Bibliometric Analysis of Studies on Metaverse in Education

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Abstract: *Cyberspace has continued to expand due to increasing empirical explorations and the invention of novel technologies that have been constantly making significant modifications to how people interact with technologies. One of the significant outcomes of those empirical explorations and inventions is Metaverse, which is a virtual environment or a cyber-simulated setting where numerous users in remote physical places can interact or work simultaneously. The application of Metaverse in education has been growing over time due to technological innovations and the inability of existing studies to cover comprehensive bibliometric analysis of literature on the application of Metaverse in education to date automatically creates a research gap that needs to be filled. The peculiarity of this study is premised on the limitations of the existing bibliometric studies on the Metaverse. This study applied bibliometric analysis via science mapping with the aid of VOSviewer software for data analysis and dissection to provide a general idea about the current knowledge base on Metaverse in education. The exploration was based on the data generated from the Scopus database. Findings from this study show the journals with the most cited publications on Metaverse in education, their attributes, and the intellectual structures of knowledge, which are; i.) the impacts of Metaverse on education, ii.) Metaverse for remote education, iii.) application of Metaverse in medical and health education, iv.) Metaverse for improved learning, assessment, and engagement, v.) Metaverse for teacher education. The collaboration network between countries placed the US at the center with no country from Eastern Europe and Africa appearing on the network visualization and suggestions were made for further research directions.*

Keywords: Metaverse, Virtual Reality, Mixed Reality, Augmented Reality, Education.

1. Introduction

Cyberspace has continued to expand due to increasing empirical explorations and the invention of novel technologies that have been constantly making significant modifications to how people interact with technologies. One of the significant outcomes of those empirical explorations and inventions is Metaverse, and to even imagine that some of the leading Tech Chief Executive Officers such as Satya Nadella of Microsoft and Mark Zuckerberg of Facebook (now Meta) discourse about Metaverse as the future of the cyberspace provide another

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significant recognition of metaverse as a novel concept that has potential to dominate the cyberspace. The pioneer description of metaverse took place in a novel titled "Snow Crash" by Neal Stephenson in 1992 and this pioneering description became the concept applied in describing virtual worlds, 3D where people relate with one another and their environment devoid of the physical restrictions of the real world (Narin, 2021). Ondrejka (2004) also affirmed that Snow Crash, a science fiction novel by Neal Stephenson in 1992 presented the idea of metaverse to readers, describing a virtual setting that serves as an actual place to the users where these users relate by applying the tangible world as a metaphor, and interacts, carry out economic activities and were kept amused. Dionisio, III, and Gilbert (2013) refer to the virtual environment as the cyber-simulated settings where various users in remote physical places can relate to play or work in real-time. Benedikt (2008) claimed that CitySpace which was in operation between 1993-1996 was the first metaverse. Afterward, Narin (2021) recorded that several metaverses like Active Worlds by Schroeder, Huxor, & Smith (2001) and Thereby Makena Technologies came into existence. Narin (2021) went further to state that Second Life created in 2003 by Linden Lab was the most famous and it gave room for the emergence of web-based virtual worlds to game lovers.

The transition from a set of autonomous virtual environments to Metaverse or an integrated network of 3D virtual environments relies on the advancement in the areas of "scalability, interoperability, the ubiquity of access and identity, and immersive realism" (Dionisio et al., 2013, p. 1). Metaverse is not a novel concept in education because it has successfully become an attraction point for pedagogists for some years based on the fact that numerous scholars, educators, and researchers have deliberated the implications of the concept for teaching and learning (Tlili et al., 2022). To mention a few of these studies, the integration of Metaverse via the application of a virtual environment named "Second Life" into the learning management systems to improve the teaching and learning process was done through the work of Kemp and Livingstone (2006). Another study (Collins, 2008) put forward an argument on the possibility of Metaverse becoming the new space where people can gather and interact with demanding educational institutions to be prepared for its application for instructional purposes with a focus on the virtuality aspect of the concept. Schlemmer (2014) added that Metaverse provides communication and collaboration platforms via the avatar that replicates the sensitivity of presence. Table 1 below shows the existing literature on Metaverse from the bibliometric analysis perspective.

