

Using Virtual Reality in Education: a bibliometric analysis

Uso de la Realidad Virtual en Educación: un análisis bibliométrico

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ABSTRACT. Virtual Reality includes different technologies through which a user can experience a virtual world created in 3 dimensions by computer. Although its adoption has been slow, since the devices required to access virtual reality were expensive, there have been experiences in education since the 1990s.

The present study carries out a bibliometric study in which 1074 articles related to the use of virtual reality in education from 1990 to the beginning of 2021 have been analyzed. It has been studied, from a quantitative point of view, the evolution of the annual scientific production, collaboration and production of authors, nationalities and sources of the articles. An analysis of citations, co-citations and bibliographical coupling has also been carried out.

RESUMEN. La Realidad Virtual incluye diferentes tecnologías a través de las cuales un usuario puede experimentar un mundo virtual en 3 dimensiones creado por ordenador. Aunque su adopción ha sido lenta, ya que los dispositivos requeridos para acceder a la realidad virtual eran caros, ha habido experiencias en el campo de la educación desde 1990.

El presente estudio lleva a cabo un análisis bibliométrico en el que se han analizado 1074 artículos relacionados con el uso de la realidad virtual en educación desde 1990 hasta principios de 2021. Se ha analizado, desde un punto de vista cuantitativo, la evolución anual de la producción científica, la colaboración y producción de autores, nacionalidades y fuentes de los artículos. También se ha llevado a cabo un análisis de citas, co-citas y acoplamiento bibliográfico.

KEYWORDS: Virtual reality, Learning, Educational innovation, Bibliometric analysis, ICT.

PALABRAS CLAVE: Realidad virtual, Aprendizaje, Innovación educativa, Análisis bibliométrico, TIC.

1. Introduction

Virtual Reality (henceforth, VR) is a broad concept that usually includes different terms such as Immersive VR (Kolomaznika, Sullivan & Vyviana, 2017), Augmented Reality (AR) (Milgram & Kishino, 1994; Barroso Osuna, Gutiérrez-Castillo, Llorente-Cejudo & Valencia Ortiz, 2019), desktop-based VR, simulations, virtual worlds or even videogames (Merchant, Goetz, Cifuentes, Keeney-Kennicutt & Davis, 2014), each of them with specific technical requirements. Although this variety there is always a three-dimensional computerized simulation of a reality in common. VR is a part of Information and Communication Technologies (ICT) that, being so present in people's daily lives, it is difficult to conceive a world without them (Barbosa Granados & Amariles Jaramillo, 2019).

However, the fact that it is virtual does not mean that it does not need physical devices (Gourlay, 2021). For instance, Immersive VR can be perceived through specific devices, such as Head Mounted Displays (HMD), datagloves or even special clothing (Conn, Lanier, Minsky, Fisher & Druin, 1989). Immersive VR provides users with simulations of visual and other senses, making them feel immersed (Hsu, 2020). The key to achieve immersion lies in features of the VR hardware such as HMDs. This is a special pair of eyeglasses that shows three-dimensional stereo pictures, one for each eye, with small perspective differences in order to create a three-dimensional illusion (Conn et al., 1989). Desktop-based VR, simulations, virtual worlds and videogames are non-immersive VR, which just focus on simulating three-dimensional worlds through classic screens (Kolomaznika et al., 2017). With regard to AR, it refers to the technology that allows to “augment” a real environment by means of computerized virtual objects (Milgram & Kishino, 1994).

One of the first researchers to explore the possibilities of this technology was Ivan Sutherland, who thought about the possibility of making a “kinesthetic display” in 1965 (Sutherland, 1965). Although his first proposal was just a brief concept, he described a system made up of several sensors collecting user's data, such as muscle and eye positions, and a computer drawing the virtual world accordingly. Three years later, in 1968, Sutherland broadened this concept and carried out the very first HMD at Massachusetts Institute of Technology: a complex mechanic sensor collected user's head position and a computer drew an object from the right perspective with the help of matrix multiplications (Sutherland, 1968). It was an extremely slow process with the technology of the time.

