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STEAM Education with Gamification: A Bibliometric Analysis

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Abstract

STEAM education with gamification, a method that integrates game elements into the learning process, has proven to be a powerful tool. It not only encompasses various forms of gamified education but also has the potential to captivate and inspire students, breathing life into the course material. This study aims to present a comprehensive summary of the research carried out in the domain of STEAM education, with a particular emphasis on gamification. The focus will be on analyzing studies published in the past seven years. A meticulous bibliometric analysis was conducted to investigate the patterns in the published literature on STEAM education with gamification from 2017 to 2023. The relevant documents were retrieved by using keywords related to steam and gamification in the title, abstract, and keywords of the documents. Thus, 34 documents were acquired from the Scopus database for bibliometric analysis. The review analyzes the rate of publication growth, identifies the papers with the highest number of citations, determines the primary sources of these articles, evaluates the productivity of authors, examines the leading countries contributing to the field, and identifies the prominent subject areas within the research domain. Thailand has the highest output level in terms of publications and citations, as inferred from the results of our analysis. The Ceur Workshop Proceedings are widely acknowledged as the foremost scholarly resource in their subject. We have identified the most important keywords related to gamified STEAM education by conducting keyword analysis. Factorial Analysis provides a visual summary of the complex relationships between various concepts related to educational technology.

Keywords: steam, steam education, gamification, bibliometric analysis, factorial analysis

1. Introduction

Integrating interactive and gamelike elements into the learning process, such as STEAM education and gamification tactics, effectively engages students in their educational endeavors. Implementing gamification in online education, shown by creating the PhyGame learning system, can enhance student motivation and cultivate a more pleasurable learning atmosphere (Katanosaka et al., 2023). Utilizing the Attention, Relevance, Confidence, and Satisfaction (ARCS) model and the Self-Determination Theory (SDT) in the context of gamification has the potential to enhance students' motivation to participate in the learning process (Katanosaka et al., 2023). Gamification, when applied in education, can alter the intents and behaviors of students, leading to increased engagement and motivation (Baah et al., 2023). Moreover, incorporating gamification design elements, including roles, bots, and experience points, into educational platforms like chat applications can engage students effectively and create a more interactive and stimulating learning environment (Huseinović, 2024). Combining STEAM education and gamification can foster an engaging and stimulating learning environment for pupils. Empirical investigations have shown that the incorporation of STEAM education and the utilization of gamification techniques have resulted in positive results in terms of student motivation, learning, and academic performance (Recabarren et al., 2023; Yıldırım & Şen, 2021; Ochihu, 2022). Research has shown that gamification can enhance student performance and proficiency in academic subjects (Cassel et al., 2019).

Furthermore, it has been demonstrated to enhance involvement and user satisfaction in other domains, such as technical training (Adams & Du Preez, 2022). Moreover, the implementation of gamification in non-honors classes has proven to be remarkably effective. Nevertheless, methodical investigations to evaluate the influence of gamification on educational learning remain needed. Applying STEAM and gamification approaches can lead

to positive results for many groups of students, enhancing their enthusiasm, involvement, and academic performance.

Various research studies have shown that using gamification strategies in STEAM disciplines, especially in programming language classes, has increased student engagement and motivation (Khaleel et al., 2020). Innovative gamification tools such as Mentimeter, Edpuzzle, Kahoot, and Quizizz have actively involved students in online lectures and learning management systems, leading to better concept learning and increased collaboration (Raju et al., 2021). Additionally, an online gamified learning environment has significantly enhanced university students' motivation and engagement in computer essentials courses (Alsadoon, 2023). However, the impact of gamification on student learning, behavior, and engagement can vary based on individual personality factors (Smiderle et al., 2020). Although systematic studies assessing the impact of gamification on learning in Computer Science courses still need to be completed, empirical studies are underway to evaluate the effect of different combinations of game elements on student motivation and engagement (Cassel et al., 2019).

Several factors have been identified as influential in determining the effectiveness of gamification in STEAM education. These factors encompass motivation, engagement, perceived utility, game design, student perspective, game forms, Internet platforms, existing educational games, game types, gamification applications, pedagogical agents, programming types, and schooling levels (Limantara et al., 2022; Astashova et al., 2023; Zhan et al., 2022). Research has demonstrated that the implementation of gamification in educational settings has been associated with the facilitation of behavioral, cognitive, and emotional engagement. However, it is important to note that the efficacy of gamification may diminish as time progresses (Jiang, 2016). The influence of gamification on educational outcomes exhibits a varied pattern, as certain investigations reveal favorable impacts on scholastic accomplishments and motivation (López Serentill et al., 2021), While other researchers have reported diverse outcomes. The utilization of gamification as a competitive mechanism has been observed to exert a substantial influence on students' cognitive abilities and motivational levels. The efficacy of gamification is found to be higher in the context of textbased programming as opposed to graphical programming. These findings underscore the need for further research to fully understand the impact of gamification. Overall, these factors and findings contribute to a better understanding of the effectiveness of gamification in STEAM education.

Bibliometrics is the quantitative examination and analysis of scientific publications and patterns within a specific academic domain (Saputro et al., 2023). The process entails examining and evaluating various scholarly sources, such as articles, books, and other published materials, to assess the contributions made by individuals or groups of researchers, organizations, and countries (Rodríguez, 2006). Bibliometrics provides insights into publications' growth and development, distribution, variable keywords, and author collaboration (Greener, 2022). It helps map relationships between concepts, identify research directions and trends, and map the state of the art in a field (Mulet-Forteza et al., 2022). Through the examination of citations and collaborations, Bibliometrics can discern fundamental research, geographical hubs of expertise, and prominent authors (Tamtam et al., 2023). It is a valuable tool for evaluating research, making editorial decisions, and providing a basis for strategic and economic intelligence activities. Overall, bibliometrics is a method that allows for the analysis of the evolution, current state, and future trends in a scientific field through the analysis of publications and their characteristics.