Table1. A summary of existing bibliometric reviews on Metaverse and their limitations

Author(s)	Study Title	Article Type	Limitations
Schmitt (2022)	Metaverse: Bibliometric Review, Building Blocks, and Implications for	Bibliometric Analysis	The bibliometric analysis was limited to studies on Metaverse from the context of Business,

	Business, Government, and Society		Government, and Society.
Tlili et al., (2022)	Is Metaverse in education a blessing or a curse: a combined content and bibliometric analysis	Bibliometric & Content Analysis.	Metaverse and education but the article could not answer bibliometric analysis questions extensively due to the integration of content analysis into the same study.
Chen & Zhang (2022)	Exploring Research Trends of Emerging Technologies in Health Metaverse: A Bibliometric Analysis	Bibliometric Analysis	The bibliometric analysis was limited to Metaverse from the context of medicine and healthcare.
Abbate et al., (2022)	A first bibliometric literature review on Metaverse	Bibliometric Analysis	The bibliometric analysis used a single keyword "Metaverse" for data collection.
Damar (2021)	Metaverse Shape of Your Life for Future: A bibliometric snapshot	Bibliometric Analysis	The bibliometric analysis used a single keyword "Metaverse" for data collection.
Tas & Bolat (2022)	Bibliometric mapping of Metaverse in education	Bibliometric Analysis	The bibliometric analysis used keywords related to Metaverse but excluded education and other keywords related to it from the search string.

The inability of existing studies to cover comprehensive bibliometric analysis of literature on the application of Metaverse in education to date automatically creates a research gap that needs to be filled. The peculiarity of this study is premised on the limitations of the existing bibliometric studies on the Metaverse. For instance, this study used keywords such as “mixed reality”, “extended reality” related to Metaverse, as against Damar (2021) and Abbate et al (2022) single keyword, in combination with other keywords such as “pedagogy”, “learning”, “teaching” related to education against Tas et al (2022) and Schmitt (2022) exclusion of keywords related to education. This study concentrated on only bibliometric analysis to provide answers to only bibliometric questions against Tlili et al. (2022) integration of content analysis questions. However, it is essential to

note that this does not in any way or form translate to an attempt to garbage these existing studies but fill the research gaps in these studies. Thus, this current study will in no doubt serve as the pioneering effort to provide an all-inclusive bibliometric analysis of literature on the application of Metaverse in education, to establish significant advancement and trends in this academic domain. This study will recommend research prospect agenda within the horizon of Metaverse in education and as create an equilibrium point for both contemporary and the past on the use of Metaverse in education for researchers. Furthermore, this study will support Metaverse developers, policy-makers, and educators to come up with novel programs on the use of Metaverse for improved instructional results.

This bibliometric study was set up with the main goal of assessing the current state of studies on Metaverse in education, with the main importance on the intellectual structure, research trends, the nature of co-authorship between countries, and key concepts. The following bibliometric analysis questions were raised for the purpose of actualizing the above research objective:

1. What are the top journals that have published the most cited articles on Metaverse application in Education, and what are their attributes?
2. What are the leading concepts (i.e., keywords) that have been explored in Metaverse in education and how are they connected?
3. What is the intellectual structure of knowledge on Metaverse in education?
4. What is the co-authorship network between countries where articles on Metaverse in education were published?

