The Use of Virtual Worlds in the Field of Education: A Bibliometric Study

Ali Battal[*]

Department of Educational Sciences, Selçuk University, Konya, Türkiye
ORCID: 0000-0001-8659-2294

Abdulkadir Taşdelen

Department of Software Engineering, Ankara Yıldırım Beyazıt University, Ankara, Türkiye
ORCID: 0000-0003-4402-1463

The purpose of this study is to examine the publications conducted in education related to virtual worlds with the bibliometric analysis method. This study employed the appropriate keywords determined via digging the Web of Science database. A total of 2,978 publications meeting the criteria of the current study were examined. VOSviewer software was used for the analysis. We utilized co-authorship analysis to see the descriptive characteristics of the examined publications. The most conducted type was proceedings and the number of publications fluctuated over time with a peak in 2012. England, USA, and Spain had the most publications among the countries, and Open University, Coventry University, and the Polytechnic University of Bucharest had the most publications among the organizations. The majority of the studies were published in the journal of Computers & Education, British Journal of Educational Technology, and Interactive Learning Environments. For revealing the most common keywords, we used the co-occurrence analysis. "e-learning", "second life" and "higher education" were the most occurred keywords in the publications. The citations analysis was used to see which authors and publications were mostly cited in the examined papers. The most cited authors were Dede, C., Lan, Y. and Ketelhut, D. J. According to the analysis of the cited references, Dalgarno and Lee, (2010), Merchant, Goetz, Cifuentes, Keeney-Kennicutt, and Davis, (2014) and Dunleavy et al. (2008) were the most cited studies. Technological developments have affected the interest in the use of VWs in education. As a new type or extension of virtual worlds, metaverse promises new opportunities in education. The findings of this study would present a road map for those future research to see the general picture of the relevant area.

Introduction

The prevalence of digitalization with the recent global outbreak around the globe has impacted human life in many aspects as well as the field of education. The traditional way of

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[*] Correspondency: albatt@gmail.com

teaching has moved to online forms nowadays. However, the traditional online format was generally conducted in 2D format consisting of web based learning environment and extensive use of video conferencing tools (i.e. Zoom), and it was well-known that this way of online learning had limitations and inefficiencies (Mystakidis, 2022). Mystakidis listed the drawbacks of 2D online learning as low self-perception, no presence, and low level of activity and emotional expression, and he has argued that those limitations could be overcome with 3D learning environments. At this point, metaverse, the new form of virtual worlds, is expected to take charge (Kye, Han, Kim, Park, & Jo, 2021). Virtual worlds (VWs) with their characteristics have been used in education for more than two decades and their use in educational research fluctuated over time (Reisoğlu, Topu, Yılmaz, Karakuş Yılmaz, & Göktaş, 2017). Today, virtual worlds drew the attention of educators and researchers again through the rise of recent technologies, such as augmented reality (Reisoğlu et al., 2017) and metaverse (Tlili et al., 2022).

Nowadays, the brand-new technology, metaverse is on the rise and there have been many expectations from this technology on behalf of education (Dionisio, Burns III, & Gilbert, 2013; Kye et al., 2021; Yu, 2022). The idea behind the metaverse was to connect independent virtual worlds and combine them into one umbrella technology. Dionisio et al., (2013) explained this as metaverse is "an amplified version of an individual virtual world to conceiving it as a large network of interconnected virtual worlds" (p. 34:7). When the historical development of metaverse was examined, the trace of virtual worlds could be seen in this continuum. Starting with the idea in the science fiction book titled "Snow Crash" corresponds to the literature stage, it has passed four more stages, namely, text-based interactive games, virtual worlds, immersive virtual environments, and metaverse era today (Lee et al., 2021). Besides, virtual world is one of the types of metaverse (Kye et al., 2021), and has been the mostly used type in education according to the systematic review of metaverse-related studies (Tlili et al., 2022).

Multiple terms interchangeably were used instead of VWs in some studies (Girvan, 2018; Kim, Lee, & Thomas, 2012) such as Multi-User Virtual Environments (Dieterle & Clarke, 2006), and Virtual Learning Environments (Reisoğlu et al., 2017). There are also various definitions of VWs today due to multiple emerging forms of virtual environments and the technology behind them (Warburton, 2009). We have preferred the term "virtual worlds" in this study and followed the definition of Girvan (2018). She has examined multiple definitions in the literature and developed a mutual definition as "shared, simulated spaces which are inhabited and shaped by their inhabitants who are represented as avatars" (p. 1099). VW applications were varied in terms of open-source or proprietary (Warburton, 2009). The most preferred ones were ActiveWorlds, Second Life, and OpenSim, (Mantziou, Papachristos, & Mikropoulos, 2018). Virtual worlds have common technical features. Girvan (2018) listed them as avatars, multiple concurrent users, multiple forms of communication, immersive and persistent environment, content building tools and she added that rather than bringing the technical features of VW applications to the fore, researchers and educators should take care of the educational activities that could be conducted in the virtual environment.

