakers in orienting their research efforts and supporting student learning effectively. Additionally, these findings serve as a valuable resource for instructors and researchers seeking relevant materials on CT, GBL, and associated authors, guiding curriculum design and planning for the future.

5. Recommendation for Future Work

The research, conducted via a comprehensive review of the literature on "CT" and "GBL", provides valuable insights and guidance for future researchers. However, it is subject to certain limitations. For instance, it relies solely on research contributions listed in

the Scopus index, potentially overlooking relevant studies from databases like WoS and PubMed. Additionally, while the research employs Biblioshiny bibliometric software with Rstudio programming for analysis, alternative software options such as VOSviewer and CiteSpace could yield different perspectives. Future studies may benefit from exploring these alternative tools to enrich the analysis and broaden the scope of findings. Moreover, this research employed data collection of CT publications from 2008 to May 2022 to analyze the contents and bibliometric with R language. Future research should select data from June 2022.

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