Because of the importance that the STEAM education with gamification has taken, the research objectives for this study are as follows:

RO1: To examine the impact and scholarly output of the subject matter within the previous seven-year period.

RO2: To identify the most frequently cited documents in STEAM education with the gamification domain.

RO3: To examine the top publications and citations of the publishing documents.

RO4: To ascertain the authors who have demonstrated the highest level of productivity, along with their respective affiliated organizations and countries.

RO5: To identify leading countries based on the number of publications in the field

RO6: To find the citation distribution of publications.

RO7: To identify the predominant and emerging keywords in the field by conducting the co-occurrence analysis of authors' keywords.

RO8: To examine the collaborative work of different countries in the field.

RO9: To identify factorial analysis provides a visual summary of the field.

2. Method

The research was classified as quantitative due to the utilization of statistical methods to analyze and interpret the data, enhancing comprehension of the findings (Sampieri, 2018). The systematic application of bibliometrics was employed, a scholarly discipline that utilizes mathematical and statistical techniques to examine and compute scientific data (Fuentealba et al., 2023). As a data collection technique, the bibliometric analysis was used, for which the search string was assigned: "TITLE-ABS-KEY ("steam" AND "gamification") AND (LIMIT-TO (LANGUAGE, "English"))" in the Scopus database. A descriptive bibliometric analysis was applied to the data obtained because the criteria were quantified by year, authors, geographic area, and type of document published (Jiménez & Landero, 2018).

2.1 Search Strategy

All journals, conference proceedings, reviews, and book chapters published to date have been considered as part of this analysis. The keywords such as steam and gamification were used to extract the desired article from the Scopus database. In order to maintain simplicity and conciseness in the literature review, the search string will consist of carefully selected keywords "steam" AND "gamification." The search query was executed on October 23, 2023. As of October 23, 2023, the study incorporated all documents about steam and gamification from the Scopus database. To investigate the patterns of growth in scholarly and professional literature about steam and gamification, the time period from 2017 to 2023, which is the most recent and relevant, was chosen as the designated timeframe for analysis. Then, we received 45 documents, upon which we used many filters to obtain the appropriate number of articles. In the specified time period, a comprehensive selection of 35 scholarly articles was identified from various sources, including journals, conference proceedings, reviews, and book chapters. Among the 35 publications considered, it was found that only 34 were published in the English language.

Consequently, our final dataset, which was carefully curated to ensure the inclusion of the most relevant articles, comprised solely of these 34 articles. These 34 documents were included in this investigation. The process of inclusion and exclusion, as described in the article, is illustrated in Figure 1.

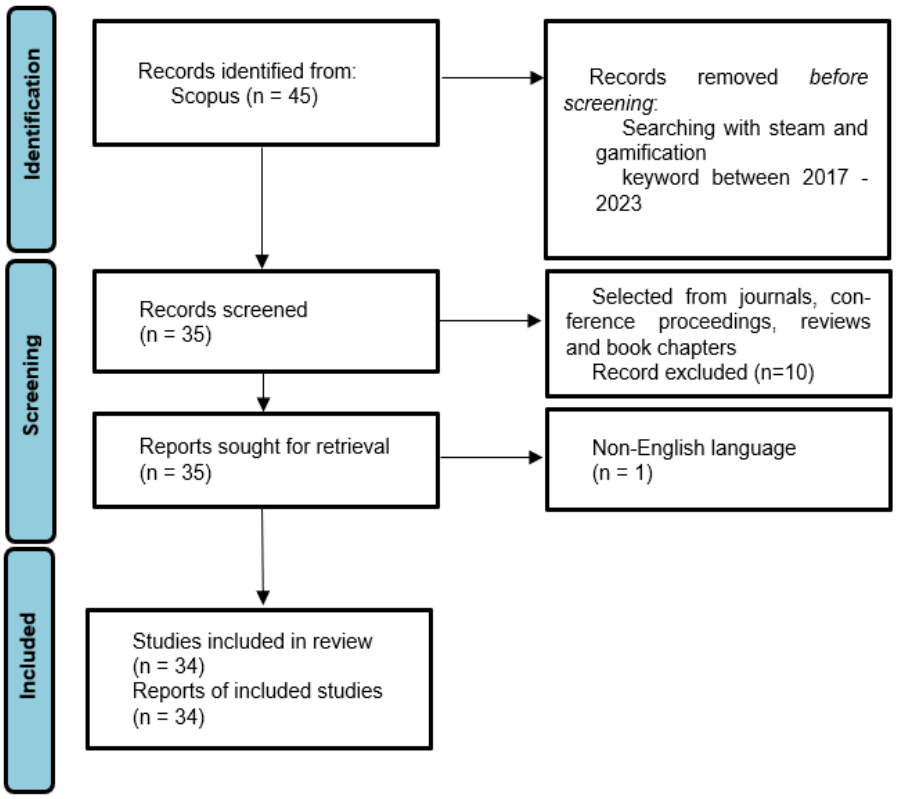

Figure 1. PRISMA 2020 of Article Selection

3. Analysis and Results

3.1 Publication Trend

It was observed that the publication count commenced in 2017, prompting a focused investigation of the quantity of publications from 2017 onwards, utilizing data spanning the preceding seven years. The publication trend can be classified into two discrete portions to clarify its development's nature. The initial phase pertains to the period between 2017 and 2019, during which scholars commenced exhibiting a keen interest in integrating gamification within STEAM education, leading to the publication of scholarly articles on this subject matter. The subsequent period of expansion in publication output spanned from 2020 to 2023, during which the annual quantity of published documents experienced a rise from 4 to 8. The growth chart of the publication effectively illustrates two key aspects: firstly, the emergence of STEAM education with gamification as a nascent field of research, and secondly, its potential as a subject of future investigation and development.

