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A Bibliometric Analysis on the Use of Computer Simulation in Teaching and Learning

Briskila Ayuba[1], Balarabe Yushau[2],
Sa'adatu A. Mohammed[3], Badamasi Imam Ya'u[4]
[1,2,3]Abubakar Tafawa Balewa University Bauchi, Nigeria
[4]Islamic University of Uganda, Mbale, Uganda
briscaborskg@gmail.com; byushua@gmail.com

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Abstract

Although computer simulation has become increasingly important in teaching and learning, the intellectual structure, collaboration patterns, and geographical distribution of research in this field remain insufficiently synthesised. This study provides a bibliometric overview of the development, current structure, and emerging directions of computer simulation research in education. A dataset of 710 journal articles retrieved from the OpenAlex database was analysed using VOSviewer to identify influential authors, publications, journals, countries, collaboration networks, and keyword co-occurrence patterns. Co-authorship analysis produced two distinct clusters, journal-level network analysis identified four clusters, and keyword co-occurrence analysis generated five thematic clusters. China emerged as the most influential country, whereas the United States was the most frequently cited. Omar Chamorro-Atalaya was identified as the most influential author, while Fengfeng Ke was the most cited. Computer Applications in Engineering Education and the British Journal of Educational Technology were identified as the most influential and most cited journals, respectively. The keyword analysis demonstrated the interdisciplinary character of computer simulation research, integrating technological, engineering, medical, educational, and social perspectives. However, research output from Africa remained limited, with most publications originating from technologically advanced regions in the Americas, Europe, and East Asia. Author collaboration networks were also relatively weak and regionally concentrated, indicating limited global integration. The study maps the intellectual and collaborative structure of computer simulation research while identifying substantial geographical and partnership disparities. It highlights the need to strengthen international research collaboration and expand empirical inquiry in developing countries to ensure that computer simulation applications reflect diverse educational settings, technological capacities, and pedagogical needs.

Keywords: Bibliometric Analysis; Computer Simulation; OpenAlex; Research Collaboration; Technology-Enhanced Learning

INTRODUCTION

The integration of computer simulation in education has gained significant acceptance in recent years as technology continues to reshape the landscape of teaching and learning. Advances in computational modeling, interactive visualization and artificial intelligence have made it possible for educators to provide immersive and interactive learning experiences that extend beyond the limits of traditional classroom instruction (Hariyanto et al., 2025). Computer simulations enable learners to explore dynamic representations of real-world systems, test hypotheses, and visualize outcomes, making abstract or complex concepts more tangible and understandable (Adelana et al., 2021). As a result, simulations have become a central component of modern educational technology, particularly in science, technology, engineering, and mathematics (STEM) education.

Computer simulation in education refers to the use of computer-based models to imitate real-life phenomena or processes for instructional purposes (Kabigting, 2021). Okolo and Oluwasegun (2020) defined it as a programme that imitates a thing, concept, process or situation of a model, especially for the purpose of teaching and learning. Computer simulations are the programmes that allow learners to systematically explore hypothetical situations, interact with that situation, and explore the changes occurring in the situations as a result of their interaction (Almasri, 2022). Such simulations provide learners with safe, cost-effective, and repeatable environments for experimentation and inquiry. For example, in physics, chemistry, and electronics education, simulations allow students to manipulate variables, observe immediate effects, and develop deeper conceptual understanding through iterative exploration (Oyeniran, & Oteyola, 2023; Almasri, 2022; Jack, 2021).

Empirical research from the past decade consistently highlights the pedagogical value of computer simulations and have shown that simulation-based learning enhances student engagement, motivation and academic performance when compared with conventional lecture-based instruction (Rosen, 2019; Jere & Mpeta, 2024; Rosali, 2020; Ambelu & Gebregziabher, 2021; Akhigbe & Ogufere, 2020; Hwang, 2023;). Simulations foster inquiry-based learning by allowing students to construct and test hypotheses, receive instant feedback, and reflect on their learning progress. Moreover, they encourage self-regulated learning and critical thinking skills that are increasingly essential for success in the education system (Hwang, 2023).

In developing countries, where laboratory resources and equipment are limited, computer simulations offer a pragmatic and scalable solution to overcome infrastructural constraints. They make laboratory-based learning experiences accessible to students regardless of physical or economic barriers (Felix & Msheliza, 2025; Ibezim & Asogwa, 2020). Furthermore, recent advances in virtual reality (VR) and augmented reality (AR) simulations have introduced new dimensions of interactivity, immersiveness, and realism, significantly improving students' learning experiences and retention (Makransky & Mayer, 2022).

Despite the clear advantages of computer simulation, their educational impact is influenced by several factors, including instructional design quality, teacher competence, student readiness, and technological infrastructure (Hao et al., 2017). The pedagogical effectiveness of simulations depends on how well they are integrated into curriculum objectives, the extent of scaffolding provided, and the degree to which they align with learning outcomes. Inadequate training or poor implementation strategies may diminish their benefits and even lead to misconceptions (Mathibedi, 2025).

Given the rapid expansion of simulation-based research and the diversity of its applications across educational levels and disciplines, a systematic bibliometric analysis is essential to map the intellectual structure, trends, and thematic evolution of this field. Bibliometric approaches, using tools such as Biblioshiny, VOSviewer and R Bibliometrix, allow researchers to quantitatively analyze patterns in publication outputs, citations, co-authorship networks and keyword co-occurrences (Donthu et al., 2021). Conducting such an analysis provides insight into the global research landscape, identifies influential authors and institutions, and reveals emerging areas of focus in the use of computer simulation for teaching and learning.