2. Method

This study applied bibliometric analysis, which deals with procedures for retrieving and statistically examining quantifiable information in published research articles (Godin, 2006), and it also integrates both statistical and quantitative analysis to account for the distribution arrangements of the published studies on certain topics and from particular periods with the capability to provide valued insights to the academic discourse arena (Martí-Parreño, Méndez-Ibáñez, & Alonso-Arroyo, 2016). According to Moral-Muñoz, Herrera-Viedma, Santisteban-Espejo, and Cobo (2020), bibliometrics has grown into a significant tool for measuring and examining the output of researchers, the collaboration between higher institutions of learning, the impacts of public-owned science finance on domestic research and development. Data sourcing was conducted on the Scopus database covering title, abstract, and keywords with certain specifications such as document type and language, but there was no time limit. Several studies have supported the adoption of the Scopus database for bibliometric studies based on the wider coverage of the database (Zhu, & Liu, 2020; Kawuki, Yu, & Musa, 2020), although they are others with divergent submissions on the said coverage (Hedding & Breetzke, 2021; Tennant, 2020). Science mapping was applied in this study to

provide a general idea about the current knowledge base on Metaverse in Education. According to Van der Veer Martens (2007), science mapping refers to a procedure for conducting a bibliometric exploration of research work and literature.

Science mapping refers to a technique for leading a bibliometric investigation of writing and academic work (Van DerVeer Martens, 2007). Chen (2017) added that science mapping research majorly comprises many mechanisms, particularly a group of scientific literature, metrics, a set of visual analytic and scientometric apparatuses, and pointers that are capable of recognizing possible significant arrays and styles, and principles of systematic modification than can lead the investigation and analysis of visualized intellectual configurations and vibrant arrangements. Science mapping has also been categorized as an interesting subdivision of bibliometric examination in which scholars endeavor to investigate and graphically show the associations among the different scientific knowledge as it advances and develops throughout the long term by Eck and Waltman (2014). Cobo, López-Herrera, Herrera-Viedma, and Herrera (2011) added that these associations can be examined by applying different units like author, institution, keyword, publication, country and journal, institution and country as the foundation for investigation.

The process of science mapping analysis can be largely illustrated in seven phases: data recovery, pre-processing, network extraction, standardization, mapping, analysis, and visual representation (Cobo et al., 2011). However, lots of these phases do not appear to be autonomous as they are done concurrently by the VOSviewer and other related software designed for the same purposes with a couple of clicks of the mouse. Moosa and Shareefa (2020) cited the instance of VOSviewer software's five stages of network extraction, standardization, mapping, analysis, and visual representation which are totally done instantaneously when the necessary boundaries are chosen as wanted. Thus, this study employed the science mapping method with the aid of VOSviewer software for data analysis and dissection.

2.1. Data Sourcing, Inclusion, and Exclusion Criteria

The data sourcing was done on the 8th of September, 2022, returning 674 articles based on certain specifications such as document type (i.e., journals, articles, with the exclusion of conference proceedings and book chapters) and language (i.e., English language) without time limitation for the identification phase. To have clear-cut and appropriate data, the following elimination criteria were adopted;

- *Incomplete Data:* Any text that does not have authors' names or missing information is excluded;
- *Peer Review:* Any text that does not go through the peer review process prior to the publication of such is excluded;

- *Title, Abstract, and Keywords:* Any article that any of the synonyms of Metaverse and Education does not appear in either the title, the abstract, or the keywords of the text is excluded.

After the screening and elimination phase based on the above benchmarks, 29 articles were eliminated from the initial number of articles, limiting the available number of articles to 645. Away from the data gotten from the Scopus database, information was collated from Scimago Journal Ranking in order to have adequate features of the eligible journals based on ranking.

3. Findings

3.1. Journals with the most Cited Publications on Metaverse in Education and their Attributes

Table 2 shows the summary of journals that have published the most cited research on the metaverse in education and their attributes. With an aggregate of 645 articles, only 20 journals have been able to publish articles with a minimum of 5 citations when a minimum of 5 publications was applied as the threshold. Virtual Reality has 12 publications with 127 citations and 10.58 citations per publication to become the leading journal with the highest number of documents and citations, followed by Applied Sciences (Switzerland) with 11 publications, 115 citations, and 10.45 citations per publication. For the summary purpose, the details of the 20 journals that met the thresholds are presented in Table 3. The results indicated that only 19 journals were ranked by ScimagoJR, where 13 journals have Q1, 5 journals have Q2, and 1 journal has Q3 to complete the 19 journals ranked by ScimagoJR while the remaining 1 journal was unranked. According to Table 2, all the ScimagoJR ranked Q1 and Q2 journals have SNIP that is higher than one except Q3 with 0.35 as the lowest-ranked journal. Of all the journals with the highest citation, only three journals with the names “World Neurosurgery”, “Medical Science Educator”, and “International Journal of Computer Assisted Radiology and Surgery” came from the medical/health education domain. Five journals with the same “Computers and Education”, “Education and Information Technologies”, “Education sciences”, “Information and Learning Science”, and “International Journal of Emerging Technologies in Learning” came from the application of IT in the education domain journals while remaining are from chemical science, engineering, etc.