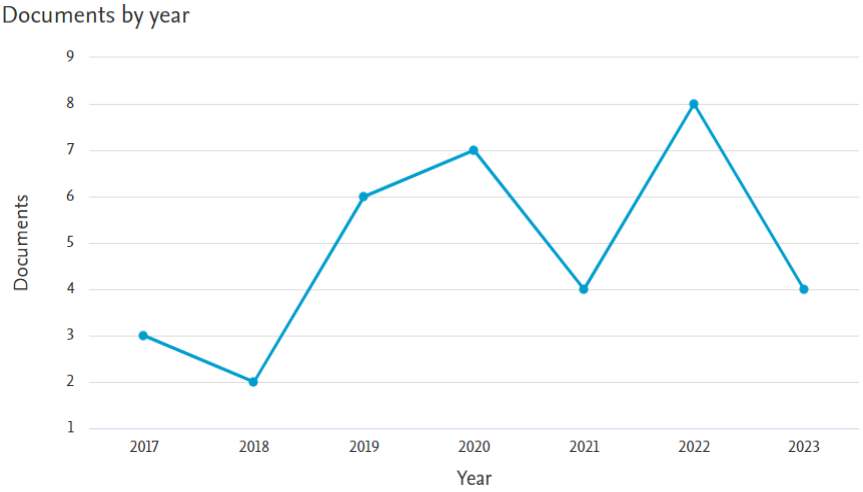

Figure 2. The publication growth trend

Figure 2 depicts the upward trajectory of scientific articles on STEAM education incorporating gamification. Scholars and experts in this domain have demonstrated an increasing fascination throughout time. In the academic sphere, the talks about "STEAM education with gamification" reached their highest point in 2022. Our research found eight published documents on this topic, as shown in Figure 2.

3.2 Top Cited Articles

The three most frequently referenced publications on the topic of STEAM education with gamification are “Thai Undergraduate Science, technology, engineering, arts, and Math (STEAM) Creative Thinking and Innovation Skill Development: A Conceptual Model Using a Digital Virtual Classroom Learning,” “A Bikesharing Optimization Framework Combining Dynamic Rebalancing and User Incentives” and “Digital learning ecosystem involving steam gamification for a vocational innovator.” Table 1 is a compilation of the top 10 articles that have received many citations, including their respective citation counts and the titles of the sources from which they originated.

Table 1. Top cited articles

Rank	Title	Authors	Year	Source Title	Citations
1	"Thai undergraduate science, technology, engineering, arts, and math (STEAM) creative thinking and innovation skill development: a conceptual model using a digital virtual classroom learning" (Wannapiroon & Pimdee, 2022)	Wannapiroon N.; Pimdee P.	2022	Education and Information Technologies	30
2	"A Bike-sharing Optimization Framework Combining Dynamic Rebalancing and User Incentives" (Chiariotti et al., 2020)	Chiariotti F.; Pielli C.; Zanella A.; Zorzi M.	2020	ACM Transactions on Autonomous and Adaptive Systems	25
3	"Digital learning ecosystem involving steam gamification for a vocational innovator" (Kummanee et al., 2020)	Kummanee J.; Nilsook P.; Wannapiroon P.	2020	International Journal of Information and Education Technology	25
4	"The effect of the STEAM-GAAR field learning model to Enhance Grit" (Chujitarom & Piriyasurawong, 2019)	Chujitarom W.; Piriyasurawong P.	2019	TEM Journal	8
5	"Gamified evaluation in STEAM for higher education: A case study" (Boytchev & Boytcheva, 2020)	Boytchev P.; Boytcheva S.	2020	Information (Switzerland)	8
6	"Improving serious games by crowdsourcing feedback from the STEAM online gaming community" (Moro et al., 2022)	Moro C.; Phelps C.; Birt J.	2022	Internet and Higher Education	7
7	"Make world, a collaborative platform to develop computational thinking and STEAM" (Guenaga et al., 2017)	Guenaga M.; Mentxaka I.; Garaizar P.; Eguiluz A.; Villagrasa S.; Navarro I.	2017	Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	7
8	"Mimicking Gamers: Understanding Gamification Through Roger Caillois" (Idone Cassone, 2017)	Idone Cassone, V.	2017	Games and Culture	6
9	"A statistical analysis of steam user profiles towards personalized gamification" (Li et al., 2022)	Li X.; Lu C.; Peltonen J.; Zhang Z.	2019	CEUR Workshop Proceedings	6
10	"Deriving a gamified learning-design framework towards sustainable community engagement and mashable innovations in smart cities: Preliminary findings" (Lee & Wong, 2022)	Lee C.-S.; Kuok-Shoong D.W. [36]	2018	International Journal of Knowledge and Systems Science	6

3.3 Top Sources

The investigation was to assess the potential influence of publishing documents on citation frequency by comparing the number of publications and citations. The five most significant documents are referenced in Table 2 The Ceur Work-shop Proceedings is the document with the most publications, totaling three, and has received a total of seven citations. Nevertheless, the most frequently referenced piece is titled "The eFacilitator as a Key Player for Interactive Dissemination of STEAM Resources for eLearning via Webinar." This article was published in the journal Advances in Intelligent Systems and Computing, which holds the second position in the list with two publications and three citations. It is not necessary that the most cited article also belongs to the top journal, but generally, it is widely believed that having one's work published in the top five or ten sources can potentially enhance the probability of receiving citations.