Virtual worlds have been used in many disciplines from computer science to language learning, from healthcare to teacher education (Tokel & Cevizci-Karataş, 2014). In their study, Mantziou et al., (2018) reviewed studies using Second Life platform and they presented discipline related learning activities applied in VWs. For example, in architecture, generally building and design of the environment were used, whereas scripting was used in the computer science discipline. Additionally, previous literature review found that virtual worlds were used for supporting learning, simulating, social interaction, and gaming, and there were a wide variety of learning

strategies applied in virtual world research such as collaborative, role play, exploration based or problem-based learning (Reisoğlu et al., 2017).

The literature reviews were conducted examining the use of VWs in education in the past at different times. However, none of them used bibliometric techniques. They mostly applied content analysis techniques to a limited number of articles within a period. Reisoğlu et al., (2017) have mentioned this issue as "the reviews often included a fairly limited number of studies falling below 50 studies per review" (p. 83) and they have reviewed 167 empirical studies using VWs in terms of various points such as applications, methods, sample size, and research topic. In another review, Pellas, Kazanidis, Konstantinou, & Georgiou, (2017) examined 50 articles published between 2000 to 2016 using VWs in STEM education. Similar to those, Kim et al., (2012) and Tokel and Cevizci-Karataş, (2014) examined a limited number of research papers in their review by applying content analysis.

All mentioned systematic reviews focused on a) research articles only b) a specific application such as just considering the use of Second Life, c) limiting a narrow period, and d) generally using content analysis. Therefore, there was a need to take the general picture of using VWs in the field of education from the beginning of its first use with the help of bibliometric analysis. The purpose of this study is to examine the publications conducted in the field of education related to virtual worlds with bibliometric analysis. In this way, it would be possible to see tendency, mutual concepts, collaboration, and citations (most cited documents, and sources). Researchers would see how virtual world research evolved in terms of studied concepts over the years. Besides, the most productive countries, organizations, authors and the most cited documents and sources would be revealed.

The research questions of the current study were as follows:

- What are the descriptive characteristics of the examined publications in terms of publication type, publication year, sources with most publications, the origin of country, and organization?
- What kind of a structure emerges according to co-occurrences?
- How are the citation ranking of examined publications in terms of top contributors, and the most cited publications?

Method

We used the bibliometric analysis method to answer the research questions of the current study. This method is used when the researchers examine the status and trends in the relevant literature by revealing some issues about the examined topic such as the most contributed authors, sources, commonly used keywords, and citations to the publications (Ellegaard & Wallin, 2015). Nowadays, this analysis was frequently used in educational studies (i.e., Deveci, 2022; Zhang et al., 2022).

The common steps of systematic literature review studies were followed in the current study. Firstly, a review protocol developed by the researchers was followed which would help eliminating researcher related bias (Newman & Gough, 2020). In this protocol, the publication types, period, and database to be examined were determined. Since the aim of this study was to reveal the tendency in the educational use of virtual worlds from a broader context, reviews, articles, and proceedings were included except than only book chapters and no period was defined. Then, the database to be searched was defined as the Web of Science™ Core Collection (WoSCC) database.

Previous literature reviews were examined to reveal the keywords associated with virtual worlds. After that, the retrieval search string was constructed by combining keywords with appropriate Boolean operators: (TS = ("virtual world*" OR "virtual learning environment*" OR "Multi-User Virtual Environment*")). On June 16, 2022, we searched for and acquired data from WoSCC. Then, we retrieved 14,652 results. Following that, we applied the criteria to reach the final publication list. Table 1. shows the selection criteria applied in the current study. We focused on the only English publication and eliminated 1,212 non-English records. Next, among different publication types, we included only articles, reviews, and proceedings. The number of publications decreased to 12873. WoSCC database has a variety of research areas. In this study, we prefer to select the records belonging to the "Education Educational Research" area by eliminating the book chapters. Consequently, we got 2,978 articles, reviews, and proceedings written in English in the field of "Education Educational Research".