This bibliometric review aims to answer the research questions listed below:

1. What is the distribution of publications by year?
2. Which countries are the most prolific in terms of publication output?
3. Who are the most prolific and influential authors in the field?
4. What are the most cited journals in the field?
5. What are the most frequently used keywords in the literatures?

METHODOLOGY

This study conducts a bibliometric analysis to investigate the current state of international publications in journals indexed in the Openalex database regarding the computer simulation in teaching and learning. Bibliometric analysis is an approach that quantitatively measures certain indicators by analyzing citations of published works, inter-author relationships, keywords, theoretical and practical topics in a specific field using various statistical techniques. This method allows for monitoring and evaluating the development and advancements within the discipline (Ulukök et al., 2024). A successful bibliometric study can lay a solid foundation for innovative and meaningful progress in a field, thereby providing researchers with a comprehensive overview, identifying knowledge gaps, generating new research ideas, and positioning their planned contributions within the existing literature.

Data Collection Process

There are many databases indexing educational research, one of the databases that can be used for various analyses, including bibliometric analyses, is the Openalex, which is an open catalog of the global research system. This bibliometric review utilized data retrieved from the Openalex database. Openalex was chosen due its open-access nature, comprehensive coverage of global scholarly outputs and structured metadata that facilitate network-based bibliometric analysis. Openalex also provides transparent, reproducible and ethically aligned data suitable for open science research (Priem & Piwowar, 2022; Visser, et al., 2023).

The study includes only articles due to their status as the most common and representative type of scientific publication, their bibliometric indicators, inclusion of original research findings, comparability and the ability to be analyzed using bibliometric methods (Atmaca-Aksoy, 2024). As of October 10, 2025, a total of 710 studies were identified in the Openalex database depending on the search criteria presented in Table 1.

Table 1: Article Selection Criteria

Parameter	Details
Database	OpenAlex
Keywords	("computer simulation" OR "instructional simulation" OR "simulation" OR "simulation-based learning" OR "Virtual Simulation" AND "learning" OR "Teaching" OR "Education")
Publication Type	Article
Publication Years	2015-2025
Language	English
Date	10th October, 2025

Data analysis

In this study, the bibliographic data of the 710 documents obtained from Openalex database were imported into VOSviewer (version 1.6.20), a software that allows for the creation and detailed examination of bibliometric maps. The imported format includes publication year, language, journal, title, author, institution, keywords, document type, abstract, and citation count. VOSviewer is a software tool designed for creating, exploring, and visualizing maps derived from bibliometric network data (Van Eck & Waltman, 2010). It can be employed to construct networks consisting of scientific publications, scientific journals, researchers, research institutions, countries, keywords or terms. The elements in these networks can be connected through co-authorship, co-publication, citation, bibliographic links or co-citation links (Van Eck & Waltman, 2022). In this context, the study identified year, country, journal, citation and keywords. Before each analysis, the relevant data were carefully examined, and essential data cleaning processes were performed.

RESULTS

Findings related to distribution of publications by year and country, the most influential authors, journals, and the most used keywords are presented. The Openalex database returned a total of 470 sources, 2206 authors and 10,799 citations for the selected 710 articles. The average citation count per document was 8.44, with document average age of 3.04.

Distribution of publication by year (2015-2025)

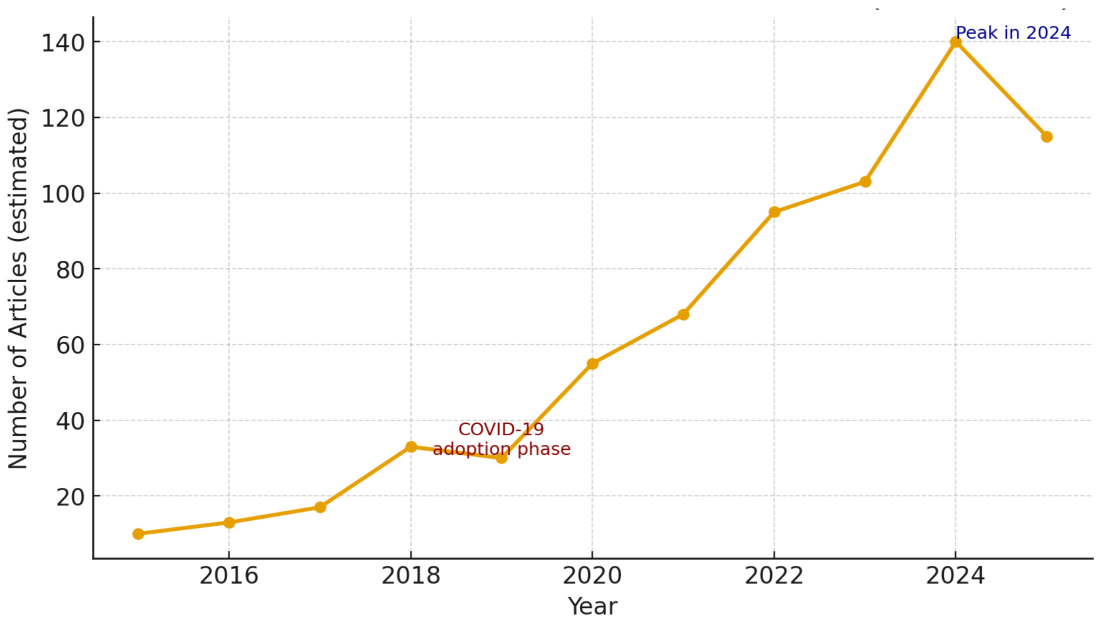

Figure 1: Trend in Publications on Computer Simulation in Education (2015–2025)