Table 2. Top Sources

Rank	Source	TP	TC	Cite Score2022	SJR 2022	SNIP 2022	Publication Type	The Most CitedArticle	Time Cited
1	Ceur Workshop Proceedings	3	7	1.1	0.202	0.223	Conference Proceeding	"A statistical analysis of steam user profiles towards personalized gamification"	6
2	Advances In Intelligent Systems and Computing	2	3	0.9	0.215	0.291	Book Series	"The e-Facilitator as a Key Player for Interactive Dissemination of STEAM Resources for e-Learning via Webinar"	3
3	TEM Journal	2	13	1.9	0.231	0.546	Journal	"The effect of the STEAM-GAAR field learning model to Enhance Grit"	8
4	ACM Transactions on Autonomous and Adaptive Systems	1	25	4.6	0.487	1.313	Journal	"A Bike-sharing Optimization Framework Combining Dynamic Rebalancing and User Incentives"	25
5	Communications In Computer and Information Science	1	1	1.0	0.194	0.241	Book Series	"Gamified evaluation in steam"	1

3.4 Top Authors

We have identified prominent authors who have published more articles and made significant contributions to the subject. Nilsook, P., Wannapiroon, P., and Kummanee, J. have emerged as the leading authors in STEAM education using gamification. They have published three papers, and their work has garnered 25 citations. Lee, C.S., holds the second position with three publications and 13 citations for each publication. Piriyasurawong, P. ranks as the third most prominent author, having authored three publications and receiving eight citations. Table 3 displays the top 5 authors, arranged according to their rankings. The table includes the relevant information of each author, such as their Scopus ID, total publication count (TP), h-index, total citation count (TC), current affiliation, and country of origin.

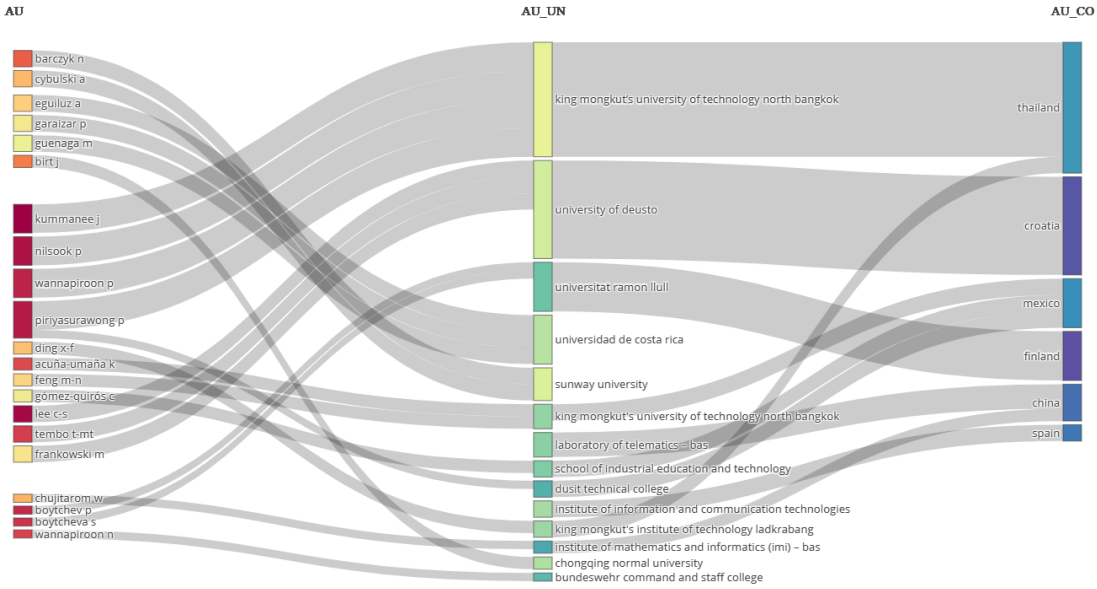

Figure 3. Three-Field Plot (Author-Affiliation-Country)

Table 3. Top 5 authors in STEAM education with gamification field

Rank	Author	Scopus Author ID	TP	h-Index	TC	Current Affiliation	Country
1	Kummanee, J.	57216508003	3	1	25	"Dusit Technical College, Bangkok"	Thailand
2	Lee, C.-S.	57205431488	3	14	13	"Sunway University, Bandar Sunway"	Malaysia
3	Nilsook, P.	35759156200	3	11	25	"King Mongkut's University of Technology North Bangkok, Bangkok"	Thailand
4	Piriyasurawong, P.	56545845100	3	5	8	"King Mongkut's University of Technology North Bangkok, Bangkok"	Thailand
5	Wannapiroon, P.	35759613600	3	10	25	"King Mongkut's University of Technology North Bangkok, Bangkok"	Thailand

3.5 Leading Countries

Figure 4 showcases the foremost countries determined by the number of publications in the respective subject. Thailand, Bulgaria, Italy, and Malaysia are the leading countries, with 6 and 3 documents, respectively. China, Croatia, Germany, Mexico, Costa Rica, Ecuador, Finland, France, Hungary, and Japan are among the prominent countries that have made significant contributions to STEAM education with gamification, as evidenced by their numerous publications.