Table 1. Bibliometric review steps for including and excluding criteria

Step #	Criterion	Details	Results
Step 1	Database	WoSCC	
	Index	All	
	Date	June 16, 2022	
	Keywords	(TS = ("virtual world*" OR "virtual learning environment*" OR "Multi-User Virtual Environment*"))	14,652
Step 2	Language	English	13,440
Step 3	Publication Type	Article + Reviews + Proceedings	12,873
Step 4	Research Area	Education and Educational Research	3,276
Step 5		Book chapters excluded	2,978

Data Analysis

By running the same query on June 16, 2022, we independently and concurrently downloaded and verified raw data from WoSCC. We double-checked each record after data verification to ensure that it was appropriate for use in the analysis program. As a result, we pre-processed all records and found no missing records. Common systematic review steps were followed (Newman & Gough, 2020) and those steps were explained a) for a transparent and rigorous study, b) for other researchers to validate results using the same database (Kerres & Bedenlier, 2020).

The preprocessed data were then analyzed in VOSviewer 1.6.18 (VOSviewer, 2022) to gain a better understanding of the use of virtual worlds in the field of education. The type and unit of analysis and counting method applied in VOSviewer software were presented in Table 2.

Table 2. Applied types, units of analysis, and counting methods in VOSviewer

Type of analysis	Unit of analysis	Counting method
Co-authorship	Authors	Full Counting
	Countries	Full Counting
	Organizations	Full Counting
Co-occurrence	Author keywords	Full Counting
Citation	Cited authors	Full Counting
	Cited documents	Full Counting

Findings

The purpose of this study is to examine the publications conducted in the field of education related to virtual worlds with the bibliometric analysis method. The results of the bibliometric analysis were presented in the following section in line with the research questions of the study.

Descriptive characteristics of the examined publications

Publications were examined according to their publication type and year. Additionally, they were evaluated in line with the country and the organization of the publications' first author. The results related to county and organization were based on the first author's information due to VOSviewer's calculation process. Finally, the sources with the most publications were investigated.

Figure 1 illustrates the annual distribution of publications on virtual worlds in the field of education according to the publication type and year. The number of publications in 2007 increased by approximately 100% compared to the previous year. As can be seen from Figure 1, the acceleration of the increase continued from this year until 2012. The year with the highest number of publications was 2012 with 266 publications. Although it increased again in 2016, the number of publications decreased from 2012 to 2022. Proceedings were generally the most conducted type until the end of 2019. After the year 2020, the number of articles was more than the number of proceedings due to suspended conferences during the COVID-19 pandemic. As to reviews, the first one was conducted in 2007 when the literature related to VWs was enough and they were conducted in the following years after then. Out of 2,978 publications, 32 are early access and they do not have a publication year. For this reason, there are 2,946 publications in Figure 1.

In total, 99 countries/regions have contributed to the study of virtual worlds in education. Table 3 lists the top ten countries/regions. England had the most publications with 5,357 citations. And, The United States had the most citations (7, 257) with 395 publications. The third country with the most publications is Spain (293; 2,225), followed by Brazil (159; 229), and Australia (151; 2,725).
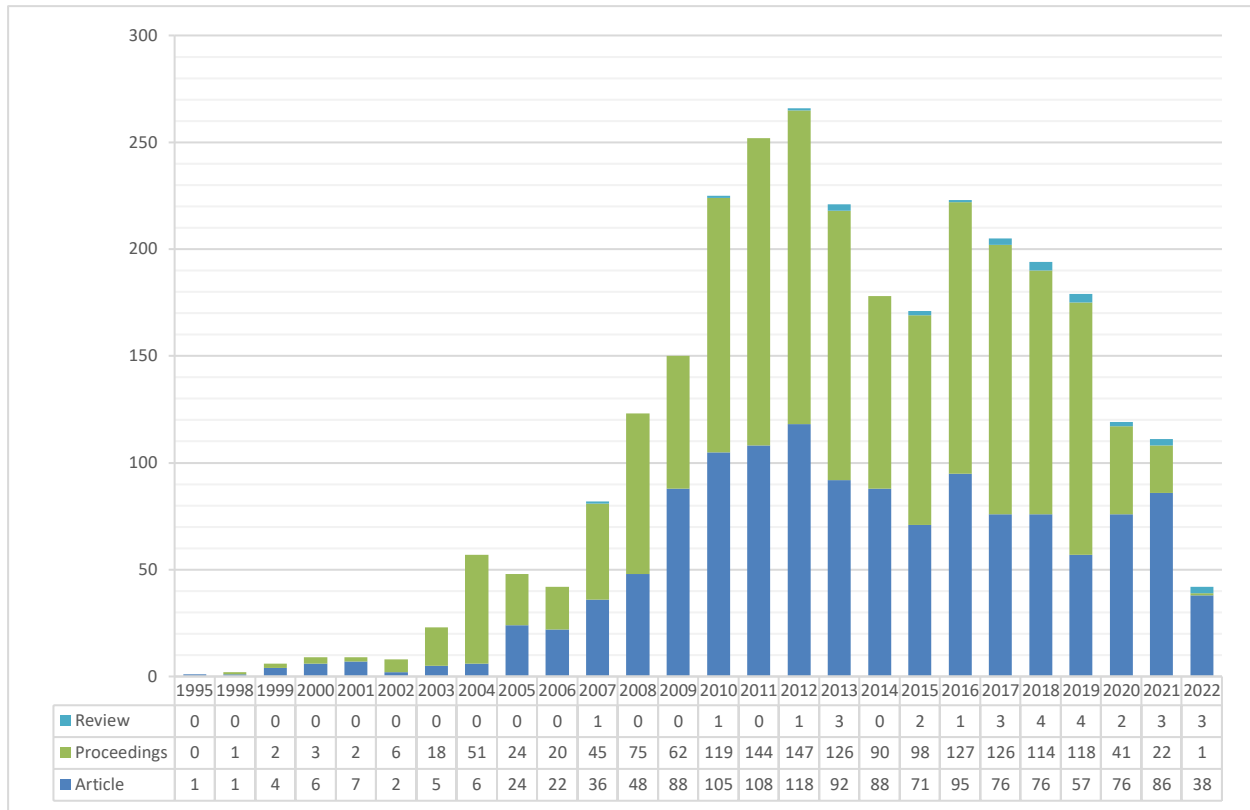
	1995	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
■ Review	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	1	3	0	2	1	3	4	4	2	3	3
■ Proceedings	0	1	2	3	2	6	18	51	24	20	45	75	62	119	144	147	126	90	98	127	126	114	118	41	22	1
■ Article	1	1	4	6	7	2	5	6	24	22	36	48	88	105	108	118	92	88	71	95	76	76	57	76	86	38