Even though computing power has increased enormously since then, the development of VR devices has been very slow and its high costs have caused such technology to be relegated to videogames, causing its adoption in education to be such a slow process (Kolomaznika et al., 2017). However, ICT plays a very relevant role in the labor market, which is often reflected in the educational world, since students will become future workers (Martínez-López et al., 2021; Infante-Moro et al., 2019, 2020).

The appearance of low-cost HMD devices in the last years, such as Google Cardboard, caused VR to spread to the general public and education didn't stay on the sidelines. Indeed, when VR is focused on education some authors use the concept Virtual Reality Learning Environments (VRLE) (Huang, Rauch & Liaw, 2010). As the cost of VR devices has gradually decreased, it has gradually become mainstream. Indeed, many companies have launched their own devices focused on several industries such as medicine, architecture, entertainment and tourism (Hsu, 2020).

2. Material and methods

This paper focuses on analyzing, from a bibliometric point of view, educational research using VR within a long-term time frame. Bibliometric methods provide quantitative analysis of written publications and allow to identify the corpus of literature within a subject area (Ellegaard & Wallin, 2015). This study followed the workflow guidelines proposed by Zupic and Čater (2015). These guidelines consist of a five-step procedure: research design, compilation of bibliometric data, analysis, visualization and interpretation.



2.1. Research design and compilation of bibliometric data

Firstly, as the goal of this study was to analyze the use of VR in the field of education over the last decades, the research design revolved around setting a knowledge base of the field, showing the foundations, fundamental theories, breakthrough early works and methodological canons of the field (Zupic & Čater, 2015).

Compiling bibliometric data involved several steps: choosing the source of data, exporting records, merging collections and refining results.

Web of Science (WoS) was chosen as the source to retrieve the raw database. In order to perform the search, both the literal sentence “virtual reality” and the keyword “education” were used together with the Boolean Operator “AND”. The full search string as well as WoS categories, indexes and timespan turned out like this:

TS=(“virtual reality” AND education).

WoS categories: EDUCATION EDUCATIONAL RESEARCH.

Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCR-EXPANDED, IC.

Timespan: 1990-2021.

This search was performed on 1st February 2021 and it resulted in 1080 records. As WoS only allows to download 500 records per file, data was downloaded in three collections that were merged in Biblioshiny, a web interface of Bibliometrix (<https://bibliometrix.org/>). Bibliometrix is an R-package focused on carrying out quantitative bibliometric research developed by Aria and Cuccurullo (2017). Once the three collections were merged in a single one, it was exported to OpenRefine, a tool for working with large amount of data (<https://openrefine.org/>). OpenRefine was used to perform a last step in order to compile bibliometric data: refining results. On the one hand, duplicates were removed ($n = 6$). On the other, author names were normalized in columns AU ($n = 122$) and CR ($n = 30$). These columns refer to “author names” and “cited references”, respectively. It was carried out by adding a hyphen to authors with two surnames, or joining some prefixes to surnames, i.e., “De”, “Al”, “Di” and so on. (Figure 1).

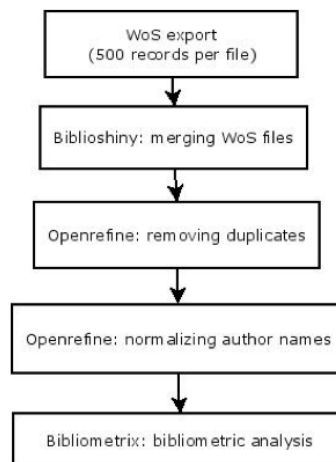


Figure 1. Data workflow. Source: Self-made.

Those steps ended up with 1074 documents related to VR and education in the timespan from 1990 to 2021. An important part of these documents were articles ($n = 536$, 49.91%). They included articles in book chapters, early access and articles published previously as proceedings papers, which were initially presented at a conference and later adapted for publication in a journal (González-Albo & Bordons, 2011). The next group in size was proceedings papers ($n = 499$, 46.46%), followed by reviews and early access reviews ($n = 31$, 2.89%). The last group was editorial material, including book chapters ($n = 8$, 0.74%). (Figure 2).