Figure 1 presents the distribution of articles obtained from the Openalex database from 2015 to 2025. The data indicates a clear trend in the annual output of scholarly works on computer simulation in teaching and learning. In general, the pattern formed reflects how academic attention to computer simulation has developed over time. This temporal analysis offers significant insights into the changing landscape of research activity within the defined timeframe.

As seen from figure 1, a consistent upward trend is observed, with gradual growth from 2015 to 2019, a marked increase between 2020 and 2024, and a slight decline in 2025. The steep rise after 2020 corresponds to the global expansion of remote learning and digital instructional tools during and after the COVID-19 pandemic. The subsequent moderation in 2025 may reflect publication lag or data indexing delays.

Table 2 gives the summary of publications on computer simulation in teaching and learning from 2015 to 2025.

Table 2: Distribution of publications on computer simulation in teaching and learning from 2015 to 2025

Year	Number of Publication	Mean Total Citation per Art	Mean Total Citation per year
20 15	16	13.44	1.22
2016	19	12.05	1.21
2017	23	24.26	2.70
2018	37	9.19	1.15
2019	33	9.73	1.39
2020	57	27.04	4.51
2021	68	8.81	1.76
2022	95	14.33	3.58
2023	102	5.00	0.98
2024	142	1.97	0.33
2025	118	0.33	0.33

Table 2 demonstrates that despite the increase in publication volume, citation impact varied across years. Publications produced in 2020 recorded the highest mean total citations per article (27.04) and the highest mean citations per year (4.51), suggesting that studies published during this period exerted considerable influence on subsequent research. Conversely, publications from 2023-2025 exhibited lower citation averages, which may be attributed to the limited time available for citation accumulation. Overall, the pattern demonstrates that simulation-based learning has transitioned from an emerging innovation to a well-established educational research area.

Distribution of publications by country

Table 3 presents the geographical distribution of publications. In analyzing the most productive countries in scientific research, a minimum threshold of 5 documents and at least 10 citations were established. Out of the 72 countries, 26 met the threshold. These criteria ensure the inclusion of countries with a substantial impact on the scholarly output, facilitating a clearer understanding of global research dynamics.

Table 3: Distribution of publications by top ten countries.

S/No.	Country	No. of Publication	Citation	TLS
1	China	147	1125	20
2	United States	63	927	27

S/No.	Country	No. of Publication	Citation	TLS
3	United Kingdom	26	196	18
4	Spain	23	862	11
5	India	17	218	6
6	Australia	16	223	4
7	Ukraine	14	46	3
8	Germany	12	411	8
9	Greece	11	335	6
10	South Korea	10	66	8

From Table 3, it can be seen that China leads the global output with 147 publications, which is more than double the second-ranked United States (63). The top three countries (China, U.S., U.K.) together contribute roughly 60% of all publications in the dataset, suggesting a strong concentration of research capacity in technologically advanced regions. European countries such as the United Kingdom, Spain, Germany, and Greece demonstrate solid representation, while India, Australia, Ukraine, and South Korea indicate growing activity from Asia-Pacific and Eastern Europe. In terms of citation, while China dominates in publication volume, the United States shows higher citation intensity per article (927 citations across 63 papers = 14.7 citations per article), compared with China's =7.7 citations per article. Spain's 862 citations for 23 papers (=37.5 citations per article) stand out—indicating fewer but more influential papers, possibly due to collaboration with high-impact authors or journals. Germany and Greece also have moderate journal production output but relatively strong citation averages, reflecting quality over quantity. In terms of the Total Link Strength (TLS) which measures the strength of international collaboration networks in bibliometric mapping, the United States (TLS = 27) leads in collaborative intensity, followed by China (20) and the United Kingdom (18) highlighting the U.S.'s pivotal role in global co-authorship and research networking. Countries such as Spain, Germany, and South Korea show modest TLS values, while Ukraine and Australia appear relatively isolated (low TLS = 3–4), suggesting emerging or less connected research communities. Figure 2 shows the global collaboration network.