Figure 1. Annual distribution of publications by document

Table 3. The distribution of the publications by the top ten countries

Rank	Country/Region	Number of publications	Citations
1	England	461	5,357
2	USA	395	7,257
3	Spain	293	2,225
4	Brazil	159	229
5	Australia	151	2,725
6	Romania	129	177
7	Peoples R. China	88	557
8	Greece	81	493
9	Italy	79	780
10	Türkiye	72	1,086

A total of 2,065 organizations contributed to the virtual world's research corpus. Open University has the most publications (52), followed by Coventry University (21), Polytechnic University of Bucharest (20), University of Aegean (19), and Open University of Catalonia (19). The top ten organizations are listed in Table 4.

Table 4. The distribution of the publications by the top ten organizations

Rank	Organizations	Country	Number of publications	Citations
1	Open University	England	52	875
2	Coventry University	England	21	349
3	Polytechnic University of Bucharest	Romania	20	71
4	University of Aegean	Greece	19	154
5	Open University of Catalonia	Spain	19	135
6	University of Granada	Spain	19	77
7	Technical University of Madrid	USA	19	19
8	Curtin University	Australia	18	501
9	National Taiwan Normal University	Taiwan	18	475
10	Arizona State University	Spain	18	312

The results showed that 688 sources have published papers about virtual worlds in total. Among the top ten sources, the first seven were journals and the last three of them were conference proceedings. All conference proceeding books belongs to the same conference, named as International Conference on Education and New Learning Technologies conducted in 2011, 2012, and 2017, respectively. Table 5 lists the top ten sources with the most publications. Most of the documents were published by Computers & Education (JCI=3.75; 92 publications; 6,444 citations), followed by British Journal of Educational Technology (JCI=2.78; 67 publications; 3,305 citations), Interactive Learning Environments (JCI=1.91; 49 publications; 883 citations), International Journal of Emerging Technologies in Learning (JCI=1.13; 49 publications; 169 citations), and Turkish Online Journal of Distance Education (JCI=0.74; 49 publications; 102 citations).Journal Citation Indicator (JCI) metric was preferred since not all journals have Journal Impact Factor (JIF). Moreover, some important points about the journals were taken from the Journal Citation Reports. Computers & Education has the highest citation score (6,444) among the top ten sources. It was the only journal that had two categories Education & Educational Research and Computer Science, Interdisciplinary Applications. It is also both indexed in SSCI and SCIE. The other journals have only an educational research category. Of the 8 journals, six were indexed in SSCI and two were indexed in ESCI. Except for Educational Technology & Society (Q2), the journals indexed in SSCI fall under the first quartile (Q1). Educational Technology & Society (SSCI), International Journal of Emerging Technologies in Learning (ESCI), and Turkish Online Journal of Distance Education (ESCI) were in the second quartile (Q2). The publication period of the sources varies from 1 to 12.