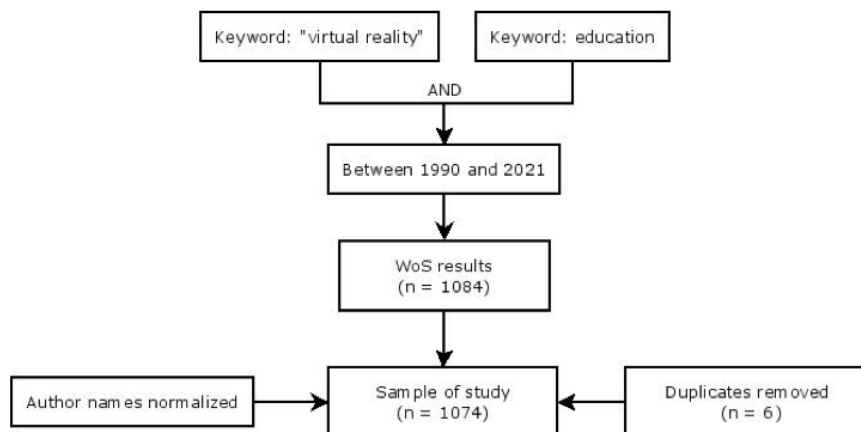


Figure 2. Sample of study flow diagram. Source: Self-made.

2.2. Analysis

Firstly, a descriptive analysis was performed referring to documents, authors, countries and sources. Documents were analyzed to show the growth of publications during years. Author analysis was focused on most productive authors, corresponding author's country as well as total citations per country and most relevant sources.

Secondly, several bibliometric techniques were performed. In order to achieve the objective of identifying the corpus of VR in education, citation, co-citation and bibliographical coupling analysis were carried out. Citation allows to find the most influential documents, authors and journals, as well as co-citation analysis and bibliographical coupling connect these documents, authors or journals in order to answer structural questions about the field (Zupic & Čater, 2015). Since co-citation revolves around cited papers, it establishes a knowledge base by the current research. Meanwhile, bibliographical coupling is best suitable for obtaining a research front (Price, 1965), that describes current documents citing papers in the knowledge base, showing the state of the art of the field (Zupic & Čater, 2015). Furthermore, bibliometric techniques were also conducted to study author's data, such as co-author analysis. It allows to map collaboration and show networks which connect scientists and organizations.

3. Results

This section is divided into two parts (descriptive and bibliometric analysis) with several sub-sections each one as was described before. Data is displayed with the help of graphs, tables and plots.

3.1. Descriptive analysis

3.1.1. Documents

The 1074 documents which conform the sample of study are distributed over years as can be seen in Figure 3. There are two things to remark:

- a) Even though the aim of this study was firstly searching from 1990, the first paper that meet the requirements was published in 1994.
- b) Search was performed in early 2021 (1st February). By then only one study had been published in such year.

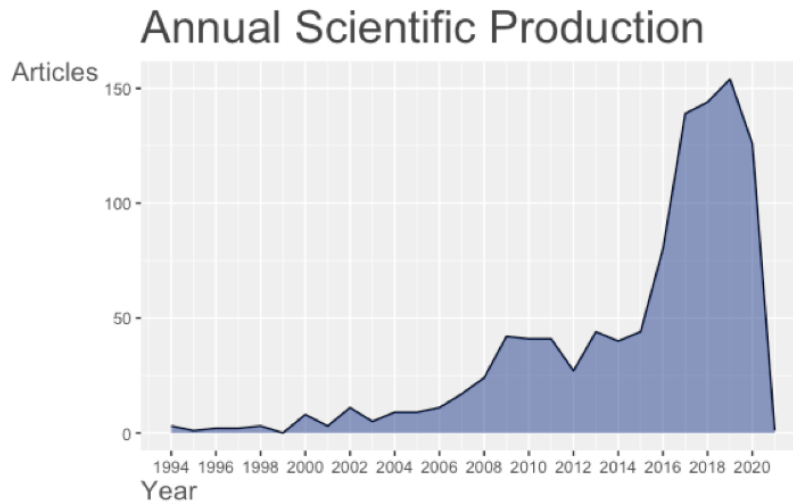


Figure 3. Annual scientific production from 1994 to 2021. Note: Data was collected on 1st February 2021. Source: Self-made.