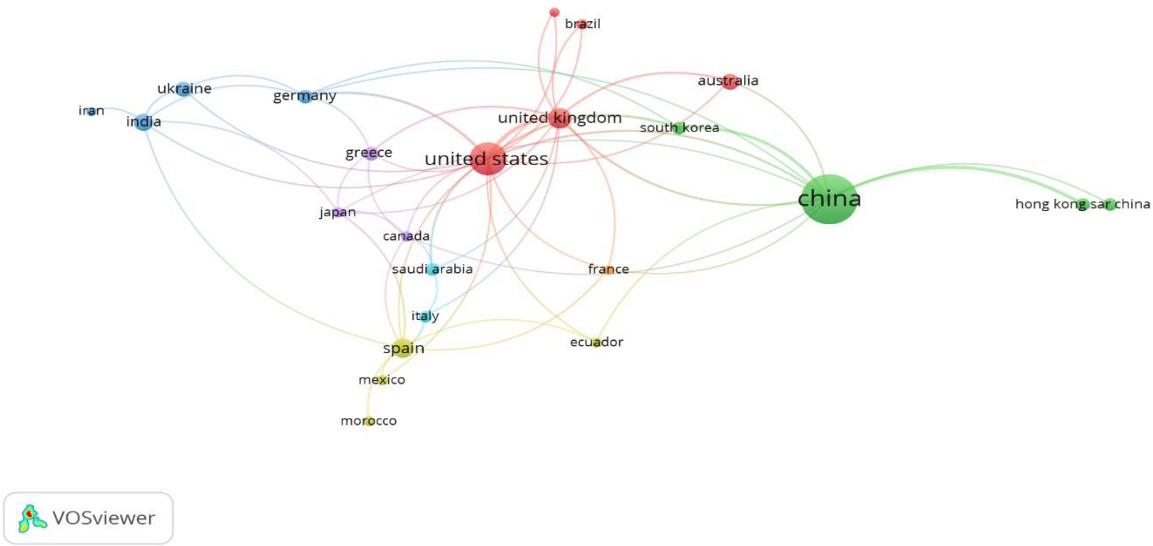

Figure 2: Global collaboration through documents published by countries

The map shows country collaboration network visualization. It shows how different countries collaborate in research publications in computer simulation in education. Each node represents a country. The size of the node reflects the number of publications from that country. The lines between the countries represent how authors from those countries co-publish articles together and the colours represent clusters of collaboration-groups of countries that frequently work together. The United States is placed centrally acting as bridge between multiple clusters linking European, Asian and American networks.

The map shows four distinct clusters: these include;

- Red cluster (United States – United Kingdom network) – includes United States, United Kingdom, Australia, and Brazil – this indicates Anglophone collaborations.
- Green cluster (China in the center): includes China, Hong Kong, SAR China and South Korea. This reflects strong regional collaboration in East Asia possibly driven by technological and educational research links.
- Blue cluster (Europe and Asia Mix): includes Germany, Greece, India, Ukraine and Iran – suggesting emerging collaborations between Europe and South Asia.
- Yellow Cluster (Spain-centered): include Spain, Mexico and Morocco. – reflects Spanish-Speaking collaborations and regional academic ties.

Most influential researchers

An analysis of the authors with highest number of publications was conducted using the criterion of at least 2 publications in the dataset and to determine the collaboration author network (see Table 3 and Figure 3). Out of the 2206 authors, 31 met the threshold.

Table 4: Ranking of the Top Ten Most Influential Researchers by Citations

Rank	Author	No. of Publication	Citation	TLS
1	Fengfeng Ke	4	120	4
2	Abdullah Alhumaidi Alotaibi	2	56	4
3	Abir Osman Elfakki	2	56	4
4	Souhir Sghaier	2	56	4
5	Omar Chamorro- Atalaya	6	31	14
6	Guillermo Morales-Romero	3	23	10
7	Elizabeth Augui-Ramos	2	20	8
8	Jose Antonio Arevalo-Tuesta	3	15	8
9	Yadit Rocca-Carvajal	2	12	7
10	Dora Arce-Santillan	2	10	7