Table 5. The publication distribution by the top ten sources

Rank	Journal	Number of publications	Citations	Publication Frequency	JCI	Category (SSCI/SCIE/ESCI)	Quartile
1	Computers & Education	92	6444	12 issues/year	3.75	Computer Science (SCIE)	
						Education & Educational Research (SSCI)	Q1
2	British Journal of Educational Technology	67	3305	6 issues/year	2.78	Education & Educational Research(SSCI)	Q1
3	Interactive Learning Environments	49	883	8 issues/year	1.91	Education & Educational Research(SSCI)	Q1
4	International Journal of Emerging Technologies in Learning	49	169	12 issues/year	1.13	Education & Educational Research(ESCI)	Q2
5	Turkish Online Journal of Distance Education	49	102	4 issues/year	0.74	Education & Educational Research(ESCI)	Q2
6	Educational Technology & Society	36	1049	4 issues/year	1.93	Education & Educational Research(SSCI)	Q2
7	Education and Information Technologies	36	254	6 issues/year	1.87	Education & Educational Research (SSCI)	Q1
8	4th EDULEARN	35	8	Annually	N/A	N/A	N/A
9	9th EDULEARN	33	11	Annually	N/A	N/A	N/A
10	3rd EDULEARN	33	8	Annually	N/A	N/A	N/A

Emerged structures according to co-occurrences analysis

We used the co-occurrence analysis of VOSviewer in the "All Keywords" area to find out the most occurred keywords and terms used in the publications. A threshold of minimum 10 times of occurrences of keywords was set.

The analysis found out 129 mostly used keywords at the outset. However, it was decreased to 99 when the 'thesaurus file' was used in the analysis of VOSviewer to reach the most accurate results by cleaning the data from the plural/singular words (i.e. serious games, simulations), the abbreviation of terms (i.e. MOOC, VLE, SL). Additionally, the keywords used in the study (i.e., virtual world, virtual learning environment) and the general keywords used in educational research (i.e., learning, education, teaching) were ignored during the analysis via the 'thesaurus file'. Such terms used in the co-occurrence analysis had little or no meaning for the analysis (Li et al., 2019). At the preliminary of the analysis, 7 clusters have occurred and the last two clusters, cluster 6 (8 keywords) and cluster 7 (7 keywords) contained keywords less than 10. Therefore, a threshold of including at least 10 keywords was set during the analysis, and 5 clusters emerged in the main analysis. Table 6. shows the most occurred keywords used in the publications. Figure 2. shows the co-occurrence map of keywords.

Five clusters including different numbers of items occurred when the map was examined. Each color corresponds to a specific cluster in Figure 2. According to the analysis, the red cluster contained 31 keywords. When the keywords were examined, this cluster include keywords related to the applications of virtual worlds such as "Second Life", "OpenSim" and characteristics of VWs such as "avatar", "interactive learning environment", "communication", "collaboration", "immersion", "interaction", "presence," "social presence", "virtual reality", "mixed reality", "simulation". Besides, three keywords "teacher education", "teacher training" and "language learning" were also in this cluster. It can be argued that different types of VW applications with their characteristics were generally used in research studies related to teacher education and language learning.
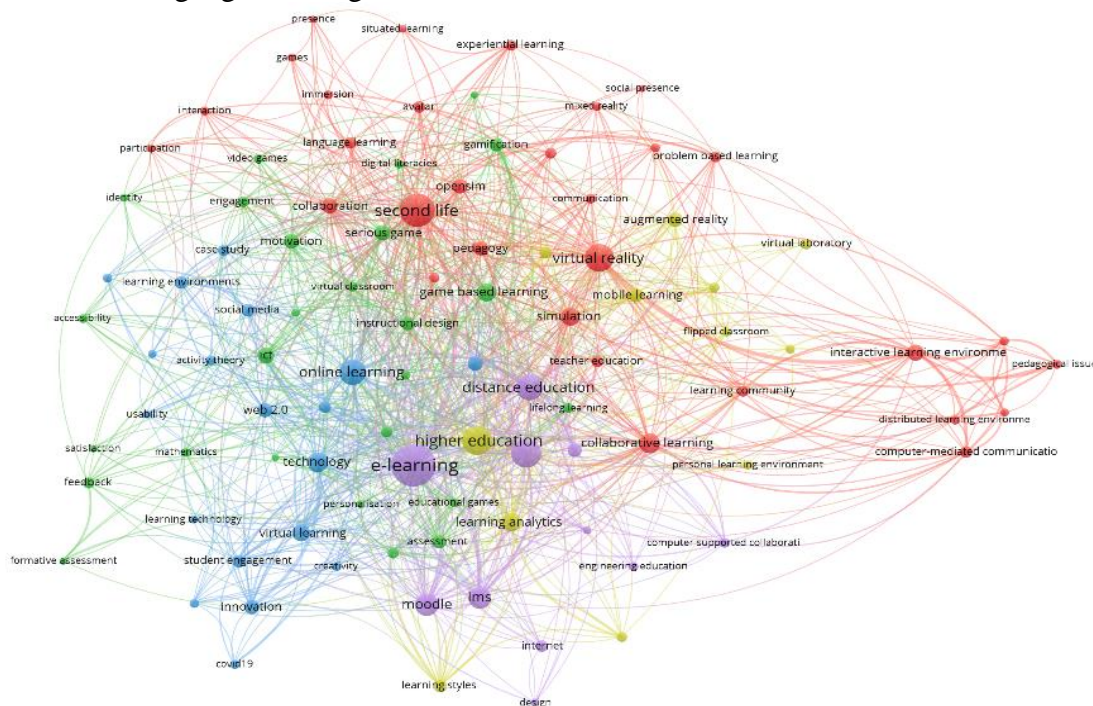