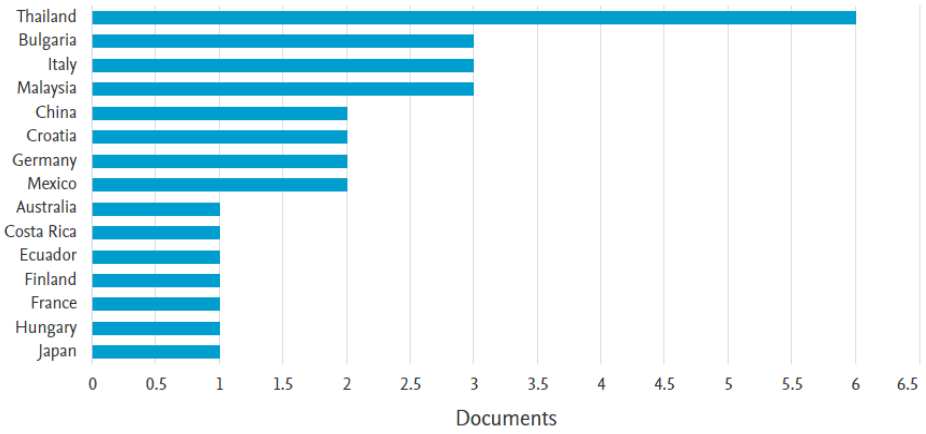

Figure 4. Leading countries

3.6 Subject Area

The dissemination of scholarly works on STEAM education incorporating gamification throughout different academic fields. According to Figure 5, 37.7% of the papers pertain to computer science, while 20.5% are pertinent to social sciences. Engineering accounts for 16.9% of all papers, whereas the field of decision sciences for 7.2% of the total publications. Merely 4.8% of the articles pertain to business, management, and accounting domains. Figure 5 illustrates the categorization of publications based on their respective subject areas.

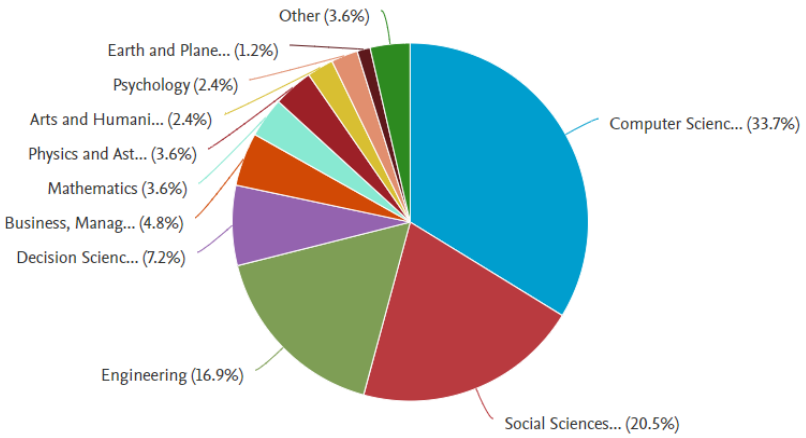

Figure 5. Subject area distribution of published articles

3.7 Co-occurrence of the Author Keywords

Co-occurrence of author keywords. We performed a co-occurrence analysis to ascertain the terms utilized by the authors in their previous studies. Our research of author keywords using co-occurrence found a total of 139 keywords that were utilized in articles about the intersection of STEAM education and gamification. The analysis required a minimum of 2 occurrences of each keyword. Consequently, 15 keywords that satisfied the specified requirements were identified. The keywords that appeared most frequently were gamification, steam, steam education, computational thinking, augmented reality, creative thinking, design thinking, education, educational software, and engagement. These keywords occurred 26, 14, 9, 3, and 2 times, respectively (Table 4). Figures 6 and 7 illustrate the data overlay display, while Table 4 presents the keywords, their frequencies, and the total link strength (TLS).

Table 4. Most significant keywords in STEAM education with gamification

Keyword	Occurrences	TLS	Keyword	Occurrences	TLS
gamification	26	19	educational software	2	2
steam	14	14	engagement	2	2
steam education	9	9	gamification in education	2	2
computational thinking	3	3	gamification teaching	2	2
augmented reality	2	2	stem	2	2
creative thinking	2	2	student evaluation	2	2
design thinking	2	2	steam learning	2	1
education	2	2			