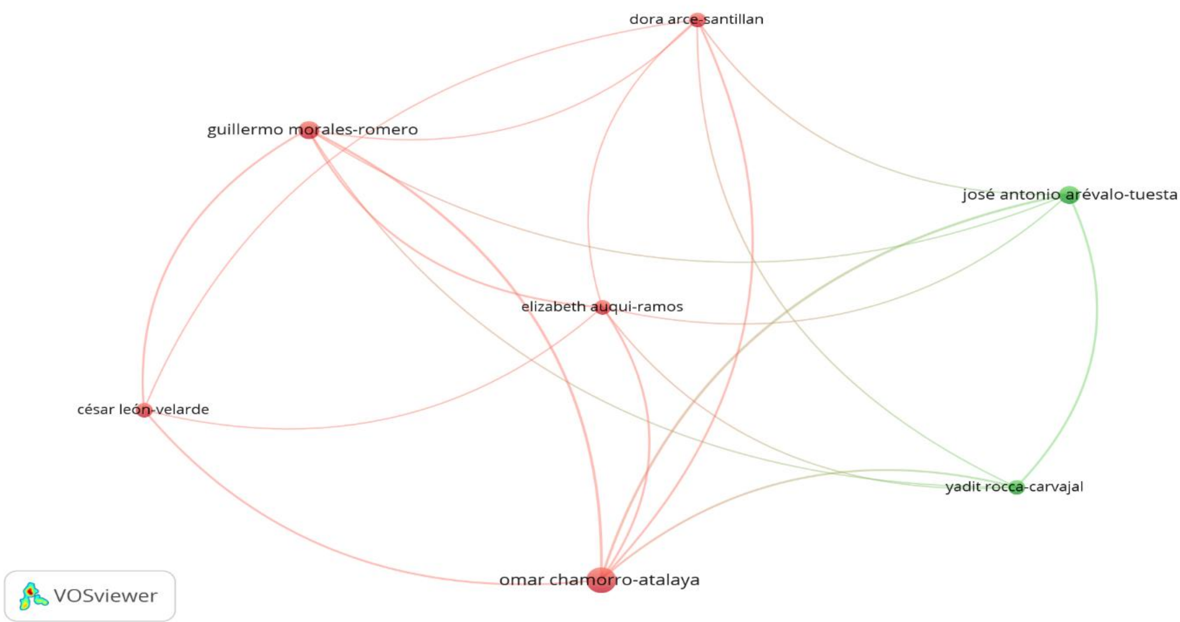

Figure 3: Author Collaboration Network

In the analysis conducted, 2 cluster, 19 links and 30 total link strength were identified. Table 3 presents the ranking of the most influential researchers in computer simulation and education, based on publication output, citation count, and total link strength (TLS). Fengfeng Ke ranked first with four publications and 120 citations, demonstrating the strongest global influence and a high citation-to-publication ratio. Abdullah Alhumaidi Alotaibi, Abir Osman Elfakki, and Souhir Sghaier each recorded two publications and 56 citations, reflecting their involvement in collaborative, high-impact international studies. Omar Chamorro-Atalaya exhibited the highest productivity with six publications and the greatest network connectivity (TLS = 14), identifying him as a central figure in the regional research community.

The most influential journal

Journals with the minimum of 4 publications were selected in the analysis. The results indicated that out of the 710 journals published, 23 meet the threshold. Table 5 presents the top ten most influential journals.

Table 5: Most Influential Journals

Rank	Author	No. of Publication	Citation	TLS
1	Computer applications in engineering	14	149	2
2	Journal of Physics conference Series	13	28	2
3	Sustainability	12	402	5
4	Applied Mathematics and Non-linear Science	11	8	2
5	International Journal of Emerging Technologies in Learning	10	138	1
6	Education Sciences	8	64	1
7	Computational Intelligence and Neuroscience	7	34	1
8	British Journal of Educational Technologies	5	633	7
9	Virtual Reality	5	48	3
10	Frontier in Education	4	33	3

According table 5, the three journals with the highest publications are Computer in Application Engineering, Journal of Physics Conference Issues and Sustainability with 14, 13 and 12 publications respectively. In terms of the highest cited journals, British Journal of Educational Technologies (633 citations), Sustainability (402 citations) and Computer Application in Engineering (149 citations) ranked first, second and third respectively.

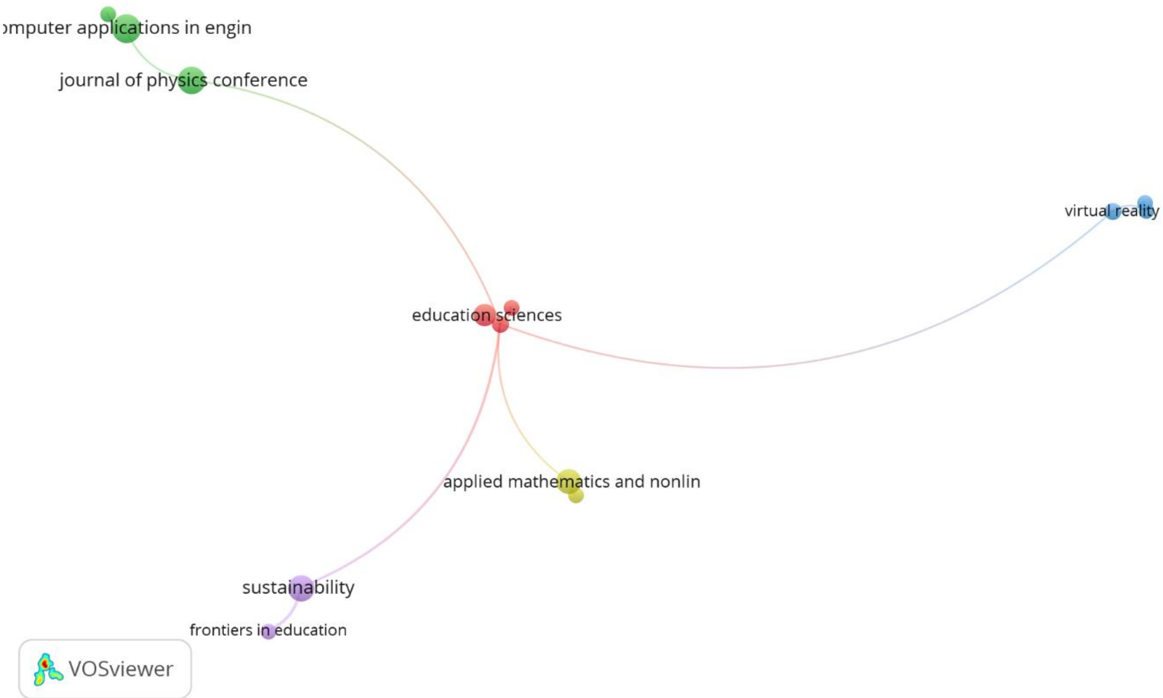

Figure 5: Journal co-cited Network

Figure 5 is the VOSviewer visualization that illustrates the citation relationships among journals that publish research on computer simulation in teaching and learning. The journal British Journal of Educational Technologies appears most central node, suggesting it serves as a key publication outlet for studies in simulation-based education. Its centrality indicates that it is frequently co-cited with journals from both the engineering, technical and pedagogical domains. This position highlights British Journal of Educational Technologies as a bridge journal, connecting educational research with applied computational and simulation methodologies.