A rapid growth can be found from 2015: there were 44 papers in 2015, almost twice in 2016 ($n = 80$) and more than three times in 2017 ($n = 135$). As was mentioned in the introduction of this study, the appearance of low-cost HMD caused VR to spread to the general public. Google Cardboard was launched at Google I/O 2014 developers conference to encourage development of VR and AR (Augmented Reality) applications, first for Android developers and next year for iOS developers (Perla & Hebbalaguppe, 2017). It had an impact on the amount of studies related to VR in education.

However, a decrease in number of publications can be found in 2020. As most studies involving VR in the classroom require face-to-face education, the effects of the COVID-19 pandemic (social distancing, school closures) could be behind this decrease, although this pandemic can be seen as an opportunity to accelerate digital transformation in education (Castañeda & Williamson, 2021).

3.1.2. Authors

Three descriptive analysis were performed: authors, authors collaboration and production (totals and over the time).

With regard to authors, the sample of study was produced by 2798 authors. There are 2605 authors of multi-authored documents (93.1%) and 193 of single-authored documents (6,9%). There are 3262 author appearances. Table 1 shows these results.

Authors	2798
Authors appearances	3262
Authors of single-authored documents	193
Authors of multi-authored documents	2605

Table 1. Authors descriptive analysis. Source: Self-made.

Focusing on authors collaboration, the average of documents per author is 0.38. Meanwhile, the average of authors per document is 2.61. There are 200 single-authored documents, 3.04 co-authors per documents and the collaboration index (authors of multi-authored documents divided by multi-authored documents) is 2.98 (Table 2).

Single-authored documents	200
Documents per author	0.38
Authors per document	2.61
Co-authors per documents	3.04
Collaboration index	2.98

Table 2. Authors collaboration descriptive analysis. Source: Self-made.

Focusing on production, Makransky is the most productive author with 9 papers, followed by Moldoveanu and Palkova with 8 studies. Ip and Jong produced 7 documents each one. Cochrane, Lanitis, Li, Szymczyk and Tsai are the authors of 6 documents. There are only 29 authors with 4 papers or more related to VR and education (1.04%). Table 3 displays the top-10 most productive authors.

Author	Articles
Makransky, G.	9
Moldoveanu, A.	8
Palkova, Z.	8
Ip, H.H.S.	7
Jong, M.S.Y.	7
Cochrane, T.	6
Lanitis, A.	6
Li, C.	6
Szymczyk, T.	6
Tsai, C.C.	6

Table 3. Top-10 most productive authors in the field. Source: Self-made.

With regard to production over the time, Figure 4 shows graphically the amount of papers published per year. Tsai is the first author publishing in a long-term period of time: his first paper was published in 2001 and produced 2 documents in 2020. The most productive authors in the last two years are Makransky (n = 4 in 2019, n = 3 in 2020), Jong (n = 5 in 2020), Ip (n = 2 in 2019, n = 2 in 2020), Li (n = 2 in 2019, n = 2 in 2020), Lanitis (n = 3 in 2019, n = 1 in 2020) and Tsai (n = 1 in 2019, n = 2 in 2020).