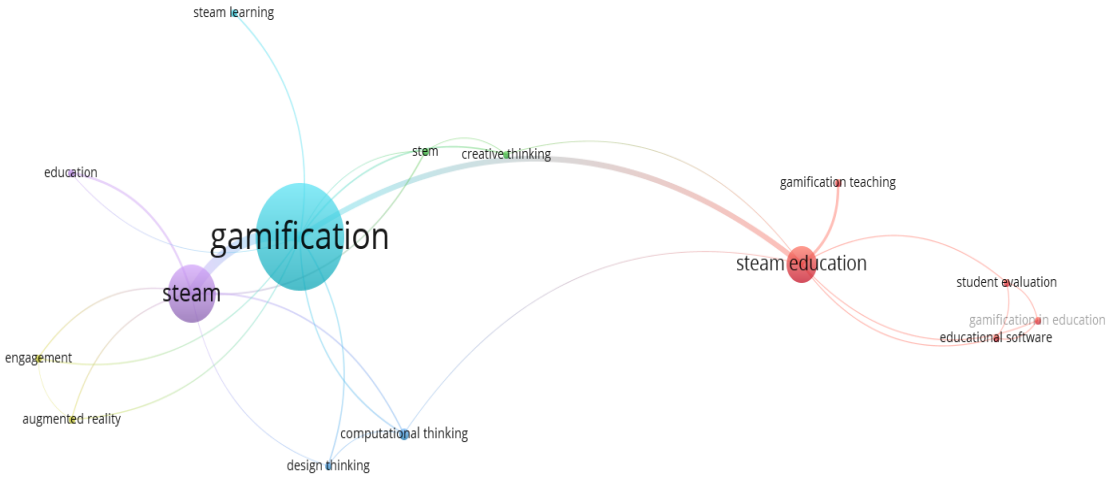

Figure 6. Co-occurrence analysis of keywords (author keywords)

The most significant keywords in the published literature on STEAM education with gamification are gamification, steam, steam education, and computational thinking (Figure 7).

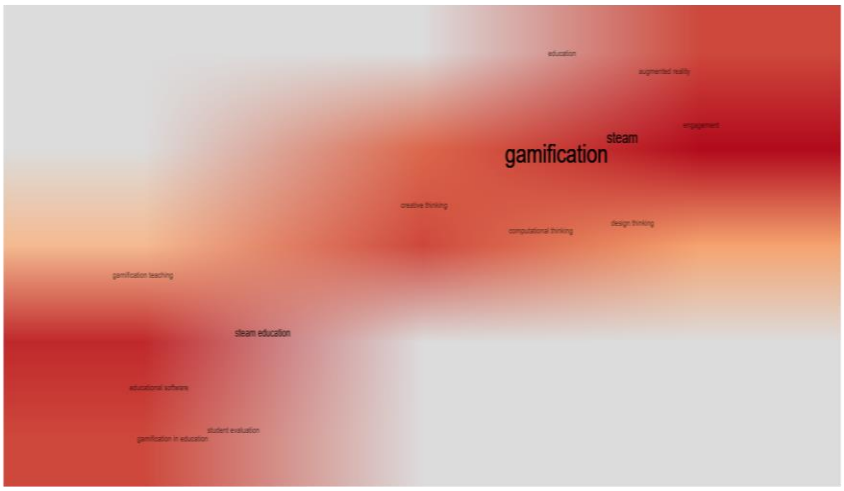

Figure 7. Overlay of Co-occurrence Network (author keywords)

3.8 Countries Analysis

Table 5 displays the data analysis for the bibliographic connection of countries using network visualization. Only one publication was the minimum criterion for each country, and 22 countries fulfilled this criterion. We computed the number of publications, citations, and total link strength for each country. Countries with the greatest cumulative link strengths were selected. Malaysia achieved the top position, with three publications,

thirteen citations, and 48 link strengths. In the case of other countries, the initial figures indicate the number of publications, the subsequent figures indicate the number of citations, and the last figures represent the overall link strengths. The other countries included in the list are Singapore (1; 6; 48), France (1; 1; 45), Germany (2; 1; 45), Latvia (1; 1; 45), Norway (1; 1; 45), Bulgaria (3; 12; 1), Hungary (1; 0; 1), Australia (1; 7; 0), China (2; 0; 0), Costa Rica (1; 0; 0), Croatia (2; 2; 0), Ecuador (1; 1; 0), Finland (1; 6; 0), Italy (3; 31; 0), Japan (1; 0; 0), Mexico (2; 5; 0), Peru (1; 0; 0), Poland (1; 1; 0), Spain (1; 7; 0), Thailand (6; 68; 0), and Ukraine (1; 1; 0).

Table 5. Top 22 countries along with the number of published documents and citations

Country	Documents	Citations	TLS	Country	Documents	Citations	TLS
Malaysia	3	13	48	Croatia	2	2	0
Singapore	1	6	48	Ecuador	1	1	0
France	1	1	45	Finland	1	6	0
Germany	2	1	45	Italy	3	31	0
Latvia	1	1	45	Japan	1	0	0
Norway	1	1	45	Mexico	2	5	0
Bulgaria	3	12	1	Peru	1	0	0
Hungary	1	0	1	Poland	1	1	0
Australia	1	7	0	Spain	1	7	0
China	2	0	0	Thailand	6	68	0
Costa Rica	1	0	0	Ukraine	1	1	0

In addition, an analysis was conducted on the distribution of publications and citations based on country, as presented in Table 5. The data presented in the table indicates that Thailand exhibits the highest number of publications (n = 6) and citations (n = 68). Italy has three publications with 31 citations, and Malaysia has three publications with 13 citations. Nevertheless, it has been observed that there is only sometimes a direct correlation between the quantity of publications and the number of citations. This is exemplified by the comparison between Germany and Australia, where Germany has more publications but significantly fewer citations.