Figure 2. Co-occurrence map of keywords

As can be seen in Figure 2, the green cluster including 26 keywords were generally focused on the games and game-based design activities. This cluster also includes variables such as "motivation", "engagement", "satisfaction", and "self-efficacy" as well as "assessment", "evaluation", "competences", "ICT", and "digital literacy". This shows that research studies used virtual worlds as a game-based learning environment and such variables related to the participants were investigated in this environment.

The third cluster containing 19 keywords was blue. The most occurred keywords in this cluster were "online learning", "technology", "virtual learning", "social media", "covid19", "e-assessment" and "technology enhanced learning". Thus, keywords in this cluster have generally related the use of virtual worlds in online education. Other terms that occurred in this cluster were "case study", "activity theory", "usability", "community of practice", and "informal learning". The research in this cluster used the case study method which was generally preferred when an educational innovation was applied.

The yellow cluster contains 12 keywords. The keywords in this cluster were "augmented reality", "mobile learning", "virtual laboratory", "learning styles", and "personal learning environment". These keywords showed the use of virtual worlds in personalization via mobile based learning. Other keywords such as "higher education", "secondary education", "active learning, "flipped classroom", "learning analytics", and "educational data mining" show that virtual worlds were used with different instructional methods. Besides, educational data mining and learning analytics were used for detecting effectiveness.

The last cluster was represented as the color purple containing 11 keywords. When the keywords were examined in this cluster, it includes keywords such as "e-learning", "blended learning", "distance education", "moodle", and "LMS", "open educational resources". Therefore, we have defined this cluster as the use of VWs in distance education.

Emerged structures according to citation analysis

The citations analysis of VOSviewer was used to see which authors and publications were mostly cited in the relevant literature. The analysis found out that there was a total of 6,784 authors contributing to virtual worlds research. Table 7. shows the distribution of the top ten authors with the most citations. The most cited authors in the use of virtual worlds in education were Dede, C. (f=896) with 9 publications followed by Lan, Y. (f= 355) with 11 publications. The other most cited authors were Ketelhut, D. J. (f=279), Nelson, B.C. (f=244), Miller, A. (f=146), and Limniou, M. (f=83) with 7 publications. Pellas, N. (f=96), Göktaş, Y.(f=81), and Songkram, N. (f=66) had 8 publications in the examined literature.

Table 6. The most occurred keywords used in the publications

Rank	Keyword	Occurrence
1	e-learning	291
2	second life	178
3	higher education	134
4	blended learning	132
5	virtual reality	125
6	distance education	114
7	online learning	102
8	Moodle	81
9	LMS	80
10	collaborative learning	68
11	technology	65
12	learning analytics	59
13	game based learning	55
14	simulation	54
15	virtual learning	50
16	ICT	46
17	interactive learning environments	45
18	collaboration	41
19	serious game	40
20	motivation	37

The citation analysis of the references revealed the top ten papers mostly cited in the examined literature (see Table 8). According to analysis, Dalgarno and Lee, (2010) was the most cited paper with 629 citations. They found out the potentials and affordances of virtual worlds for educational purposes. The other most cited document (f=556) was Merchant, Goetz, Cifuentes, Keeney-Kennicutt, and Davis, (2014). They conducted a meta-analysis to understand the effects of virtual reality-based instruction. Dunleavy, Dede, and Mitchell's (2009) study was the other most cited document with 525 citations. They examined the affordances and limitations of augmented reality with a design-based study.