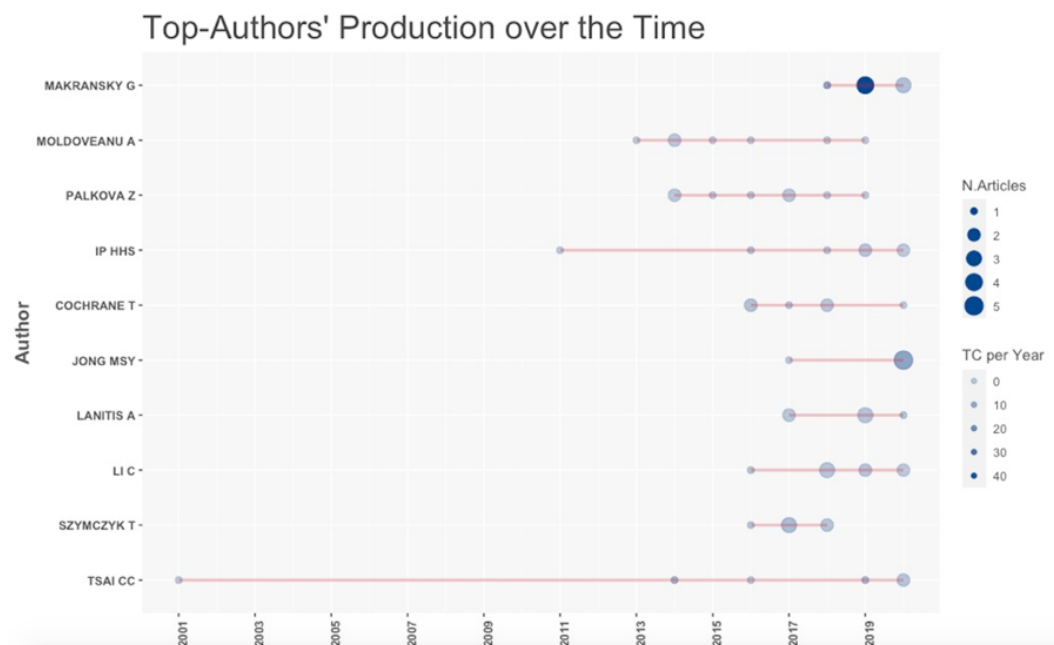


Figure 4. Top-authors' production over the time. Source: Self-made.



3.1.3. Countries

Attending to author's countries, USA was the first one with 177 articles, 163 SCP (Single Country Publications) and 14 MCP (Multiple Country Publications), followed by China with 167 papers (156 SCP, 11 MCP). In third place we can find Spain with 68 documents (61 SCP, 7 MCP). The full top-10 list can be found in Table 4.

Country	Articles	Frequency	SCP	MCP	MCP Ratio
USA	177	0.17	163	14	0.08
China	167	0.16	156	11	0.07
Spain	68	0.06	61	7	0.13
UK	52	0.05	45	7	0.13
Romania	40	0.04	36	4	0.1
Australia	36	0.03	29	7	0.19
Turkey	36	0.03	36	0	0
Greece	32	0.03	27	5	0.16
Brazil	26	0.02	26	0	0
Germany	26	0.02	26	0	0

Table 4. Top-10 corresponding author's countries. Source: Self-made.

Most of documents have been produced by authors of the same country. The sum of the top-ten SCP values is 605 against 55 MCP articles. In fact, the highest MCP Ratio value is 0.19 (Australia). MCP Ratio can be defined as the result of MCP documents divided by total articles (SCP + MCP). It suggests that collaboration between countries in order to produce documents has been low.

3.1.4. Sources

There have been 394 sources which have published papers about VR and education. The most relevant source of documents in the field of VR and education has been Computers & Education, with the amount of 99 articles from 1990 to early 2021. Second relevant source, International Journal of Emerging Technologies in Learning, drops to 29 articles (70.7% less than Computers & Education). A thing to bear in mind is that a half of sources in the top-10 list are conferences. (Table 5).

Source	Articles
Computers & Education	99
International Journal of Emerging Technologies in Learning	29
Interactive Learning Environments	27
British Journal of Educational Technology	25
Edulearn18: 10th International Conference on Education and New Learning Technologies	24
13th International Technology Education and Development Conference (Inted2019)	20
Bmc Medical Education	17
Edulearn19: 11th International Conference on Education and New Learning Technologies	16
14th International Technology Education and Development Conference (Inted2020)	15
11th International Conference of Education Research and Innovation (Iceri2018)	14

Table 5. Most relevant sources. Source: Self-made.

3.2. Bibliometric analysis

3.2.1. Citation

With regard to bibliometric analysis in itself, it started studying most cited papers as WoS database stores these references. It means that citation variable is global and covers the whole WoS database over the time.

The most global cited papers are Current status, opportunities and challenges of augmented reality in education (Wu, Lee, Chang, & Liang, 2013) (n = 571), followed by Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis (Merchant et al., 2014) (n = 383) and Investigating the impact of video games on high school students' engagement and learning about genetics (Annetta, Minogue, Holmes, & Cheng, 2009) (n = 289).

Table 6 shows the top-10 most cited manuscripts.