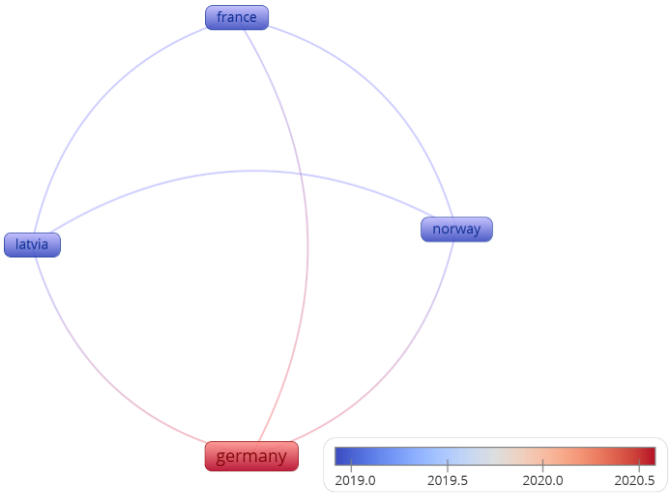

Figure 8. Coupling of the Countries

Figure 8 displays distinct clusters that exhibit a higher frequency of interconnection, as denoted by the utilization of various colors. This implies a higher citation frequency between studies from countries within the same cluster. The largest cluster comprises Germany, while the second includes Latvia, Norway, and France.

3.9 Factorial Analysis

Table 6 and Figure 9 illustrate a Factorial Analysis with three distinct clusters of academic topics, represented by blue, green, and red polygons. The axes, Dim1 and Dim2, capture 66.69% of the data variance, effectively highlighting significant differences. The blue cluster, on the right, groups educational methodologies and tools such as teaching and serious games. The green cluster, at the top, focuses on student-centered learning

environments like high school students and learning by designs. The red cluster, on the left, encompasses educational technologies and engagement strategies, including augmented reality and e-learning. This visualization aids in understanding the relationships and distinctions between these academic topics.

Table 6. Words by Cluster

word	Dim.1	Dim.2	cluster
gamification	-0.06	0.13	1
students	0.28	0.17	1
steam	0.36	-0.07	1
education.computing	-0.01	-0.51	1
learning.systems	-0.04	0.07	1
engineering.education	1.12	-0.64	2
e.learning	0.34	0.83	1
computer.aided.instruction	0.08	1.74	3
high.school.students	0.66	2.05	3
human.computer.interaction	1.45	-0.6	2
learning.experiences	-0.71	-0.42	1
learning.process	-0.49	-0.31	1
surveys	-0.36	-0.63	1
teaching	2.26	-0.09	2
augmented.reality	-1.02	-0.15	1
curricula	2.57	-1.05	2
design.thinking	-0.54	-0.49	1
educational.contents	-0.46	0.94	1
engagement	-0.47	0.5	1
instructional.designs	-0.71	-0.71	1
learning.activity	2.51	0.45	2
learning.by.designs	0.97	2.54	3
learning.environments	-0.08	2.43	3
middle.school.students	-0.1	1.73	3
quality.control	-0.25	-0.8	1
science.technologies	0.2	-0.07	1
serious.games	2.13	-0.7	2
virtual.reality	-0.89	-0.08	1

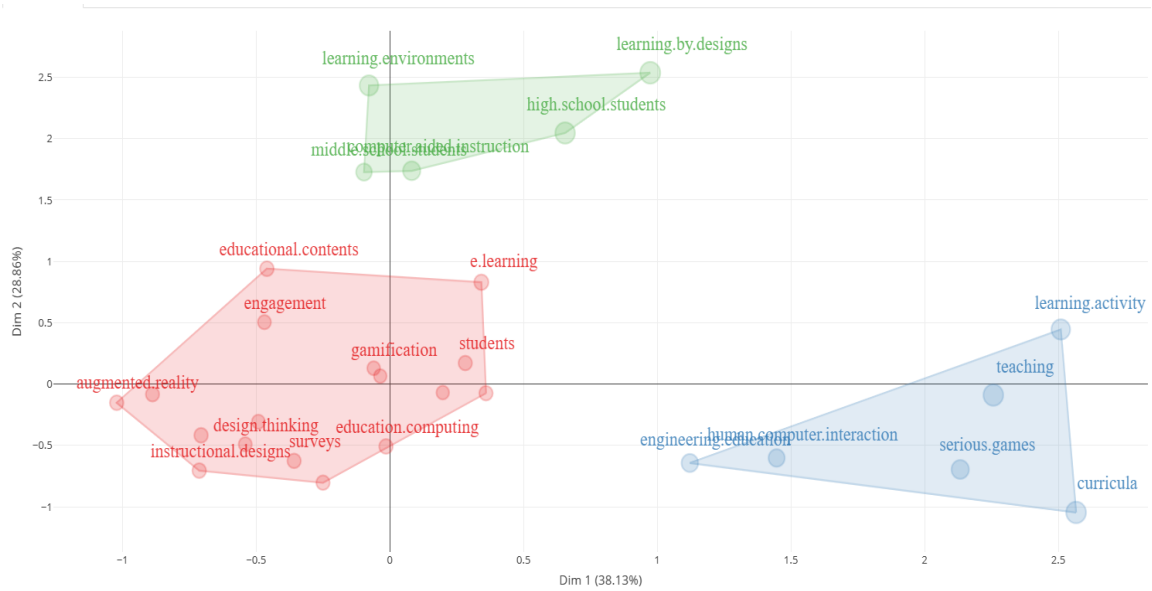

Figure 9. Factorial Analysis (Word Map: KeywordPlus)

Figure 10 illustrates the method commonly used in hierarchical clustering. This type of analysis groups similar items together and arranges them in a tree-like diagram. The different colors indicate different clusters.

Blue Cluster: Contains topics related to education methodologies and interaction tools, such as engineering education, human-computer interaction, curricula, serious games, teaching, and learning activities.

Green Cluster: Focuses on student-centered environments and instruction, including high school students, learning by designs, learning environments, computer-aided instruction, and middle school students.