Keywords analysis

The minimum threshold for the number of keywords was set at 50. As a result of the analysis, 64 keywords, 5 clusters, 1717 links and 38368 total link strength emerged. Table 6 shows the top ten most influential keywords.

Table 6: Top Ten Most Influential Keywords

Rank	Keyword	Occurrences	TLS
1	Computer simulation	1755	7229
2	Computer Science	1510	6752
3	Human-Computer Interaction	1117	2450
4	Psychology	927	1072
5	Artificial Intelligence	443	806

Rank	Keyword	Occurrences	TLS
6	Engineering	358	695
7	Mathematics Education	315	487
8	Medicine	248	398
9	Medical Education	232	243
10	Pedagogy	183	236

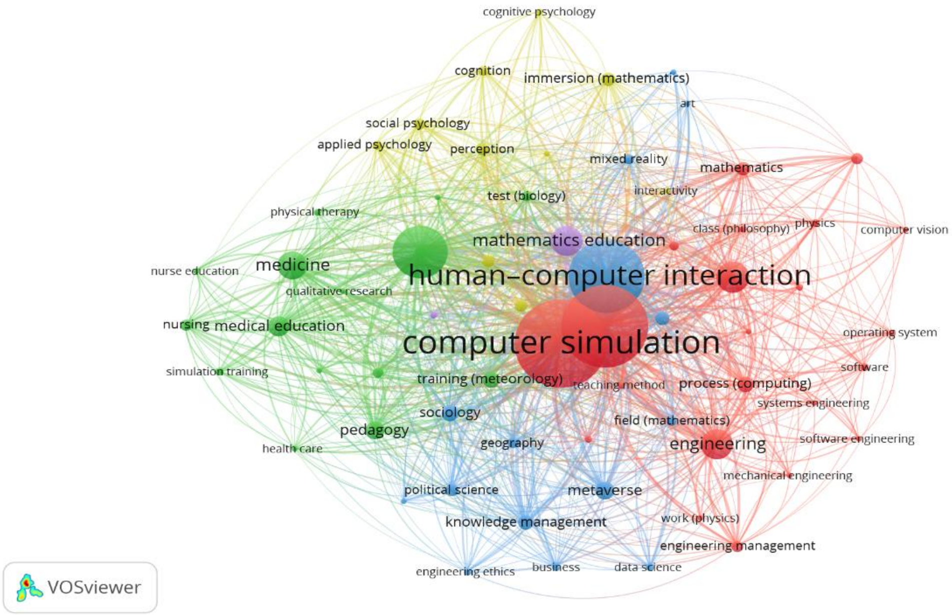

Figure 6: Keywords Network

Figure 6 presents keyword co-occurrence network generated using VOSviewer. The map reveals a highly interconnected research landscape centred on computer simulation, with five major thematic clusters that represent distinct but related research domains.

The Red Cluster-Engineering and Computing Applications

The red cluster is dominated by words such as computer simulation, computer science, engineering, Physics, Mathematics, Software, Computer Vision, Software Engineering, Mechanical Engineering, computer graphics etc. This cluster represents the technological and computational foundation of computer simulation research.

The Green Cluster- Medical and Health Education

The green cluster encompasses words such as Psychology, Medicine, Medical education, Nursing, Nurse education, Simulation training, Healthcare, Physical therapy, Curriculum etc. This cluster reflects the extensive adoption of simulation in healthcare training and professional education showing that medical simulation has become one of the most established areas of simulation research.

The Blue Cluster- Social Sciences and Emerging Technologies

The blue cluster includes words such as Human-Computer Interaction, Sociology, Geography, Political science, Business, Data science, Knowledge management, Metaverse, Engineering ethics, Mixed reality, Art etc. This cluster demonstrates the broadening application of simulation beyond STEM fields. The presence of metaverse, mixed reality, and data science suggests increasing interest in digital transformation and virtual environments.

The Yellow Cluster- Cognitive and Psychological Foundations

Major keywords in this cluster include: Cognition, Cognitive psychology, Perception, Social psychology, Applied psychology, Immersion, Interactivity etc. This cluster focuses on understanding how individuals think, perceive, learn, and interact within simulated environments.

The Purple Cluster- Mathematics Education and Learning- Oriented

This cluster has only two keywords. These are mathematic education and experiential learning. The cluster, though very small, suggests that simulation-based approaches have become an identifiable research area within mathematics teaching and learning.

DISCUSSION

In this study, publication related to computer simulation in education were retrieved from Openalex database and analysed using VOSviewer. The study comprises articles published in English Language. A total of 710 articles indexed in the Openalex database on the topic computer simulation in teaching and learning from 2015 to 2025 (the past eleven years) were contained in the bibliometric analysis.