Document	Citations	Cit. per year
Current status, opportunities and challenges of augmented reality in education (Wu et al.)	571	63.4
Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis (Merchant et al.)	383	47.9
Investigating the impact of video games on high school students' engagement and learning about genetics (Annetta et al.)	289	22.2
The effects of computer games on primary school students' achievement and motivation in geography learning (Tuezuen et al.)	242	18.6
Virtual world teaching, experiential learning, and assessment: An interdisciplinary communication course in Second Life (Jarmon et al.)	216	16.6
Augmented Reality in Education and Training (Lee)	210	21.0
Combining software games with education: Evaluation of its educational effectiveness (Virvou et al.)	209	12.3
Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach (Huang et al.)	200	16.7
Not just fun, but serious strategies: Using meta-cognitive strategies in game-based learning (Kim et al.)	195	15.0
Virtual laboratories for education in science, technology, and engineering: A review (Potkonjak et al.)	186	31.0

Table 6. Most cited documents globally. Source: Self-made.

Next step was performing the analysis of the most cited documents within the sample of study. Now, the WoS global citation variable over the time is not considered and only has been taken into account citations in the 1074 documents analyzed in this study.

The first three papers were Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis (Merchant et al., 2014) (n = 87), What are the learning affordances of 3-D virtual environments? (Dalgarno & Lee, 2010) (n = 52) and Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach (Huang et al., 2010) (n = 40). (Table 7).

Document	Citations
Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis (Merchant et al.)	87
What are the learning affordances of 3-D virtual environments? (Dalgarno et al.)	52
Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach (Huang et al.)	40
Educational virtual environments: A ten-year review of empirical research (1999-2009) (Mikropoulos et al.)	35
A Survey of Augmented Reality (Azuma)	33
A Taxonomy of Mixed Reality Visual Displays (Milgram et al.)	33
Current status, opportunities and challenges of augmented reality in education (Wu et al.)	33
Virtual reality and learning: Where is the pedagogy? (Fowler)	32
Defining Virtual Reality: Dimensions Determining Telepresence (Steuer)	31
Immersive Interfaces for Engagement and Learning (Dede)	30

Table 7. Most cited documents within the sample of study. Source: Self-made.



There are only three documents that intersect between local and global top-10 lists: Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis (Merchant et al., 1st position locally and 2nd position globally), Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach (Huang et al., 3rd position locally and 8th position globally) and Current status, opportunities and challenges of augmented reality in education (Wu et al., 7th position locally and 1st position globally). It reveals that those three papers are cornerstones in the field of VR and education because they have been most cited papers globally as well as locally. Table 8 shows these three documents and the percentage of citations within the sample of study among global citations.

Document	Local cit.	Global cit.	%
Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis (Merchant et al.)	87	383	22.71
Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach (Huang et al.)	40	200	20.00
Current status, opportunities and challenges of augmented reality in education (Wu et al.)	33	571	5.78

Table 8. Documents that intersect between local and global top-10 lists. Source: Self-made.

3.2.2. Co-citation

Co-citation analysis allows to find the similarity of content between documents due to the frequency in which a pair of documents have been cited together (Garfield, 1979). This kind of analysis shows networks of authors or documents belonging to a similar field of study (Hsiao & Yang, 2011). Since it is focused on cited papers, co-citation analysis is capable of identifying the knowledge base and intellectual structure of the field (Zupic & Čater, 2015).

In order to achieve this analysis, two sub-steps were carried out. Firstly, a net matrix was calculated. Each item of this matrix contained a pair of cited documents (N, M), which was referenced to a citing paper (A). Cited documents data was retrieved from CR column in WoS database, which includes all cited documents per paper separated by a delimiter character (for instance “;”). Secondly, this matrix was plotted as a network using a circle map layout using the 10 most cited documents. Figure 5 shows this plot.