3.2. The Leading Concepts that have been explored on Metaverse in education and their connection

This study examines the co-occurrence of keywords that covered the keywords allocated by authors with a threshold of 10 as the minimum occurrence of a keyword and the findings are presented in Figure 1.

Table 2. Overview of topmost journals with most-cited publications and their attributes

Journal Name	TP	TC	CPP	CiteScore	SNIP[a]	SJR[b]
Applied Sciences (Switzerland)	11	115	10.45	3.7	1.03	0.51, Q2
Computers and Education	6	559	93.16	19.8	5.21	3.67, Q1
Computers and Graphics (Pergamon)	8	423	52.87	5.3	1.07	0.93, Q1
Education and Information Technologies	6	37	6.16	6.6	2.12	1.05, Q1
Education sciences	5	13	2.6	2.9	1.31	0.51, Q2
Electronics (Switzerland)	5	12	2.4	3.7	1.01	0.59, Q2
Frontiers in Virtual Reality	7	8	1.14	N/A	N/A	N/A
IEEE Access	13	111	8.53	6.7	1.32	0.92, Q1
IEEE Transactions on Visualization and Computer Graphics	10	78	7.8	11.4	2.43	1.75, Q1
Information and Learning Science	6	12	2	3.9	1.56	0.68, Q1
International Journal of Computer Assisted Radiology and Surgery	6	58	9.66	5.8	1.397	1.0, Q1
International Journal of Emerging Technologies in Learning	8	45	5.62	3.8	1.41	0.63, Q1
Journal of Chemical Education	5	79	15.8	4.8	1.25	0.50, Q2
Journal of Universal Computer Science	6	117	19.5	2.7	0.71	0.39, Q2
Medical Science Educator	6	21	3.5	0.9	0.35	0.22, Q3
Multimedia Tools and Applications	6	30	5	5.3	1.05	0.71, Q1
Research in Learning Technology	14	140	10	4.8	1.33	0.77, Q1
Sustainability	8	56	7	5.0	1.31	0.66, Q1
Virtual Reality	12	127	10.58	7.8	2.63	1.01, Q1
World Neurosurgery	6	58	9.66	3.6	1.1	0.69, Q1

TP = Total Publication, TC = Total Citations, CPP = Citation Per Publications, SNIP = Source Normalized Impact Per Paper, SJR = Scimago Journal Ranking, [a] Figures for 2021 from SCOPUS, [b] Figures for 2021 from ScimagoJR

According to the findings, the key concepts entrenched in all the articles can be plotted into five clusters and the most substantial keywords based on cluster size are “virtual reality”, “education”, “mixed reality”, “hololens”, and “mobile learning”. The most frequent keyword in Cluster 1 (i.e., Red) is “virtual reality” out of the 7 keywords that made up the entire cluster and it appeared 21 times.