The results of analysis conducted showed that studies on computer simulation in teaching and learning has increased significantly in recent years. A close look at the distribution of the 710 publications revealed that between 2015 (16 articles) and 2019 (33 articles) there was gradual growth in publications. A rapid rise occurred from 2020 reaching a peak around 2024. There is a slight drop in 2025, possibly due to incomplete journal indexing since the year has not ended. The increase in the number of publications in recent years can be attributed to advancements in digital and simulation technologies, a shift toward competency-based learning or pandemic-driven adoption of virtual instruction. The review is in line with the findings of Yao, *et al.,* (2022) who retrieved data from the Web of Science Core Collection (WOSCC). A total of 1,178 publications were included in their review. VOSviewer and CiteSpace were used for network mapping and keyword analysis. They found that Publications increased from 48 in 2011 to 175 in 2021. The steady increase in publications (48 → 175) confirms the upward trajectory of simulation based medical education research; matching the dataset's overall growth trend in the study. Harahap, et al. (2025) examined 82 articles retrieved from Scopus database from 2006–2024. The results indicate a significant increase in publications since 2017, peaking in 2020–2021 due to technology adoption during the COVID 19 pandemic. Similarly, Xu et al. (2025) selected 982 papers from the Web of Science database related to virtual simulation in education from 2000 to September 2, 2024. They reported that the first publication in the field appeared in 2000, it is interesting that significant contributions to the field were not recognized until 2002. Nonetheless, there was a significant exponential increase in the number of publications between 2007 and 2023. The observed significant increase indicates a growing interest in research on the application of virtual simulation in education. These findings suggest a potential rise in research on simulations in teaching and learning in the future.

The distribution of publications reveals an uneven but globally expanding research landscape in computer simulation in teaching and learning. China's dominance mirrors its national strategy of investing in educational technology and STEM simulation research over the past decade, supported by substantial government funding and partnerships between universities and technology enterprises (Liu et al., 2023; Ba et al., 2025).The United States remains the second most productive country and exhibits the highest level of global collaboration, consistent with its historical leadership in simulation-based learning research and cross-disciplinary partnerships (Yao et al., 2022; Harahap et al., 2025; Arshad, et al., 2024). The central position of the United States suggests its important role in facilitating international research cooperation, bridging multiple clusters and fostering cross-regional knowledge exchange. Similarly, the United Kingdom and Spain serve as European hubs, producing fewer but highly cited studies often in collaboration with U.S. and Chinese institutions (Alharbi et al., 2024). Emerging contributions from India, South Korea, and Ukraine signify an encouraging diversification of research geography. However, their relatively low TLS values suggest limited integration into the broader global network;

a gap that future initiatives could bridge through international research associations, exchange programs, and co-authored projects.

Overall, this stresses the fact that publication volume alone does not guarantee research influence. Countries such as Spain and Germany demonstrate how strategic collaboration and focus on high-impact journals can yield strong citation outcomes even with fewer publications. This pattern aligns with global bibliometric findings that show increasing centralization of scientific influence around collaborative hubs rather than sheer productivity (Ba et al., 2025). Overall, collaboration networks reveal global interdisciplinary efforts, but regional imbalances persist. Therefore, fostering partnership between leading and developing countries could enhance the dissemination of simulated-based teaching models across various educational discipline (Bidayan, 2025).

When examining authors who have conducted research on computer simulation in teaching and learning, it is evident that Omar Chamorro- Atalaya (6), Fengfeng Ke (4) Guillermo Morales-Romero (3) and Antonio Arevalo-Tuesta (3) are the most influential authors based on their publication output. In terms of citation, Fengfeng Ke ranked first with 120 citations, demonstrating the strongest global influence and a high citation-to-publication ratio. Abdullah Alhumaidi Alotaibi, Abir Osman Elfakki, and Souhir Sghaier each recorded two publications and 56 citations, reflecting their involvement in collaborative, high-impact international studies. On the other hand, Omar Chamorro-Atalaya who exhibited the highest productivity with six publications and the greatest network connectivity (TLS = 14), is identified as a central figure in the regional research community. Together with Guillermo Morales-Romero, Elizabeth Auqui-Ramos, José Antonio Arévalo-Tuesta, Dora Arce-Santillan, and Yadit Rocca Carvajal, he forms a cohesive Latin American cluster characterized by strong institutional collaboration but moderate citation visibility. Upon reviewing Fengfeng Ke works, it is evident that her highly cited and valuable work (2022), on "educational applications of artificial intelligence in simulation-based learning: A systematic mapping review" identifies five specific areas in AI-powered simulation-based learning where more research is needed, thereby providing a valuable resource for those entering the field. Alotaibi, Elfakki and Sghaier (2023) represent emerging influencers in simulation-based learning with a distinctive niche (abled / disabled learners) in machine-enhanced simulation environments as evidenced by their high citation. Their work aligns with key trends in simulation research: 3D simulation, adaptive assessment, which have high potential for innovative contributions in the field of education.

The top three journals that published the most articles are "Computer applications in Engineering", "Journal of Physics Conference Series" and "Sustainability" while "British Journal of Educational Technologies", "Sustainability" and "Computer Application in Engineering" are the three most cited journals in the use of computer simulation in teaching and learning. The VOSviewer map shows a central education technology journal ("British Journal of Educational Technologies) that is strongly co-cited with outlets from several distinct thematic clusters (virtual reality, applied engineering journals, applied mathematics, and sustainability). These citation dynamics mirror recent bibliometric and systematic reviews showing the field's interdisciplinary citation structure and the emergent role of immersive technologies (Xu, et al., 2025).

The visualization in keywords analysis reveals different colours clusters, indicating the interdisciplinary nature of research in the use of computer simulation in teaching and learning. Five clusters were obtained from this analysis. The red cluster (Engineering and Computing Applications), green cluster (Medical and Health Education), blue cluster (Social Sciences and Emerging Technologies), yellow cluster (Cognitive and Psychological Foundations) and purple cluster (Mathematics Education).