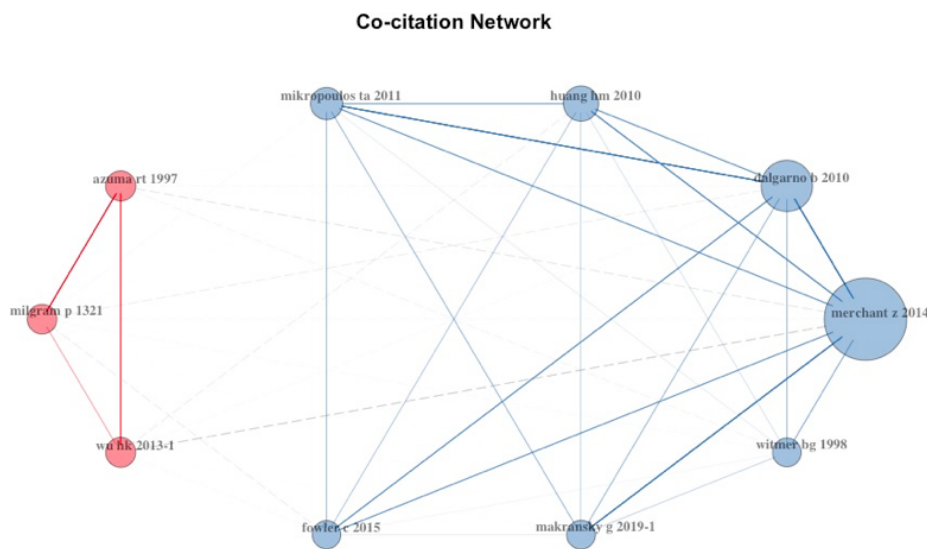


Figure 5. Co-citation network. Source: Self-made.



Co-citation network depicts two main clusters: one of them is lead by Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: A meta-analysis (Merchant et al., 2014), What are the learning affordances of 3-D virtual environments? (Dalgarno et al., 2010) and Investigating learners' attitudes toward virtual reality learning environments: Based on a constructivist approach (Huang et al., 2010). As it was mentioned at the beginning of this study, VR concept usually includes different technologies such as Augmented Reality (AR), Immersive VR, virtual worlds, simulations or even videogames; the three papers in first cluster revolve around virtual worlds, simulations and videogames. Second co-citation cluster is composed by Current status, opportunities and challenges of augmented reality in education (Wu et al., 2013), A Taxonomy of Mixed Reality Visual Displays (Milgram et al., 1994) and A Survey of Augmented Reality (Azuma, 1997), and conceptually is focused on AR.

3.2.3. Bibliographical coupling

In opposition to co-citation analysis, which is focused on cited papers, bibliographical coupling studies citing documents, allowing to analyze the research front of a field (Price, 1965), which represents the state of the art of the field of study at any given time (Zupic & Čater, 2015). The more two cited sources appear in two documents, the more bibliographically coupled are. The process in order to perform this study, another net matrix was calculated as in co-citation analysis, but this time focused on citing papers and coupling. Then, the network matrix was plotted and the outcome can be seen in Figure 6.

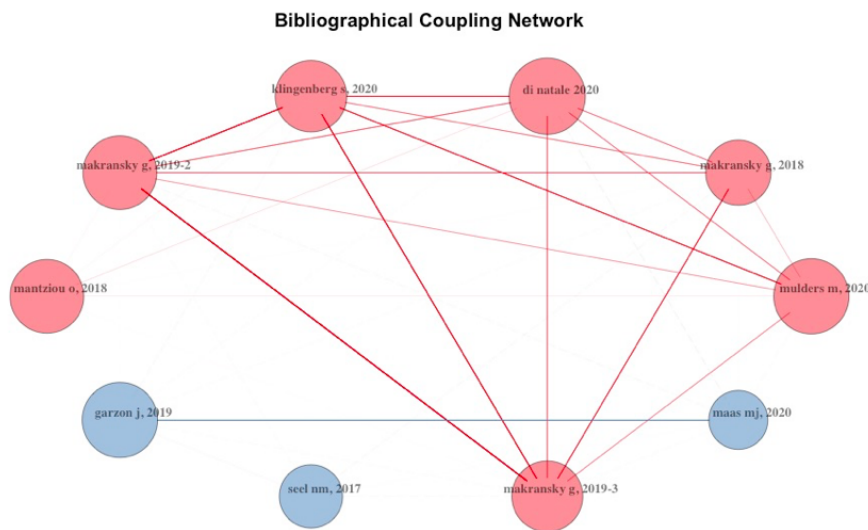


Figure 6. Bibliographical Coupling Network. Source: Self-made.

This bibliographical coupling network results completely different than the co-citation previous one. Now there are papers who were not included in the co-citation analysis due to the different methods of analysis. For instance, we can find three documents of Makransky in the bibliographical coupling, the most productive author in the last two years as it was shown previously (Figure 4), whereas none of them were included in the co-citation analysis. In fact, no paper in the bibliographical coupling was found in the co-citation analysis and vice versa.