Purple Cluster: Encompasses a wide range of topics associated with educational technologies and quality control measures, such as virtual reality, instructional designs, learning processes, design thinking, educational computing, surveys, quality control, educational core methods, engagement, e-learning, gamification, learning systems, students, STEAM, and science technologies.

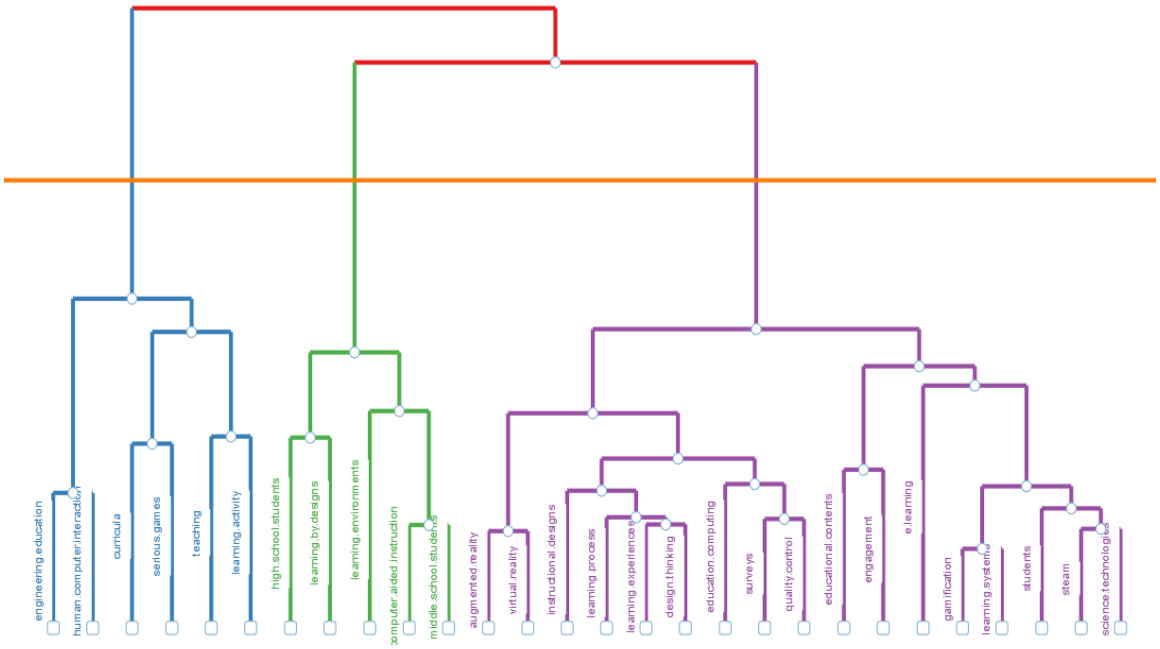

Figure 10. Topic Dendrogram of KeywordPlus

4. Conclusion

The results of this study will enhance the academic community's understanding and awareness of the global impact of integrating STEAM education with gamification. Quantitative techniques in bibliometric analysis enable identifying and assessing numerous significant characteristics within a specific subject of study. These elements encompass the fundamental sources, leading authors, prominent keywords, primary publication country, highly cited papers, maps illustrating the co-occurrence of terms, and the co-occurrence of author keywords, among other factors. Over the previous seven years, 34 research documents and 155 citations have been gathered in STEAM education with gamification. The publication trend phenomenon has grown substantially over the past several years and is expected to continue. The publications with significant citations have been found, along with the authors, journals, and nations that have exhibited the highest productivity levels. Around 37.7% of the papers in the literature on STEAM education with gamification come from computer science, while 20.5% are from the social sciences sector. The article authored by Wannapiroon N. and Pimdee P., titled "Thai Undergraduate Science, technology, engineering, arts, and Math (STEAM) Creative Thinking and Innovation Skill Development: A Conceptual Model Using a Digital Virtual Classroom Learning," has received significant attention, being cited a total of 30 times. The Ceur Workshop Proceedings is the document that has yielded the most publications, with six total in the specific domain. Nilsook, P., Wannapiroon, P., Kummanee, J., Lee, C.-S., and Piriyasurawong, P. have the highest number of publications, with three each in the specified field. The countries at the forefront of STEAM education with gamification research are Thailand, Bulgaria, Italy, and Malaysia. The predominant keywords in the published literature on STEAM education with gamification include gamification, STEAM, STEAM education, and computational thinking. Germany, Latvia, Norway, and France are the countries that are most actively engaged in joint research. Factorial Analysis provides a visual summary

of the complex relationships between various concepts related to technology in education. It can be used to guide research and development efforts and inform educational policy and practice. By identifying the underlying factors and their relationships with specific applications, educators and researchers can better understand the potential of technology to enhance learning outcomes and improve educational experiences.

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Authors contributions

Assistant Professor Dr. Thada Jantakoon was responsible for the conceptualization, methodology, formal analysis, writing-original draft preparation, writing-reviewing, editing preparation for creating the published work, project administration, and funding acquisition. Assistant Professor Dr. Thiti Jantakun and Assistant Professor Dr. Kitsadaporn Jantakun supervised the conceptualization, methodology, validation, investigation, writing review, and editing preparation. Assistant Professor Dr. Somsuk Trisupakitti and Assistant Professor Potsirin Limpinan participated in the data curation. All authors read and approved the final manuscript.

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Competing interests

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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Obtained.

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The Publication Ethics Committee of the Canadian Center of Science and Education.

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The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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No additional data are available.

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