The main keywords identified from the red cluster include; computer simulation, computer science, engineering, Physics, Mathematics, Software, Computer Vision, Software Engineering, Mechanical Engineering, computer graphics. The prominence of these keywords indicates that simulation research remains strongly grounded in technological and computational disciplines. Historically, computer simulation emerged as an engineering and scientific tool for modelling complex systems and predicting their behavior under different conditions (Naciri et al., 2024). The strong linkage between computer simulation and engineering-related terms suggests that simulation continues to play a critical role in design optimization, system analysis, and computational experimentation (Patel & Patel, 2024).

In the green cluster, the main keywords identified are Psychology, Medicine, Medical education, Nursing, Nurse education, Simulation training, Healthcare, Physical therapy, Curriculum. This cluster demonstrates the extensive adoption of simulation technologies in health-related disciplines. Healthcare has emerged as one of the most significant application domains of simulation because it enables learners and practitioners to develop clinical competencies in safe and controlled environments without exposing patients to unnecessary risks (Jones et al., 2015; Sivrikaya & Gonenli, 2024). The strong relationships among medical education, nursing education, and simulation training suggest that simulation has become an integral component of contemporary healthcare education. It shows that simulations are used not only in technical fields but also in medical education to improve medical students' conceptual understanding and engagement (Sivrikaya & Gonenli, 2024).

The main keywords in the blue clusters are Human-Computer Interaction, Sociology, Geography, Political science, Business, Data science, Knowledge management, Metaverse, Engineering ethics, Mixed reality, Art. This cluster demonstrates the increasing diversification of simulation research beyond traditional scientific and engineering disciplines. The inclusion of social science concepts suggests that simulation methodologies are increasingly employed to model human behavior, social interactions, organizational systems, and policy outcomes. Social simulations allow researchers to investigate complex societal phenomena that may be difficult to study through conventional experimental approaches (Gilbert & Troitzsch, 2005). It links technical and educational simulations with policy, ethics and management. Engineering ethics suggest concerns about ethical use of simulation technologies while knowledge management and political science point to how simulation supports decision-making and governance in educational or industrial contexts. Similar interdisciplinary trends were reported by various researchers. For instance, Suh and Prophet (2018) observed that simulations, especially those employing virtual and augmented reality enhance interdisciplinary collaboration by linking technical problem-solving with leadership and ethical reasoning. In engineering education, Kandakatla et al. (2020) proposed a simulation-ethics framework showing that embedding ethical dilemmas in simulation-based learning improves both ethical reasoning and managerial decision making alongside technical understanding. De Jong et al. (2019) further argued that simulations enhance learners' inquiry and decision-making abilities by encouraging them to consider technical feasibility, resource allocation and social responsibility concurrently.

The fourth cluster, represented in yellow, focuses on cognitive and psychological dimensions of simulation research. Key terms include cognition, cognitive psychology, attention, perception, social psychology, applied psychology, and immersion. The existence of this cluster indicates that simulation research is not solely concerned with technological development but also with understanding how individuals think, learn, and behave within simulated environments. Cognitive theories have become increasingly important in explaining how learners process information, develop mental models, and transfer knowledge acquired through simulation experiences (Mayer, 2024). Research has consistently shown that immersive simulation environments can enhance psychological mechanisms that influence engagement, motivation, concentration, learning effectiveness and knowledge retention by creating realistic and engaging learning experiences (Slater et al., 2009; Grabarczyk & Pokropski, 2016; Radianti et al., 2020).

The fifth cluster, represented in purple, is centered on mathematics education. Although this cluster contains fewer keywords than the others, its position near the center of the network suggests considerable intellectual significance. Based on the map, the purple cluster appears to revolve around mathematical education applications of computer simulation, particularly those emphasizing active, experiential, and constructivist learning approaches. Mathematics often involves abstract concepts and dynamic relationships that learners may find difficult to visualize through traditional instructional approaches. Simulation-based environments provide opportunities for exploration, visualization, and conceptual understanding, thereby enhancing mathematical reasoning and problem-solving abilities (Borba et al., 2016). The inclusion of experiential learning further highlights the pedagogical orientation of this cluster. Experiential learning theory posits that knowledge is created through the transformation of experience, with learners actively engaging in observation, experimentation, reflection, and application (Kolb, 1984). The close association between experiential learning and simulation suggests that researchers increasingly view simulation as a means of creating authentic learning experiences in which learners can explore complex phenomena within safe and controlled environments.

CONCLUSIONS

This bibliometric analysis provides a comprehensive examination of the use of computer simulation in teaching and learning, highlighting its critical role in enhancing the educational sector. This approach employs advanced methods, including author, country, publication and keyword co-occurrence analyses. The result of the bibliometric analysis confirms that computer simulation has become an integral component of modern educational research and practices. Its continued development, supported by interdisciplinary collaboration and advances in artificial intelligence and virtual reality promises to further transform how knowledge is being taught, learned and applied. The field is progressing, emphasizing not only the effectiveness of simulations in enhancing learning outcomes but also their role in preparing learners for complex, real-world problem solving. Despite the progress, there seems to be limited research output from developing region like Africa. Most publications originated from technologically advanced regions such as America, Europe and East Asia. There is a need for more research in developing countries to reflect diverse educational contexts and challenges. Moreso, collaboration network among authors remains weak, indicating that research efforts are regional rather than globally integrated.

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