4. Discussion

This study focused on analyzing educational research using VR over the last decades. In order to achieve this objective, a bibliometric methodology was chosen. Both descriptive and bibliometric analysis were performed; authors, countries and sources were analyzed in the descriptive stage whereas citation, co-citation and bibliographical coupling methods were carried out in the bibliometric analysis.

It showed that the first document in the field of VR and education was published in 1994. Since then, the number of documents published per year has grown to the top of 154 in 2019, although it decreased to 126 in 2020 probably due to COVID-19 pandemic consequences in education. It must be pointed out that Google Cardboard, a low-cost HMD, was launched in 2014; it could be behind the fact of a rapid growth in number of papers from 2015.

There were found 2798 authors within the 1074 papers which were the sample of study. A big amount of documents were multi-authored (93.1%) and the collaboration index was 2.98; in other words, the average of authors collaborating in order to produce a single study was almost 3. The most productive author was Makransky and it must be pointed out that his first paper was published in 2018. On the other hand, the first author publishing in the long-term period of time was Tsai, whose documents have been published from 2001 to 2020. There are 29 authors with 4 papers or more and only 5 authors with 7 studies or more since 1990.

Most of the papers have been published in USA followed by China and both countries are the only ones with more than 150 studies. Indeed, their documents are a 32.03% of sample of study. Spain and UK are the third and fourth countries in number of documents respectively, quite below first countries (for instance, UK only has a third of China papers). Following countries in the top-10 (Romania, Australia, Turkey, Greece, Brazil and Germany) are all under 50 studies. Furthermore, there has been a small collaboration between countries, because a 91.67% of documents in the top-10 list of most productive countries were produced in a single country.

Talking about sources, the most relevant one was Computers & Education, which published 99 articles, a 9.22% of papers related to VR and education between 1990 and early 2021. There must be pointed out that next source with regard to the field of study, International Journal of Emerging Technologies in Learning, drops to 29 papers published, a 2.7% of studies. Another thing to bear in mind is that a half of sources in the top-10 list are conferences, what could be explained from the interest of conferences in this kind of technologies in education.

Bibliometric analysis was performed in several stages. Firstly, a citation study showed that only three papers intersected between most cited documents globally (according to WoS data) and locally (within the sample of study). Secondly, co-citation analysis found two clusters in the knowledge base and intellectual structure of the field; one of them revolved around virtual worlds, simulations and videogames, three technologies usually are included in the concept of VR. The second cluster was focused on AR and mixed-reality concepts. Finally, a bibliographical coupling study was performed in order to analyze the research front (Price, 1965) of VR and education, which represents the state of the art of this field of study at any given time (Zupic & Čater, 2015). This bibliographical coupling network showed several papers which were not found in the knowledge base of the field previously analyzed. The reason was the contemporaneity of some papers, which have yet to be cited sufficiently in order to appear in a co-citation study.

With regard to the limitations of the present study, as it was mentioned before VR term includes several technologies (IVR, AR, videogames, simulations, desktop-based VR and virtual worlds) and all of them have been included in this study. Future studies that would focus on certain fields of VR should perform a search specifying which technologies to include, not VR in general. Therefore, as the keywords in order to carry out this study were VR and "education", the documents retrieved from WoS database are the ones which have these keywords in English; papers with the same keywords in other languages were not included in the sample of study. Another limitation is that data was retrieved in the early 2021 as well as the decrease in number of documents in 2020, what modifies the curve of growth in number of papers.

5. Conclusions

According to the data showed in the present study, papers related to VR and education started in 1994, and they were increasing slowly until the launching of Google Cardboard in 2014; this fact produced a rapid

growth in number of publications which shows the impact of this low-cost device in education. Therefore, these studies were performed in single countries, and there was found a small index of collaboration between countries. USA and China were the more active countries with regard to studies in the field and Computers and Education was the most interested source in publishing this kind of studies, although there were found a big amount of sources related to conferences. It suggests an interest of several events in the field of VR and education. Finally, there were found a research front of authors very active in the last years who have yet to be part of the knowledge base.

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