Table 7. The distribution of the top ten authors

Rank	Author	Count	Citation
1	Dede, C	9	896
2	Lan, Yj	11	355
3	Ketelhut, Dj	7	279
4	Nelson, Bc	7	244
5	Miller, A	7	146
6	Savin-Baden, M	9	108
7	Pellas, N	8	96
8	Limniou, M	7	83
9	Goktas, Y	8	81
10	Songkram, N	8	66

Discussion and Conclusion

This study examined the literature on the use of VWs in the field of education with bibliometric analysis. A total of 2,978 articles, reviews, and proceedings written in English in the field of " Educational Research" indexed in the Web of Science database were reached. The results showed the descriptive characteristics of examined publications (the type of publications across the years, sources with most publications, the origin of country and organization), emerged structures based on the co-occurrence analysis, the top contributors, and the most cited publications based on the co-citation analysis.

The distribution of publications across the years was varied. The number of publications increased until 2012, then decreased slowly until the end of 2015. It was understood that the greatest number of documents were published in 2012. This finding was in line with the argumentation of Reisoğlu et al., (2017) which inclined the year 2012 as the "remarkable interest" towards VWs (p. 81), and Kim, Lee, and Thomas, (2012) also pointed out the increase towards the use of VWs in 2012. We found that they increased in 2016 again. Until the date this research was conducted (June 2022), there was a slight decrease in numbers. The number of proceedings was generally more than the number of articles except for the period of the COVID-19 global outbreak (between 2020-2022) due to the suspended conference meetings. This finding was in line with the study of Tlili et al., (2022) in which they found more proceedings than articles in metaverse studies. The researchers attributed this issue to the proceedings' quick publication process and academia's effort to reveal the potential of new technology.

Table 8. The distribution of the most cited documents

Rank	Author(s)	Document Title	Citation
1	Dalgarno, B., & Lee, M. J. W. (2010).	What are the learning affordances of 3-D virtual environments?	629
2	Merchant, Z., Goetz, E. T., Cifuentes, L., Keeney-Kennicutt, W., & Davis, T. J. (2014).	Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta- analysis.	556
3	Dunleavy, M., Dede, C., & Mitchell, R. (2009).	Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning.	525
4	Warburton, S. (2009).	Second Life in higher education: Assessing the potential for and the barriers to deploying virtual worlds in learning and teaching.	338
5	Potkonjak, V., Gardner, M., Callaghan, V., Mattila, P., Guetl, C., Petrovic, VM., & Jovanovic, K. (2006)	Virtual laboratories for education in science, technology, and engineering: A review	290
6	Tuzun, H., Yilmaz-Soylu, M., Karakus, T., Inal, Y., & Kizilkaya, G. (2009)	The effects of computer games on primary school students' achievement and motivation in geography learning	268
7	Dickey, M. D. (2005)	Three-dimensional virtual worlds and distance learning: two case studies of Active Worlds as a medium for distance education.	247
8	Hew, K. F., & Cheung, W. S. (2010)	Use of three-dimensional (3-D) immersive virtual worlds in K-12 and higher education settings: A review of the research.	243
9	Jarmon, L., Traphagan, T., Mayrath, M., & Trivedi, A. (2009)	Virtual world teaching, experiential learning, and assessment: An interdisciplinary communication course in Second Life	236
10	Steinkuehler, C.,& Duncan, S. (2008)	Scientific Habits of Mind in Virtual Worlds	227

The fluctuation in virtual world research was due to the rise of new technologies. Mantziou, Papachristos, and Mikropoulos, (2018) have argued that the interest in the use of VWs for educational purposes was fading away, however, the technology behind them, Virtual Reality has gained popularity. Similarly, Coban, Bolat, and Goksu, (2022) have argued that positive outcomes of VR technologies would draw the attention of educators and researchers especially after they become more affordable and powerful. On the other side, Reisoğlu et al., (2017) inclined that augmented reality was an enabler in increasing the interest in VWs. In the near future, the rise of metaverse allocating different technologies would affect the trend of using VW for educational purposes positively (Hwang & Chien, 2022; Kye et al., 2021).

The analysis showed that 2065 organizations across 99 countries around the globe have contributed to the body of VW research. While England, USA, Spain, Brazilian and Australia have contributed to the study of VWs in education mostly across the countries, Open University (England), Coventry University (England), Polytechnic University of Bucharest (Romania), University of Aegean (Greece), and Open University of Catalonia (Spain) were the most contributor organizations. The most productive organizations were in the European region and the most productive countries were developed/developing. This could be due to the fact that the use of VWs and other associated brand-new technologies still requires high costs (Coban et al., 2022; Pregowska, Masztalerz, Garlińska, & Osial, 2021).