Other keywords in this cluster based on appearance are “augmented reality” appearing 20 times, “extended reality” appearing 14 times, and “metaverse” appearing 14 times, while “machine learning” and “deep learning” had 9 and 7 appearances respectively. From Cluster 2, the most frequent keyword in this cluster (i.e., Green) is “education” out of the 7 keywords that made up the entire cluster and it has a 15-occurrence rate to also retain the first spot in the aggregate number of keywords in the cluster. “Learning” shared a similar occurrence rate with “education” in Cluster but with a weaker link strength compared to “education”. The third cluster (i.e., Blue) has “mixed reality” out of the entire 4 keywords that made up the cluster as the most frequent keyword with a 20-occurrences rate, followed by “covid-19”, “science education”, and “embodied learning” claiming 11, 7, and 6 occurrence rates respectively. “E-learning” competed with “hololens” by sharing a similar occurrence rate of 9 in Cluster 4 (i.e., Yellow), but “hololens” claimed the top spot in the cluster with a stronger link strength of 30 compared to 24 for “e-learning”. “Virtual worlds” is the least leading concept of the entire 3 keywords that made up the entire Cluster 4. Cluster 5 (i.e., Purple) has “mobile learning” as the only keyword that made up the cluster with stronger links to other keywords like “mixed reality”, “augmented reality”, “virtual reality”, “medical education”, and “simulation”.

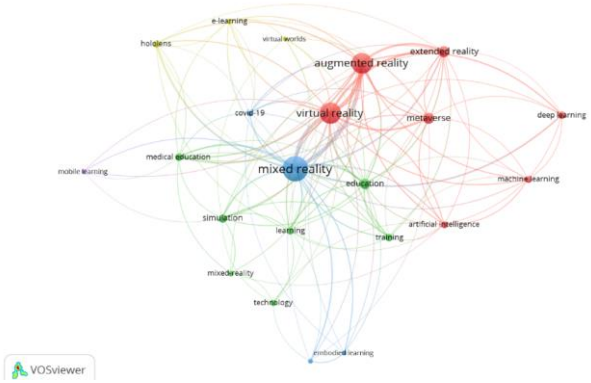

Figure 1. Co-occurrence mapping of the leading concepts.
Note: A least possible occurrence of 10 was used for the keywords whereby 22 of the 1942 keywords met the threshold.

3.3. The Intellectual Structure of Publications on Metaverse in education

This study conducted a co-citation network analysis of authors cited to ascertain the intellectual structure of the knowledge base as indicated in Figure 2.

The results from Figure 2 indicated that the intellectual structure of knowledge of articles published on Metaverse in education has 5 divergent bodies of knowledge; i.) the general impacts of Metaverse on education (Cluster 1 in Red), ii.) Metaverse for remote education (Cluster 2 in Green), iii.) Metaverse in medical and health education (Cluster 3 in Blue), iv.) Metaverse for improved learning, assessment, and engagement (Cluster 4 in Yellow) and v.) Metaverse for teacher education (Cluster 5 in Purple). Thus, these five clusters are regarded as the main themes of studies conducted on Metaverse in education respectively.

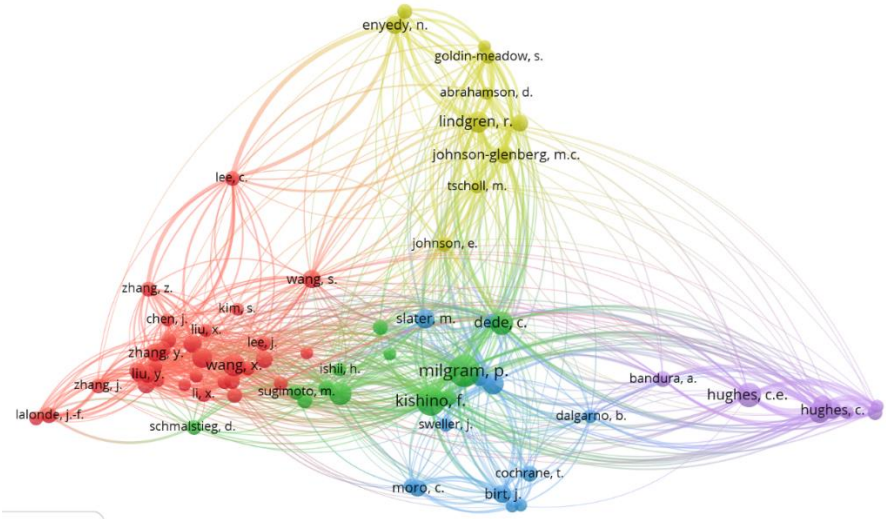

Figure 2. Co-citation network of publications on Metaverse in education.
Note: Using full counting, a threshold of 30 citations per article was adopted for the purpose of having a clearer interpretation of the co-citation network for establishing the intellectual structure. The network was only established for 75 authors out of the 42,787 authors.