In terms of the number of publications per source on the use of VWs in education, the findings revealed the top three journals as Computer & Education, British Journal of Educational Technology, and Interactive Learning Environments. These journals were all prestigious in the field of educational technology indexed in SSCI and all in the first quartile with high impacts according to Journal Citation Reports (JCR, 2022). These journals are all well-recognized in the instructional technology field and according to Hwang and Chien, (2022) they are expected to include metaverse related research studies in the coming years.   Besides, in the top ten productive sources list, the conference proceeding of EDULEARN conducted in 2011, 2012, and 2017 took place in the last three orders. It was interesting that all three conference proceedings belong to the same conference.

Co-occurrence analysis revealed the most used keywords in VW research studies. E-learning, second life, higher education, blended learning, virtual reality, distance education, and online learning were the most preferred keywords according to the analysis. Damar, (2021) found the most used keywords in his bibliometric analysis of metaverse literature as second life, virtual world, avatar, augmented reality, virtual reality, e-learning, and higher education. Previous literature review by Tokel & Cevizci-Karataş, (2014) found similar results to the finding of the current study. They found out that e-learning was the most frequent use case of VWs conducted with students at "higher education level in online or blended courses" in many disciplines (p. 4). The most used application in VWs studies was Second Life which was in line with the findings of previous reviews (Kim et al., 2012; Pellas et al., 2017; Reisoğlu et al., 2017; Tokel & Cevizci-Karataş, 2014).

Citation analysis revealed the most cited authors in VW studies for educational purposes. Chris Dede with nine publications, Yu-Ju Lan with 11 publications, and Diane Jass Ketelhut, Brian C. Nelson and Alan Miller each with seven publications were the most cited authors in the relevant area. When the most cited documents were examined, it was revealed that Dalgarno and Lee, (2010), Merchant, Goetz, Cifuentes, Keeney-Kennicutt, and Davis, (2014), Dunleavy et al. (2008) were the most cited studies in VW literature related to education.

Consequently, virtual world research has a continuum for about two decades though its fluctuation over the years. They have been used in many disciplines of education (Pellas,

Mystakidis, & Christopoulos, 2021; Prime, Can, & Vallance, 2019). In this study, 2978 publications (articles, proceedings, and reviews) without a time limitation from the beginning of the use of VWs were examined with bibliometric analysis. Demographic characteristics of publications (the number of publication types over the years, most contributing country, and organization), co-occurrence of keywords, most cited authors, and publications were revealed. Literature review showed that developing technology has affected its use (Mantziou et al., 2018; Reisoğlu et al., 2017). Nowadays, the brand-new technology of today, metaverse was mentioned with virtual worlds frequently. VWs were located in the historical development of metaverse (Lee et al., 2021) and metaverse was understood as an "amplified version of an individual virtual world to conceiving it as a large network of interconnected virtual worlds" (Dionisio et al., 2013, p. 34:7). The majority of the metaverse studies were related to the use of Virtual World Metaverse type (Tlili et al., 2022).

This study showed that technological developments have affected the interest in the use of VWs in education. It was estimated that in the near future, metaverse related publications in the field of education will increase in prestigious journals (Hwang & Chien, 2022) and conferences. Research studies in the relevant area would be on the rise again and the researchers could head to metaverse. They should keep in mind that review studies investigating the advantages and drawbacks of the recent technology draw the attention of other researchers. Such types of review studies also have the potential to be cited by others. To conduct research in this area requiring high-cost new technology, researchers especially in undeveloped countries should find funding opportunities.

This study had some limitations that future research should focus on. We have reached a total of 2,978 publications by using search parameters in the WoSCC database. Future research should focus on other databases which might include educational research indexed out of the WoSCC database. The search parameters constituting the criteria of the current study could be expanded in future studies. Additional studies published in other languages could be taken into consideration rather than just focusing only on studies in English. Since the use of VWs has a continuum and their use will evolve with the metaverse, follow-up studies could be conducted by combining bibliometric analysis with content analysis focusing on publications within a time limit. In this way, it will be possible not only to see the general tendency in the relevant literature but also to reveal the focused section of the literature deeply. In this study, the general picture of the use of VWs in education was revealed within a long-time frame from the beginning of the use of VWs to the date this research was conducted (June 2022). As the technology develops, the use of VWs is subject to evolving from the previous use cases into new ones, as happened in the example of metaverse.

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