Considering published articles in the first theme, (i.e., the general impacts of Metaverse on education) the most extremely co-cited authors are “Wang, X.” with 88 citation weight and 680 total link strength, followed by “Wang, J.”, with 72 citation weight and 769 total link strength. The leading co-cited authors as far as the second theme (i.e., Metaverse for remote education) are concerned, are “Milgram, P.” with 180 citation weight and 1696 total link strength, “Dede, C.” with 103 citation weight and 1104 total link strengths, etc., The two leading co-cited authors as far as the third theme (i.e., Metaverse in medical and health education) are concerned, are “Mayer, R.E.” with 82 citation weight and 1080 total link strength and “Moro, C.” with 51 citation weight and 415 total link strength. Other authors on this theme include Bailenson, J. N., Birt, J., Cochrane, T., Cook, D. A., etc. The two leading co-cited authors as far as the fourth theme (i.e., Metaverse for improved learning, assessment, and engagement) are concerned, are “Lindgren, R.” with 85 citation weight and 1407 total link strength and “Johnson-

Glenberg, M.C." with 61 citation weight and 1069 total link strength. Other authors on this theme include Abrahamson, D., Alibali, M. W., Birchfield, D., etc. The two leading co-cited authors as far as the fifth theme (i.e., Metaverse for teacher education) are concerned, are "Hughes, C.E." with 106 citation weight and 1234 total link strength and "Dieker, L.A." with 79 citation weight and 1114 total link strength. Other authors on this theme include Hynes, M.C., Straub, C., etc.

3.4. The Collaboration Network between Countries

Co-authorship analysis was conducted on the aggregate number of articles under investigation to ascertain the collaboration network between countries as indicated in Figure 3. As shown in Figure 3, the results indicated that the collaboration network between countries where articles on Metaverse in education were published has three alliance groups. Cluster 2 in Green with the United States leading the likes of Australia, Japan, New Zealand, and South Korea in the group. Cluster 1 is in Red with the United Kingdom leading countries like Brazil, France, Germany, Greece, Italy, Malaysia, Netherlands, Spain, and Taiwan in the group. Cluster 3 is in Blue with China leading the likes of India, Canada, and Singapore. From Figure 3, every collaboration network centered around the United States with 199 publications. China from cluster 3 has 53 publications, followed by the United Kingdom in cluster 1 with 48 publications, and Australia which belongs to the same cluster as the United States has 44 with three publications.

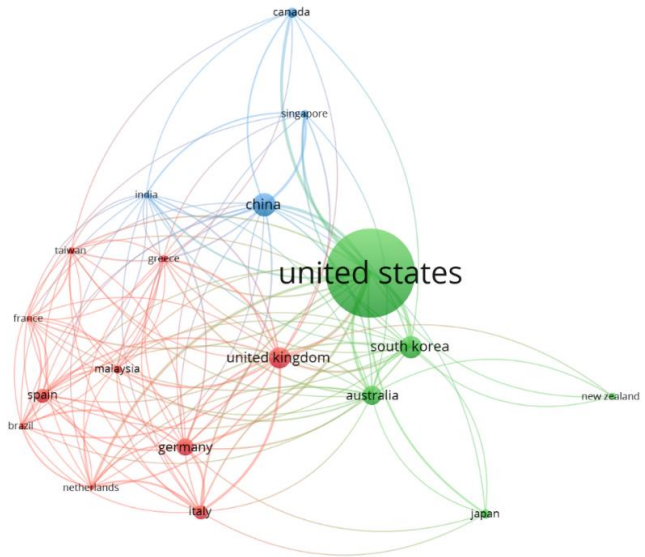

Figure 3. Collaboration network between countries. Note: Using full counting, a threshold of 10 publications per country was adopted for the purpose of having a clearer interpretation of the collaboration network. Only 19 countries met the threshold out of the 89 countries.

This result indicated that collaboration between the United States and other countries is at its peak without any visible alliance from Eastern European countries and Africa appearing on the co-authorship network visualization.

4. Discussion

The findings of the study indicated that from the 20 journals that published the most cited articles on the application of Metaverse in education, 1 journal was not ranked at all, 13 journals have Q1, 5 journals have Q2, and 1 journal has Q3 to complete the 19 journals ranked by ScimagoJR. According to Eck et al. (2014), SNIP evaluates the average citation per article in a particular journal as a portion of the citation potential of the same journal in the particular topic area. Thus, when the SNIP score of a particular journal is higher than one, it is an indication that the average citation per paper in that journal is higher compared to the citation potential of the journal in its area of concentration (Björk & Solomon, 2014; Moosa et al., 2020). The SNIP scores in Table 3 indicated that only 17 journals out of the 20 top journals with the most cited papers have significant citation impacts in their area of concentration.

HoloLens happens to be the odd key concept from the leading five key concepts because the remaining 4 key concepts are general concepts connected with Metaverse in education while HoloLens is just a device captured under mixed reality. HoloLens is a mixed reality device with holographic processing that blends effortlessly with both the virtual world and the real world, advanced optics, and several sensors. Virtual reality and mixed reality are both related to education and mobile learning based on their application for the customary mode of teaching and learning, blended or hybrid education, and remote education. Away from co-citation network interpretation, it is essential to note that there is a close association between three divergent bodies of knowledge (i.e., the general impacts of Metaverse on education, Metaverse for remote education, and Metaverse in medical and health education), while the remaining two clusters (i.e., Metaverse for improved learning, assessment, and engagement, and Metaverse for teacher education) distant themselves from the first three as indicated on the bibliometric coupling map. Another major point of attraction to the co-occurrence mapping of the leading concepts showed “Covid-19” with 11 occurrence rates and this can be attached to the dependency of education during the Covid-19 pandemic on e-learning that integrated Metaverse. From the collaboration network between countries, it is evident that the United States has the highest number of collaborations, followed by China which belongs to the same cluster as the aforementioned, then the United Kingdom from cluster 1, Australia, and Germany. This implies that the United States is at the center of collaboration network between countries because it has a collaboration network with the other two clusters that appeared on the collaboration map.

5. Conclusions

This study conducted a bibliometric analysis of articles on the application of Metaverse in education without time limitation. Citations of articles were analyzed to ascertain the most cited articles, the journals that published those articles, and the features of those journals, the leading concepts that have been explored were presented using the keywords, the intellectual structure of knowledge, and the collaboration network between countries where articles on the application of Metaverse in education were published was established. The SNIP scores indicated that only 17 journals out of the 20 top journals with the most cited papers have significant citation impacts in their area of concentration, making it recommendable that scholars should consider journal metrics that will include SNIP and quartile rank in order to publish in journals that have significant citation impacts in their area of concentration. From the intellectual structure mapping, five divergent groups were discovered, the first group covered the general impacts of Metaverse on education, the second group covered Metaverse for remote education, the third group covered Metaverse in medical and health education, the fourth group covered Metaverse for improved learning, assessment, and engagement, and the fifth group covered Metaverse for teacher education. This might aid future scholars in comprehending the existence of five bodies of knowledge in the application of Metaverse in education. The result indicated that collaboration between the United States and other countries is at its peak without any visible alliance from Eastern European countries and Africa appearing on the co-authorship network visualization. Since no African and Eastern European countries appeared on the collaboration map, this gives a clear indication that researchers from Africa and Eastern Europe need to collaborate more across the globe in order to have global visibility and impacts on Metaverse and education. It is recommended to explore the potential of applying Metaverse in special education as assistive technology, the affordability of Metaverse tools by educators and learners in both developed and developing countries, and the issue of equity and accessibility with respect to the application of Metaverse in education.

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